GENESIS

ANALYSIS EXAMPLES MANUAL

VERSION 11.0

November 2009

1767 South 8th Street, Suite 200
Colorado Springs, CO 80905
Phone: (719) 473-4611 Fax: (719) 473-4638
http://www.vrand.com
email: genesis.support@vrand.com

TABLE OF CONTENTS

GENESIS

Analysis Examples Manual

CHAPTER 1 Introduction

1.1 Overview - - - 3

1.2 Analysis Examples - - - 4

CHAPTER 2 Analysis Examples

2.1 Classical Three Rod Truss - - - 11

2.1.1 Input Data . . . 13

2.1.2 Output . . . 14

2.2 Ten Rod Truss - - - 20

2.2.1 Input Data . . . 22

2.2.2 Output . . . 24

2.3 Portal Frame - - - 28

2.3.1 Input Data . . . 30

2.3.2 Output . . . 32

2.4 Circular Ring - - - 38

2.4.1 Input Data . . . 41

2.4.2 Output . . . 43

2.5 Wide Column/Wide Beam Frame - - - 47

2.5.1 Input Data . . . 49

2.5.2 Output . . . 51

2.6 Deformed Beam - - - 55

2.6.1 Input Data . . . 57

2.6.2 Output . . . 58

2.7 Two Bar Symmetric Frame - - - 61

2.7.1 Input Data . . . 63

2.7.2 Output . . . 65

2.8 Three Story Facade with a Panel - A - - - - - - - - - - - - - - - - 68
2.8.1 Input Data 71
2.8.2 Output 73

2.9 Three Story Facade with a Panel - B - - - - - - - - - - - - - - - - 77
2.9.1 Input Data 79
2.9.2 Output 81

2.10 Vibration of a Skewed Beam - 86
2.10.1 Input Data 89
2.10.2 Output 90

2.11 Beam with Temperature Load - 95
2.11.1 Input Data 97
2.11.2 Output 98

2.12 Portal Frame with Flexible Nodes - - - - - - - - - - - - - - - - - - 102
2.12.1 Input Data 106
2.12.2 Output 108

2.13 Beam Supported by Springs - 112
2.13.1 Input Data 114
2.13.2 Output 115

2.14 Planar Grillage with Internal Pin - - - - - - - - - - - - - - - - - - 119
2.14.1 Input Data 122
2.14.2 Output 123

2.15 Rod Modeled with Tetra Elements - - - - - - - - - - - - - - - - - 127
2.15.1 Input Data 131
2.15.2 Output 134

2.16 Rod Modeled with Penta Elements - - - - - - - - - - - - - - - - - 139
2.16.1 Input Data 142
2.16.2 Output 144

2.17 Anisotropic Plate with Thermal Load - A - - - - - - - - - - - - 148
2.17.1 Input Data 151
2.17.2 Output 153

2.18 Anisotropic Plate with Thermal Load - B - - - - - - - - - - - - 158
2.18.1 Input Data 161
2.18.2 Output 162

2.19 Straight Uniform Fin Analysis - - - - - - - - - - - - - - - - - - - 167
2.19.1 Input Data 169
2.19.2 Output 171

2.20 Square Plate With Volume Heat Generation and Enforced Temperature - - - - 173
2.20.1 Input Data 176
2.20.2 Output 178
2.21 Conduction on an Elliptical Bar Heated by a Distant Source 180
2.21.1 Input Data 182
2.21.2 Output 183
2.22 Heat Conduction in an Anisotropic Plate - - - - 185
2.22.1 Input Data 188
2.22.2 Output 190
2.23 Heat Conduction in an Anisotropic Solid - - - - 192
2.23.1 Input Data 195
2.23.2 Output 197
2.24 Convection-Conduction Heat Transfer in the Straight Cantilever Problem - - - - 200
2.24.1 Input Data 203
2.24.2 Output 205
2.25 Dynamic Response of the Cantilevered Beam - - - - 208
2.25.1 Input Data 212
2.25.2 Output 214
2.26 Dynamic Response of the Cantilevered Beam With Element Structural Damping - - - - 220
2.26.1 Input Data 223
2.26.2 Output 225
2.27 Dynamic Response of the Cantilevered Beam With and Without Modal Damping - - - - 231
2.27.1 Input Data 234
2.27.2 Output 236
2.28 Dynamic Response of a CELAS1/CDAMP1/CMASS1 Structure - - - - 242
2.28.1 Input Data 244
2.28.2 Output 245
2.29 Three Rod Truss - Analysis Using Multidisciplinary Load Cases - - - - 248
2.29.1 Input Data 252
2.29.2 Output 254
2.30 Thin Axisymmetric Annulus - - - - 259
2.30.1 Input Data 262

2.30.2 Output 266

2.31 Three Independent Beams - 308

2.31.1 Input Data 311

2.31.2 Output 313

2.32 Two Pairs of Beams with and without Warping Coefficients 318

2.32.1 Input Data 320

2.32.2 Output 322

2.33 Two Independant Beams, with and without Offset - - - - 326

2.33.1 Input Data 328

2.33.2 Output 330

2.34 Buckling Analysis of a Tripod - 338

2.34.1 Input Data 341

2.34.2 Output Data 343

2.35 Enforced Dynamic Displacement with the Large Mass Method - 352

2.35.1 Input Data 354

2.35.2 Output Data 357

2.36 Enforced Dynamic Displacement with the Lagrange Multiplier Method - 376

2.36.1 Input Data 378

2.36.2 Output Data 381

2.37 Random Response of a Simple Spring/Mass/Damper Structure - 400

2.37.1 Input Data 402

2.37.2 Output Data 404

2.38 Random Response of a Cantilever Plate - - - - - - - - - - - - 431

2.38.1 Input Data 433

2.38.2 Output Data 437

2.39 Rigid Body Modes of Doubly Curved Shells - - - - - - - - - 440

2.39.1 Input Data 442

2.39.2 Output Data 446

2.40 Rigid Body Modes of Double Hat Structure - - - - - - - - - 449

2.40.1 Input Data 451

2.40.2 Output Data 455

CHAPTER 1

Introduction

- Overview
- Analysis Examples

1.1 Overview

The purpose of this volume is to provide a variety of simple analysis examples to assist the user in becoming familiar with the *GENESIS* analysis capabilities. These examples are also provided with the *GENESIS* software so they may be executed for comparison.

It should be remembered that, because of different machine precisions, the results may differ slightly from those presented here.

1.2 Analysis Examples

To assist the user in understanding the *GENESIS* analysis capabilities, a variety of examples are presented in Chapter 2.
The following table lists the examples, together with the features demonstrated by each:

SECTION	PROBLEM SOLVED	SPECIAL FEATURES
2.1	**Classical Three Rod Truss**	Mass Element.
2.2	**Ten Rod Truss**	None.
2.3	**Portal Frame**	None.
2.4	**Circular Ring**	Cylindrical Coordinate System
2.5	**Wide Column/Wide Beam Frame**	Bar offsets
2.6	**Deformed Beam**	Enforced displacements.
2.7	**Two Bar Symmetric Frame**	Multi-point constraints. Load combinations.
2.8	**Three Story Facade with a Panel - A**	Rigid elements.
2.9	**Three Story Facade with a Panel - B**	None.
2.10	**Vibration of a Skewed Beam**	Two coordinate systems.
2.11	**Beam with Temperature Load**	Single point constraints.
2.12	**Portal Frame with Flexible Nodes**	Multi-point constraints. Scalar springs.
2.13	**Beam Supported by Springs**	Scalar springs.
2.14	**Planar Grillage with Internal Pin**	Pin flags.
2.15	**Rod Modeled with Tetra Elements**	None.
2.16	**Rod Modeled with Penta Elements**	None.
2.17	**Anisotropic Plate with Thermal Load - A**	Orthotropic material, MAT8.
2.18	**Anisotropic Plate with Thermal Load - B**	Anisotropic material, MAT2.
2.19	**Straight Uniform Fin Analysis**	Convection using boundary elements LINE and POINT.

SECTION	PROBLEM SOLVED	SPECIAL FEATURES
2.20	Square Plate With Volume Heat Generation and Enforced Temperature	Enforced temperature.
2.21	Conduction on an Elliptical Bar Heated by a Distant Source	Utilization of boundary element ELCYL and vector flux loading.
2.22	Heat Conduction in an Anisotropic Plate	Utilization of anisotropic material MAT5 with PSHELL.
2.23	Heat Conduction in an Anisotropic Solid	Utilization of anisotropic material MAT5 with PSOLID.
2.24	Convection-Conduction Heat Transfer in the Straight Cantilever Problem	Utilization of ambient temperature loading and use of boundary element AREA4.
2.25	Dynamic Response of the Cantilevered Beam	Frequency response analysis using direct dynamic analysis and modal dynamic analysis.
2.26	Dynamic Response of the Cantilevered Beam With Element Structural Damping	Use of element structural damping, GE value in MAT1.
2.27	Dynamic Response of the Cantilevered Beam With and Without Modal Damping	Use of modal structural damping, TABDMP1.
2.28	Dynamic Response of a CELAS1/CDAMP1/CMASS1 Structure	Use of scalar elements and SPOINTs.
2.29	Three Rod Truss - Analysis Using Multidisciplinary Load Cases	Use of multiple load case types.
2.30	Thin Axisymmetric Annulus	None.
2.31	Three Independent Beams	PBEAM statement.
2.32	Two Pairs of Beams with and without Warping Coefficients	Use warping coefficients in the PBEAM statement.
2.33	Two Independant Beams, with and without Offset	Use offset in the CBEAM statement.
2.34	Buckling Analysis of a Tripod	Use of buckling analysis.
2.35	Enforced Dynamic Displacement with the Large Mass Method	Large Mass Method for enforced dynamic displacement.
2.36	Enforced Dynamic Displacement with the Lagrange Multiplier Method	Use of constraint equations using DMIG.

2.37	Random Response of a Simple Spring/Mass/Damper Structure	Use of Random response
2.38	Random Response of a Cantilever Plate	Use of Random response
2.39	Rigid Body Modes of Doubly Curved Shells	Use of weld element
2.40	Rigid Body Modes of Double Hat Structure	Use of weld element

CHAPTER 2

Analysis Examples

- Classical Three Rod Truss
- Ten Rod Truss
- Portal Frame
- Circular Ring
- Wide Column/Wide Beam Frame
- Deformed Beam
- Two Bar Symmetric Frame
- Three Story Facade with a Panel - A
- Three Story Facade with a Panel - B
- Vibration of a Skewed Beam
- Beam with Temperature Load
- Portal Frame with Flexible Nodes
- Beam Supported by Springs
- Planar Grillage with Internal Pin
- Rod Modeled with Tetra Elements
- Rod Modeled with Penta Elements
- Anisotropic Plate with Thermal Load - A
- Anisotropic Plate with Thermal Load - B
- Straight Uniform Fin Analysis

- **Square Plate With Volume Heat Generation and Enforced Temperature**
- **Conduction on an Elliptical Bar Heated by a Distant Source**
- **Heat Conduction in an Anisotropic Plate**
- **Heat Conduction in an Anisotropic Solid**
- **Convection-Conduction Heat Transfer in the Straight Cantilever Problem**
- **Dynamic Response of the Cantilevered Beam**
- **Dynamic Response of the Cantilevered Beam With Element Structural Damping**
- **Dynamic Response of the Cantilevered Beam With and Without Modal Damping**
- **Dynamic Response of a CELAS1/CDAMP1/CMASS1 Structure**
- **Three Rod Truss - Analysis Using Multidisciplinary Load Cases**
- **Thin Axisymmetric Annulus**
- **Three Independent Beams**
- **Two Pairs of Beams with and without Warping Coefficients**
- **Two Independant Beams, with and without Offset**
- **Buckling Analysis of a Tripod**
- **Enforced Dynamic Displacement with the Large Mass Method**
- **Enforced Dynamic Displacement with the Lagrange Multiplier Method**
- **Random Response of a Simple Spring/Mass/Damper Structure**
- **Random Response of a Cantilever Plate**
- **Rigid Body Modes of Doubly Curved Shells**
- **Rigid Body Modes of Double Hat Structure**

2.1 Classical Three Rod Truss

Example ID

A001

Analysis Data Used

GRID, GRDSET, CONM2, CROD, PROD, MAT1, LOADCASE, LOAD, FORCE, METHOD, EIGR, ELFORCE, OLOAD, SPCFORCES, STRESS, DISP and SVECTOR.

Special Features Used

Utilization of Mass element CONM2.

Problem Statement

The 3 rod truss structure of **Figure 2-1** is loaded in two separate load cases. For the first load case find the nodal displacements, element forces, stresses, and reaction forces. For the second load case find the two natural frequencies and the corresponding two modes shapes with a lumped mass of 1000.0 at node 4.

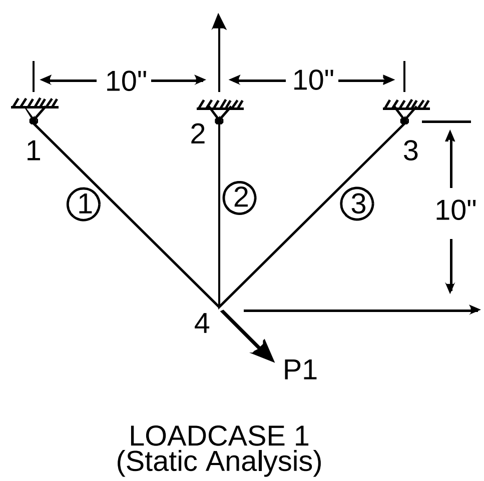
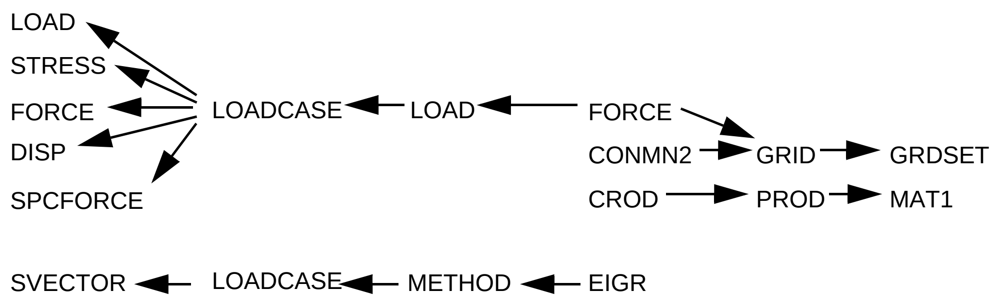


Figure 2-1

Structural Analysis Model

1. Three CROD elements and one CONM2 mass element.
2. Section properties: A1=A3=1.0 in^2. A2=2.0 in^2
3. Material: E=1.0E7 psi
4. Two load cases.
1. P1=20000 lb.
2. Natural vibrations. Lumped mass: M=1000. Distributed mass: m=0.1

Analysis Data Relationships



Special Modeling Techniques

NONE

Reference Solutions

NONE

2.1.1 Input Data

```
ID A001
SOL COMPAT0
CEND
TITLE = THREE BAR TRUSS
ECHO=NONE
LINE=64,80
SPC = 100
LOADCASE 1
        LABEL = LOAD CONDITION 1
        LOAD = 300
        ELFORCE=ALL
        OLOAD=ALL
        SPCFORCE=ALL
        STRESS=ALL
        DISP=ALL
LOADCASE 2
    METHOD=2
    SVECTOR=ALL
BEGIN BULK
$ GRID DATA
GRID    1               -10.    0.0     0.0
GRID    2               0.0     0.0     0.0
GRID    3               10.0    0.0     0.0
GRID    4               0.0     -10.0   0.0
$ SUPPORT DATA
SPC1    100     123456  1       2       3
SPC1    100     3456    4
$ ELEMENT DATA
CROD    1       11      1       4
CROD    2       12      2       4
CROD    3       13      3       4
$   MASS ELEMENTS DATA
CONM2   4       4               1000.0  0.0     0.0     0.0
+       0.0     0.0     0.0     0.0     0.0     0.0
$ PROPERTY DATA
PROD    11      1       1.0
PROD    12      1       2.0
PROD    13      1       1.0
$       2       3       4       5       6       7       8       9       10
MAT1    1       1.0E+7          0.33    0.1
PARAM,WTMASS,.00259
$ EXTERNAL LOADS DATA
FORCE   300     4               20000.  0.8     -0.6
$
GRDSET                                                  3456
$
$   EIGENSOLVER DEFINITION
EIGR    2       SUB                             2       MAX
$
ENDDATA
```

2.1.2 Output

```
1







              GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
             G        E       NN  N   E       S          I     S
             G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
             G    G   E       N  NN   E            S     I          S
              GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                 STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                              COPYRIGHT, 1991-2002

                    VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                         ALL RIGHTS RESERVED, WORLDWIDE

                                  VERSION 7.2

                            BUILD CODE 200212131048



     PROJECT NAME: A001
     RUN STARTED:  Dec 13, 2002 12:49
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    1
 THREE BAR TRUSS


                            ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                      4
                   NUMBER OF CROD ELEMENTS:                    3
                   NUMBER OF CONM2 ELEMENTS:                   1
```

```
                    TOTAL NUMBER OF NON RIGID ELEMENTS:         4
                    NUMBER OF ELEMENT PROPERTIES:               3
                    NUMBER OF MATERIALS:                        1
                    NUMBER OF DEGREES OF FREEDOM:               2



                                LOAD CASES SUMMARY

                   NUMBER OF STATIC LOAD CASES:                   1
                   NUMBER OF USER FREQUENCY LOAD CASES:           1
                   TOTAL NUMBER OF LOAD CASES:                    2

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    2
 THREE BAR TRUSS


                ********************************************
                *  D E S I G N  C Y C L E      0 (ANALYSIS)*
                ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    3
 THREE BAR TRUSS


                    M A S S / V O L U M E   S U M M A R Y

                    SYSTEM MASS              2.602506E+00
                    SYSTEM VOLUME            4.828427E+01
                    SYSTEM MASS/VOLUME       5.389966E-02
                    WTMASS PARAMETER         2.590000E-03
                    SYSTEM MASS/WTMASS       1.004828E+03

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    4
 THREE BAR TRUSS


                   S O L U T I O N   R E S I D U A L S

 LOADCASE        1 ; RESIDUAL :  2.759199E-16 ; STRAIN ENERGY :  2.076160E+02
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    5
 THREE BAR TRUSS


                     O L O A D   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1  1.6000E+04 -1.2000E+04  0.0000E+00  0.0000E+00  0.0000E+00  1.6000E+05
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    6
 THREE BAR TRUSS


                   S P C F O R C E   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3
```

```
      1 -1.6000E+04  1.2000E+04  0.0000E+00  0.0000E+00  0.0000E+00 -1.6000E+05
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    7
 THREE BAR TRUSS


               M A X I M U M   A P P L I E D   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

       1        4     2.0000E+04  1.6000E+04 -1.2000E+04  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    8
 THREE BAR TRUSS


                   M A X I M U M   S P C   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

       1        1     1.3530E+04 -9.5672E+03  9.5672E+03  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    9
 THREE BAR TRUSS


                  M A X I M U M   D I S P L A C E M E N T

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

       1        4     2.3058E-02  2.2627E-02 -4.4328E-03  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   10
 THREE BAR TRUSS

 LOAD CONDITION 1                                            LOADCASE         1

                           L O A D   V E C T O R

       ID             F1                 F2                F3
                      M1                 M2                M3

        4      1.600000E+04     -1.200000E+04      0.000000E+00
               0.000000E+00      0.000000E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   11
 THREE BAR TRUSS

 LOAD CONDITION 1                                            LOADCASE         1

                      G R I D   D I S P L A C E M E N T S

  GRID ID             T1                 T2                T3
                      R1                 R2                R3

        1      0.000000E+00      0.000000E+00      0.000000E+00
               0.000000E+00      0.000000E+00      0.000000E+00
```

```
        2     0.000000E+00     0.000000E+00     0.000000E+00
              0.000000E+00     0.000000E+00     0.000000E+00

        3     0.000000E+00     0.000000E+00     0.000000E+00
              0.000000E+00     0.000000E+00     0.000000E+00

        4     2.262742E-02    -4.432777E-03     0.000000E+00
              0.000000E+00     0.000000E+00     0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   12
 THREE BAR TRUSS

 LOAD CONDITION 1                                             LOADCASE        1

                   R E A C T I O N   F O R C E S

      ID             F1                F2                F3
                     M1                M2                M3

        1    -9.567223E+03     9.567223E+03     0.000000E+00
              0.000000E+00     0.000000E+00     0.000000E+00

        2     0.000000E+00     8.865554E+03     0.000000E+00
              0.000000E+00     0.000000E+00     0.000000E+00

        3    -6.432777E+03    -6.432777E+03     0.000000E+00
              0.000000E+00     0.000000E+00     0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   13
 THREE BAR TRUSS

 LOAD CONDITION 1                                             LOADCASE        1

                 F O R C E S   I N   R O D   E L E M E N T S

   ROD ID           FORCE-A            FORCE-B

        1       1.353010E+04       1.353010E+04
        2       8.865554E+03       8.865554E+03
        3      -9.097320E+03      -9.097320E+03
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   14
 THREE BAR TRUSS

 LOAD CONDITION 1                                             LOADCASE        1

             S T R E S S E S   I N   R O D   E L E M E N T S

   ROD ID          STRESS-A           STRESS-B

        1       1.353010E+04       1.353010E+04
        2       4.432777E+03       4.432777E+03
        3      -9.097320E+03      -9.097320E+03
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   15
 THREE BAR TRUSS
```

```
                                                                 LOADCASE         2

                                      E I G E N V A L U E S

                                                                 GENERALIZED   GENERALIZED
   MODE       CYCLES      EIGENVALUE     RADIANS          MASS       STIFFNESS

       1  8.309283E+01  2.725755E+05  5.220876E+02  2.594169E+00  7.071068E+05
       2  1.625825E+02  1.043535E+06  1.021536E+03  2.594169E+00  2.707107E+06
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   16
 THREE BAR TRUSS

                                                                 LOADCASE         2
                                      E I G E N V E C T O R

 EIGENVECTOR NUMBER        1      FREQUENCY (HZ) =  8.309283E+01
                                  EIGENVALUE     =  2.725755E+05

  GRID ID            T1                 T2                 T3
                     R1                 R2                 R3

       1      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

       2      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

       3      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

       4      1.000000E+00     -2.250613E-18      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   17
 THREE BAR TRUSS

                                                                 LOADCASE         2
                                      E I G E N V E C T O R

 EIGENVECTOR NUMBER        2      FREQUENCY (HZ) =  1.625825E+02
                                  EIGENVALUE     =  1.043535E+06

  GRID ID            T1                 T2                 T3
                     R1                 R2                 R3

       1      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

       2      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

       3      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

       4      2.250613E-18      1.000000E+00      0.000000E+00
```

```
          0.000000E+00      0.000000E+00      0.000000E+00
1                            ***** END OF OUTPUT *****
```

2.2 Ten Rod Truss

Example ID

A002

Analysis Data Used

GRID, GRDSET, CROD, PROD, MAT1,
LOADCASE, LOAD, FORCE,DISP, FORCE, STRESS

Special Features Used

NONE

Problem Statement

Find the nodal displacements, element forces and the stresses of the ten rod truss (see **Figure 2-2**).

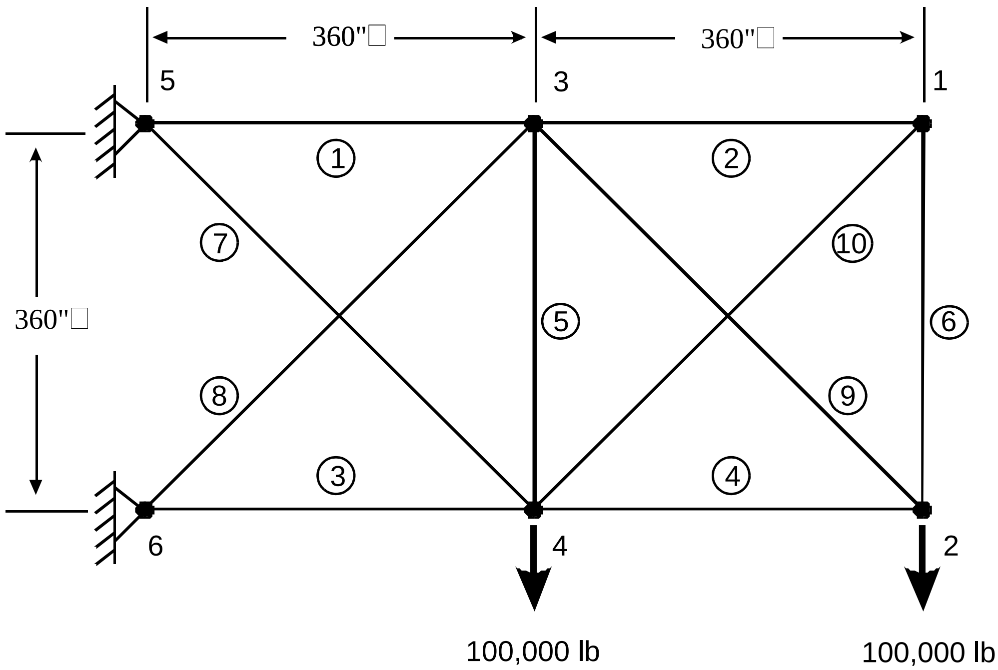
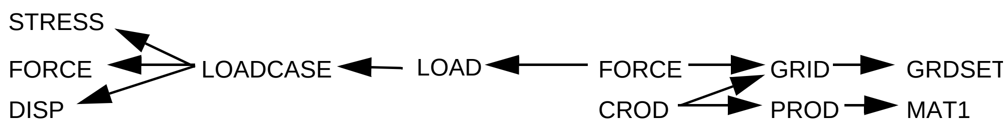


Figure 2-2

Structural Analysis Model

1. Planar truss structure modeled with 10 CROD elements.
2. Section properties: Area=5.0in^2
3. Material: E=1.0E7 psi.
4. One load case: Two 100,000 lb loads applied simultaneously to GRIDS 2 and 4.

Analysis Data Relationships



Special Modeling Techniques

NONE

Reference Solutions

NONE

2.2.1 Input Data

```
ID AAA
SOL COMPAT1
CEND
TITLE=10 ROD TRUSS
SUBTITLE=STRESSES, FORCES AND DISPLACEMENTS CALCULATIONS
ECHO = NONE
LINE = *,80
LOADCASE        1
   LABEL=
   LOAD   =       1
   DISP   =ALL
   FORCE  =ALL
   STRESS =ALL
$
BEGIN BULK
$
$     GRID POINTS
$
GRDSET                                                  0    3456
GRID           1         720.000 360.000    .000
GRID           2         720.000    .000    .000
GRID           3         360.000 360.000    .000
GRID           4         360.000    .000    .000
GRID           5            .000 360.000    .000             123456
GRID           6            .000    .000    .000             123456
$
$     ELEMENT DEFINITIONS
$
CROD           1       1       5       3
CROD           2       1       3       1
CROD           3       1       6       4
CROD           4       1       4       2
CROD           5       1       3       4
CROD           6       1       1       2
CROD           7       1       5       4
CROD           8       1       6       3
CROD           9       1       3       2
CROD          10       1       4       1
$
$     MATERIAL DEFINITIONS
$
MAT1    11      1.0+7           0.3
$
$     PROPERTY DEFINITIONS
$
PROD           1      11.500E+01              .000E+00               P1
$
$     LOAD DEFINITIONS
$
FORCE          1       2       0   1.0       .0 -100000.     .0
FORCE          1       4       0   1.0       .0 -100000.     .0
ENDDATA
```

2.2.2 Output

```
1
```

```
  GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
 G        E       NN  N   E       S          I     S
 G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
 G    G   E       N  NN   E            S     I          S
  GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS
```

```
                 STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                              COPYRIGHT, 1991-2002

                   VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                       ALL RIGHTS RESERVED, WORLDWIDE

                                 VERSION 7.2

                            BUILD CODE 200212131048



     PROJECT NAME: A002
     RUN STARTED:  Dec 13, 2002 12:49
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    1
 10 ROD TRUSS
 STRESSES, FORCES AND DISPLACEMENTS CALCULATIONS

                            ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                     6
                   NUMBER OF CROD ELEMENTS:                  10
                   TOTAL NUMBER OF NON RIGID ELEMENTS:       10
```

```
                     NUMBER OF ELEMENT PROPERTIES:              1
                     NUMBER OF MATERIALS:                       1
                     NUMBER OF DEGREES OF FREEDOM:              8



                                 LOAD CASES SUMMARY

                    NUMBER OF STATIC LOAD CASES:                  1
                    TOTAL NUMBER OF LOAD CASES:                   1

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    2
 10 ROD TRUSS
 STRESSES, FORCES AND DISPLACEMENTS CALCULATIONS

                 ********************************************
                 *  D E S I G N   C Y C L E      0 (ANALYSIS)*
                 ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    3
 10 ROD TRUSS
 STRESSES, FORCES AND DISPLACEMENTS CALCULATIONS

                    M A S S / V O L U M E   S U M M A R Y

                    SYSTEM MASS              0.000000E+00
                    SYSTEM VOLUME            2.098234E+04
                    SYSTEM MASS/VOLUME       0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    4
 10 ROD TRUSS
 STRESSES, FORCES AND DISPLACEMENTS CALCULATIONS

                   S O L U T I O N   R E S I D U A L S

 LOADCASE        1 ; RESIDUAL : -1.844394E-15 ; STRAIN ENERGY :  5.741690E+05
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    5
 10 ROD TRUSS
 STRESSES, FORCES AND DISPLACEMENTS CALCULATIONS

                     O L O A D   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1  0.0000E+00 -2.0000E+05  0.0000E+00  0.0000E+00  0.0000E+00 -1.0800E+08
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    6
 10 ROD TRUSS
 STRESSES, FORCES AND DISPLACEMENTS CALCULATIONS

                   S P C F O R C E   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1  0.0000E+00  2.0000E+05  0.0000E+00  0.0000E+00  0.0000E+00  1.0800E+08
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    7
 10 ROD TRUSS
 STRESSES, FORCES AND DISPLACEMENTS CALCULATIONS
```

```
             M A X I M U M   A P P L I E D   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1        2     1.0000E+05  0.0000E+00 -1.0000E+05  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    8
 10 ROD TRUSS
 STRESSES, FORCES AND DISPLACEMENTS CALCULATIONS

                 M A X I M U M   S P C   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1        5     3.1772E+05 -3.0000E+05  1.0464E+05  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    9
 10 ROD TRUSS
 STRESSES, FORCES AND DISPLACEMENTS CALCULATIONS

                M A X I M U M   D I S P L A C E M E N T

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1        2     8.1060E+00 -1.9045E+00 -7.8791E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   10
 10 ROD TRUSS
 STRESSES, FORCES AND DISPLACEMENTS CALCULATIONS
                                                                LOADCASE        1

                    G R I D   D I S P L A C E M E N T S

  GRID ID           T1                 T2                 T3
                    R1                 R2                 R3

       1      1.695525E+00     -7.590253E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

       2     -1.904475E+00     -7.879150E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

       3      1.406628E+00     -3.348705E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

       4     -1.473372E+00     -3.604230E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

       5      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

       6      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   11
 10 ROD TRUSS
 STRESSES, FORCES AND DISPLACEMENTS CALCULATIONS
```

```
                                                                     LOADCASE         1

                F O R C E S   I N   R O D   E L E M E N T S

   ROD ID          FORCE-A             FORCE-B

        1       1.953650E+05        1.953650E+05
        2       4.012463E+04        4.012463E+04
        3      -2.046350E+05       -2.046350E+05
        4      -5.987537E+04       -5.987537E+04
        5       3.548962E+04        3.548962E+04
        6       4.012463E+04        4.012463E+04
        7       1.479763E+05        1.479763E+05
        8      -1.348665E+05       -1.348665E+05
        9       8.467656E+04        8.467656E+04
       10      -5.674480E+04       -5.674480E+04
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   12
 10 ROD TRUSS
 STRESSES, FORCES AND DISPLACEMENTS CALCULATIONS
                                                                     LOADCASE         1

            S T R E S S E S   I N   R O D   E L E M E N T S

   ROD ID         STRESS-A            STRESS-B

        1       3.907300E+04        3.907300E+04
        2       8.024926E+03        8.024926E+03
        3      -4.092700E+04       -4.092700E+04
        4      -1.197507E+04       -1.197507E+04
        5       7.097924E+03        7.097924E+03
        6       8.024926E+03        8.024926E+03
        7       2.959525E+04        2.959525E+04
        8      -2.697329E+04       -2.697329E+04
        9       1.693531E+04        1.693531E+04
       10      -1.134896E+04       -1.134896E+04
1                            ***** END OF OUTPUT *****
```

2.3 Portal Frame

Example ID

A003

Analysis Data Used

GRID, GRDSET, CBAR, PBAR, MAT1, LOADCASE, LOAD, FORCE, MOMENT, SPC, SPC1, DISP, FORCE, STRESS.

Special Features Used

NONE

Problem Statement

Find the nodal displacements, element forces and stresses of the portal frame for each of the load cases indicated in **Figure 2-3**.

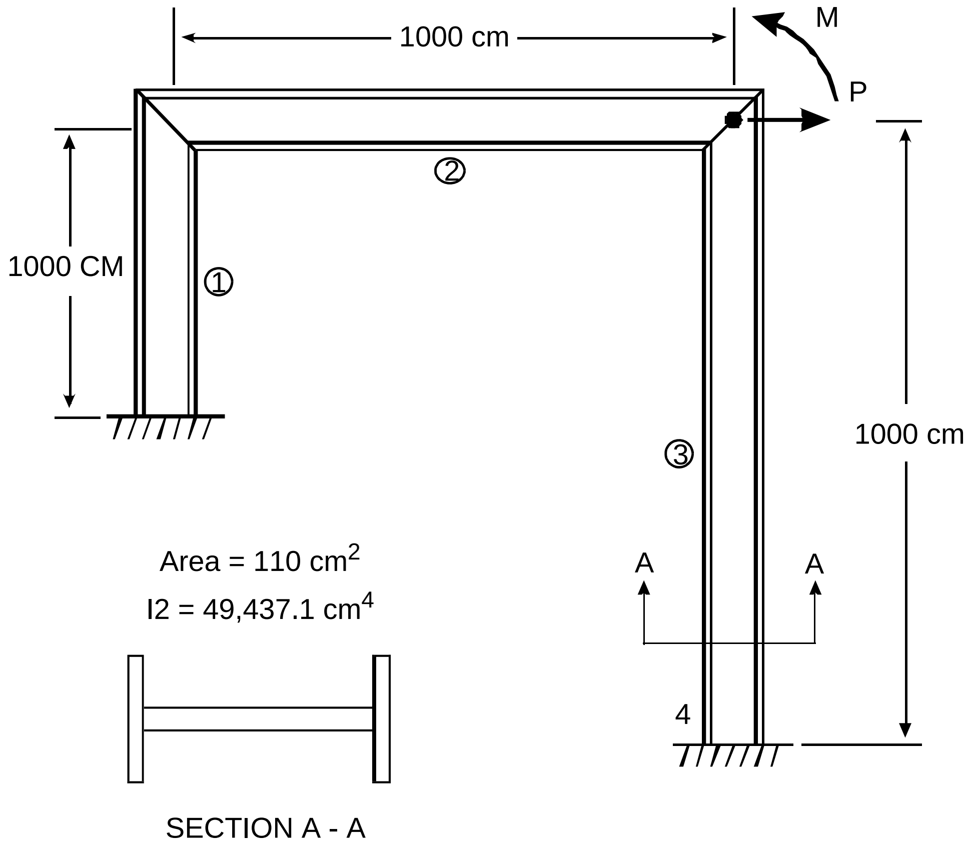
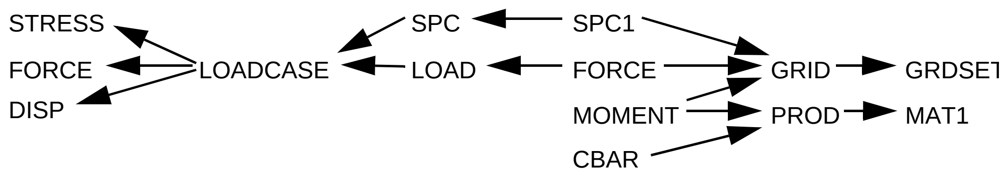


Figure 2-3

Structural Analysis Model

1. Planar three bar frame assembled with 3 CBAR elements.
2. Section properties of I beams: Area=110.0cm^2, I2=49437.1 cm^4.
3. Material: Aluminum Alloy, E=7.06E+6 N/cm^2, ν = 0.33.
4. Two Load cases:
1. P=50,000.0 N.
2. M=20E+6 N-cm.

Analysis Data Relationships



Special Modeling Techniques

NONE

Reference Solutions

NONE

2.3.1 Input Data

```
ID A003
SOL COMPAT1
CEND
TITLE = PORTAL FRAME
ECHO=NONE
LINE=64,80
DISP = ALL
STRESS = ALL
FORCE = ALL
SPC = 100
SUBCASE 1
        LABEL = A FORCE AT NODE 3
        LOAD = 300
SUBCASE 2
        LABEL = A MOMENT AT NODE 3
        LOAD = 310
$
BEGIN BULK
$
$     BOUNDARY CONDITIONS
$
SPC1    100     123456  1       4
$
$     GRID POINTS
$
GRDSET                                                  345
GRID    1               0.0     500.    0.0
GRID    2               0.0     1000.   0.0
GRID    3               1000.   1000.   0.0
GRID    4               1000.   0.0     0.0
$
$     ELEMENT DEFINITIONS
$
CBAR    1       1       1       2       0.0     0.0     -1.0
CBAR    2       1       2       3       0.0     0.0     -1.0
CBAR    3       1       3       4       0.0     0.0     -1.0
$
$     PROPERTIY DEFINITIONS
$
PBAR    1       51      110.0   4504.0  49437.1                         +P1
+P1     15.0    26.0    0.0     26.0    0.0     0.0     0.00    -26.0
$
$     MATERIAL DEFINITIONS
$
MAT1    51      7.06E6           0.33    0.1
$
$     LOAD DEFINITIONS
$
FORCE   300     3               50000.0 1.0     0.0     0.0
MOMENT  310     3               20.E6   0.0     0.0     -1.0
$
ENDDATA
```

2.3.2 Output

```
1








             GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
            G        E       NN  N   E       S          I     S
            G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
            G    G   E       N  NN   E            S     I          S
             GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                 STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                              COPYRIGHT, 1991-2002

                    VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                         ALL RIGHTS RESERVED, WORLDWIDE

                                  VERSION 7.2

                              BUILD CODE 200212131048




     PROJECT NAME: A003
     RUN STARTED:  Dec 13, 2002 12:49
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    1
 PORTAL FRAME


                              ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                       4
                   NUMBER OF CBAR ELEMENTS:                     3
                   TOTAL NUMBER OF NON RIGID ELEMENTS:          3
```

```
                    NUMBER OF ELEMENT PROPERTIES:              1
                    NUMBER OF MATERIALS:                       1
                    NUMBER OF DEGREES OF FREEDOM:              6


                                LOAD CASES SUMMARY

                   NUMBER OF STATIC LOAD CASES:                  2
                   TOTAL NUMBER OF LOAD CASES:                   2

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    2
 PORTAL FRAME


               ********************************************
               *  D E S I G N  C Y C L E      0 (ANALYSIS)*
               ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    3
 PORTAL FRAME


                    M A S S / V O L U M E   S U M M A R Y

                    SYSTEM MASS                2.750000E+04
                    SYSTEM VOLUME              2.750000E+05
                    SYSTEM MASS/VOLUME         1.000000E-01
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    4
 PORTAL FRAME


                   S O L U T I O N   R E S I D U A L S

 LOADCASE         1 ; RESIDUAL : -2.089031E-14 ; STRAIN ENERGY :  6.142640E+04
 LOADCASE         2 ; RESIDUAL : -2.171412E-16 ; STRAIN ENERGY :  7.573223E+04
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    5
 PORTAL FRAME


                    O L O A D   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1  5.0000E+04  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00 -5.0000E+07
      2  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00 -2.0000E+07
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    6
 PORTAL FRAME


                   S P C F O R C E   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1 -5.0000E+04  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  5.0000E+07
      2  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  2.0000E+07
```

```
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    7
 PORTAL FRAME


               M A X I M U M   A P P L I E D   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1           T2           T3

      1        3     5.0000E+04  5.0000E+04  0.0000E+00  0.0000E+00
      2              0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    8
 PORTAL FRAME


                   M A X I M U M   S P C   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1           T2           T3

      1        1     4.2634E+04 -4.1139E+04 -1.1193E+04  0.0000E+00
      2        4     2.0446E+04  1.4716E+04  1.4195E+04  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    9
 PORTAL FRAME


                  M A X I M U M   D I S P L A C E M E N T

 LOADCASE GRID ID      MAGNITUDE      T1           T2           T3

      1        3     2.4571E+00  2.4571E+00 -1.4412E-02  0.0000E+00
      2        3     2.7369E-01  2.7308E-01 -1.8278E-02  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   10
 PORTAL FRAME

 A FORCE AT NODE 3                                           LOADCASE        1

                     G R I D   D I S P L A C E M E N T S

  GRID ID             T1                 T2                 T3
                      R1                 R2                 R3

       1      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

       2      2.404083E+00      7.206126E-03      0.000000E+00
              0.000000E+00      0.000000E+00     -4.705191E-03

       3      2.457056E+00     -1.441225E-02      0.000000E+00
              0.000000E+00      0.000000E+00     -6.827082E-04

       4      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   11
 PORTAL FRAME
```

```
 A MOMENT AT NODE 3                                          LOADCASE        2

                     G R I D   D I S P L A C E M E N T S

  GRID ID            T1                 T2                 T3
                     R1                 R2                 R3

        1      0.000000E+00      0.000000E+00      0.000000E+00
               0.000000E+00      0.000000E+00      0.000000E+00

        2      2.541343E-01      9.138893E-03      0.000000E+00
               0.000000E+00      0.000000E+00      7.402269E-04

        3      2.730833E-01     -1.827779E-02      0.000000E+00
               0.000000E+00      0.000000E+00     -7.573223E-03

        4      0.000000E+00      0.000000E+00      0.000000E+00
               0.000000E+00      0.000000E+00      0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   12
 PORTAL FRAME

 A FORCE AT NODE 3                                           LOADCASE        1

                F O R C E S   I N   B A R   E L E M E N T S

   BAR ID  END     BENDING MOMENT 1   BENDING MOMENT 2     AXIAL FORCE
                    SHEAR FORCE 1      SHEAR FORCE 2         TORQUE


        1    A       0.000000E+00      -1.356916E+07       1.119255E+04
                     0.000000E+00      -4.113878E+04       0.000000E+00
             B       0.000000E+00       7.000228E+06       1.119255E+04
                     0.000000E+00      -4.113878E+04       0.000000E+00


        2    A       0.000000E+00       7.000228E+06       4.113878E+04
                     0.000000E+00       1.119255E+04       0.000000E+00
             B       0.000000E+00      -4.192326E+06       4.113878E+04
                     0.000000E+00       1.119255E+04       0.000000E+00


        3    A       0.000000E+00      -4.192326E+06      -1.119255E+04
                     0.000000E+00      -8.861219E+03       0.000000E+00
             B       0.000000E+00       4.668892E+06      -1.119255E+04
                     0.000000E+00      -8.861219E+03       0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   13
 PORTAL FRAME

 A MOMENT AT NODE 3                                          LOADCASE        2

                F O R C E S   I N   B A R   E L E M E N T S

   BAR ID  END     BENDING MOMENT 1   BENDING MOMENT 2     AXIAL FORCE
```

		SHEAR FORCE 1	SHEAR FORCE 2	TORQUE
1	A	0.000000E+00	-3.162221E+06	1.419453E+04
		0.000000E+00	-1.471575E+04	0.000000E+00
	B	0.000000E+00	4.195654E+06	1.419453E+04
		0.000000E+00	-1.471575E+04	0.000000E+00
2	A	0.000000E+00	4.195654E+06	1.471575E+04
		0.000000E+00	1.419453E+04	0.000000E+00
	B	0.000000E+00	-9.998874E+06	1.471575E+04
		0.000000E+00	1.419453E+04	0.000000E+00
3	A	0.000000E+00	1.000113E+07	-1.419453E+04
		0.000000E+00	1.471575E+04	0.000000E+00
	B	0.000000E+00	-4.714624E+06	-1.419453E+04
		0.000000E+00	1.471575E+04	0.000000E+00

1GENESIS VERSION 7.2 DATE 12-13-2002 TIME 12:49 PAGE 14
PORTAL FRAME

A FORCE AT NODE 3 LOADCASE 1

S T R E S S E S   I N   B A R   E L E M E N T S

BAR ID	END	STRESS-C	STRESS-D	STRESS-E	STRESS-F
1	A	7.238056E+03	7.238056E+03	1.017505E+02	-7.034555E+03
	B	-3.579815E+03	-3.579815E+03	1.017505E+02	3.783316E+03
2	A	-3.307577E+03	-3.307577E+03	3.739889E+02	4.055555E+03
	B	2.578821E+03	2.578821E+03	3.739889E+02	-1.830843E+03
3	A	2.103081E+03	2.103081E+03	-1.017505E+02	-2.306582E+03
	B	-2.557218E+03	-2.557218E+03	-1.017505E+02	2.353717E+03

1GENESIS VERSION 7.2 DATE 12-13-2002 TIME 12:49 PAGE 15
PORTAL FRAME

A MOMENT AT NODE 3 LOADCASE 2

S T R E S S E S   I N   B A R   E L E M E N T S

BAR ID	END	STRESS-C	STRESS-D	STRESS-E	STRESS-F
1	A	1.792119E+03	1.792119E+03	1.290412E+02	-1.534037E+03
	B	-2.077541E+03	-2.077541E+03	1.290412E+02	2.335623E+03
2	A	-2.072802E+03	-2.072802E+03	1.337795E+02	2.340361E+03
	B	5.392395E+03	5.392395E+03	1.337795E+02	-5.124836E+03
3	A	-5.388842E+03	-5.388842E+03	-1.290412E+02	5.130759E+03
	B	2.350478E+03	2.350478E+03	-1.290412E+02	-2.608560E+03

1 ***** END OF OUTPUT *****

2.4 Circular Ring

Example ID

A0046

Analysis Data Used

GRID, CORD2C, CBAR, PBAR, MAT1, LOADCASE, PLOAD1, DISP

Special Features Used

Utilization of cylindrical coordinate system for input grid coordinates and for the displacement output.

Problem Statement

Find the radial and rotational displacements of a round, solid ring of radius R=25.0 in. and circular cross section of D=4.0 in. The ring is subjected to two separate load cases. The first load case corresponds to normal pressure while the second load case corresponds to constant torsion. Combinations of this two load cases are found in rings that are use to stiffen spherical domes.

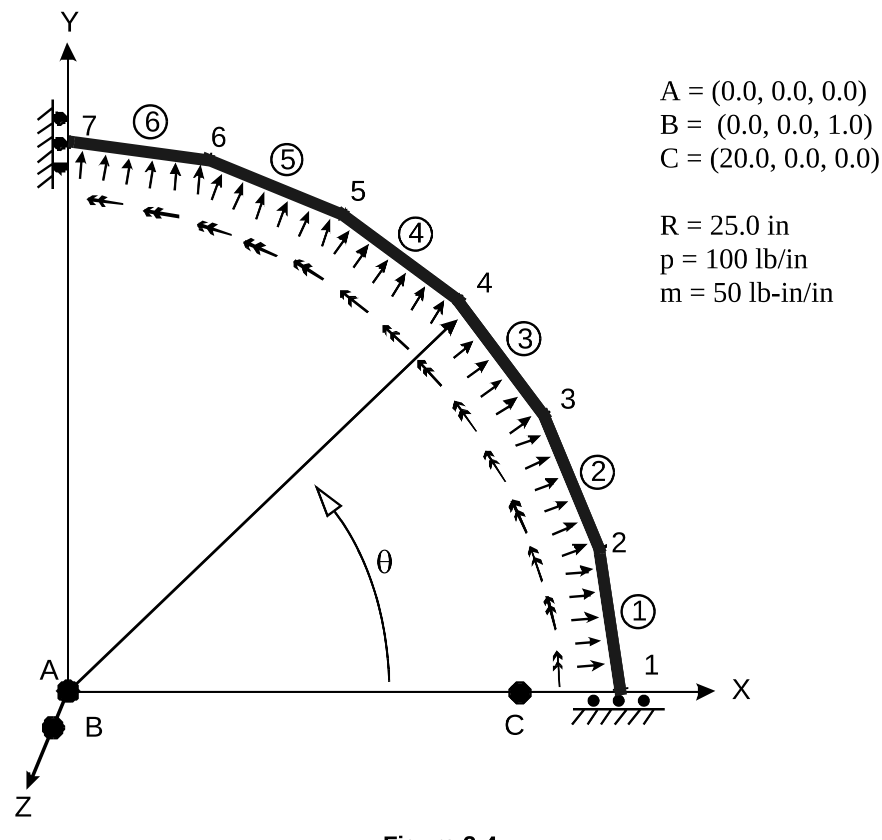
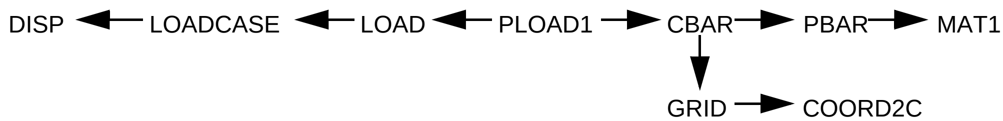


Figure 2-4

Structural Analysis Model

1. Due to symmetry a quarter model with 6 round CBAR elements is used.
2. The section properties are: Area=12.57 m^2, I=12.57 m^4, J=25.14 m^4 and AS=11.16 m^2
3. Material: E=1.0E7 psi.
4. Two load cases:
    1. Normal pressure p=100.0 lb/in.
    2. Constant torsion m= 50.0 lb-in/in.

Analysis Data Relationships



Special Modeling Techniques

NONE

Reference Solutions

The analytical solutions assuming that inner radius is equal to the external radius are:

$$u_r = \frac{R^2 \rho}{EA} = 0.000497 \mathrm{in}$$

$$\theta = \frac{R^2 m}{EI} = 0.000246 \mathrm{rad}$$

where R is the radius, E the Young's modulus, A the cross sectional area, I the area moment of inertia, p is the normal pressure and m is the torsion per unit length.

Calculated Solutions

$$u_r = 0.000493$$

$$\theta = 0.000246 \mathrm{rad}$$

Comparison Between Calculated Solutions and Reference Solutions

The differences between analytical solutions and *GENESIS* solutions are:

$$u_r = -0.8\%$$

$$\theta = -0.8\%$$

2.4.1 Input Data

```
ID A004
SOL COMPAT1
CEND
TITLE= CIRCULAR RING
ECHO=NONE
LINE=64,80
LOADCASE 1
     LOAD=12
     DISP=ALL
LOADCASE 2
     LOAD=22
     DISP=ALL
BEGIN BULK
$
$   CYLINDRICAL COORDINATE SYSTEM
$
CORD2C  7               0.0     0.0     0.0     0.0     0.0     1.0
+       20.0    0.0     0.0
$
$   GRID DATA
$
GRID    1       7       25.0    00.0    0.0     7       246
GRID    2       7       25.0    15.0    0.0     7
GRID    3       7       25.0    30.0    0.0     7
GRID    4       7       25.0    45.0    0.0     7       3
GRID    5       7       25.0    60.0    0.0     7
GRID    6       7       25.0    75.0    0.0     7
GRID    7       7       25.0    90.0    0.0     7       246
$
$   ELEMENT DEFINITIONS
$
CBAR    1       1       1       2       -1.0    0.0     0.
CBAR    2       1       2       3       -1.0    0.0     0.
CBAR    3       1       3       4       -1.0    0.0     0.
CBAR    4       1       4       5       -1.0    0.0     0.
CBAR    5       1       5       6       -1.0    0.0     0.
CBAR    6       1       6       7       -1.0    0.0     0.
$
$   PROPERTY DATA: CIRCULAR BEAM,  D = 4.0 in.
$
PBAR    1       1       12.57   12.57   12.57   25.13
+       0.0     2.0     2.0     0.0     -2.0    0.0     0.0     -2.0
+       10.888  0.888   0.0
$
$   MATERIAL DEFINITION
$
MAT1    1       10.0+6          0.3     0.0     0.0     25.0
$
$   LOADS: NORMAL PRESSURE LOAD.
$
PLOAD1  12      1       FYE                     -100.0          -100.0
PLOAD1  12      2       FYE                     -100.0          -100.0
```

```
PLOAD1  12      3       FYE                     -100.0          -100.0
PLOAD1  12      4       FYE                     -100.0          -100.0
PLOAD1  12      5       FYE                     -100.0          -100.0
PLOAD1  12      6       FYE                     -100.0          -100.0
$
$   LOADS: DISTRIBUTED TORCIONAL MOMENT
$
PLOAD1  22      1       MXE                     50.0            50.0
PLOAD1  22      2       MXE                     50.0            50.0
PLOAD1  22      3       MXE                     50.0            50.0
PLOAD1  22      4       MXE                     50.0            50.0
PLOAD1  22      5       MXE                     50.0            50.0
PLOAD1  22      6       MXE                     50.0            50.0
$
ENDDATA
```

2.4.2 Output

```
1









              GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
             G        E       NN  N   E       S          I     S
             G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
             G    G   E       N  NN   E            S     I          S
              GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                  STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE



                               COPYRIGHT, 1991-2002

                     VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                          ALL RIGHTS RESERVED, WORLDWIDE

                                  VERSION 7.2

                            BUILD CODE 200212131048




     PROJECT NAME: A004
     RUN STARTED:  Dec 13, 2002 12:49
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    1
 CIRCULAR RING


                            ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                      7
                   NUMBER OF LOCAL COORDINATE SYSTEMS:         1
                   NUMBER OF CBAR ELEMENTS:                    6
```

```
                 TOTAL NUMBER OF NON RIGID ELEMENTS:         6
                 NUMBER OF ELEMENT PROPERTIES:               1
                 NUMBER OF MATERIALS:                        1
                 NUMBER OF DEGREES OF FREEDOM:              35


                            LOAD CASES SUMMARY

                NUMBER OF STATIC LOAD CASES:                   2
                TOTAL NUMBER OF LOAD CASES:                    2
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    2
 CIRCULAR RING


              ********************************************
              *  D E S I G N  C Y C L E     0 (ANALYSIS)*
              ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    3
 CIRCULAR RING


                  M A S S / V O L U M E   S U M M A R Y

                  SYSTEM MASS              0.000000E+00
                  SYSTEM VOLUME            4.922143E+02
                  SYSTEM MASS/VOLUME       0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    4
 CIRCULAR RING


                 S O L U T I O N   R E S I D U A L S

 LOADCASE        1 ; RESIDUAL : -1.581308E-15 ; STRAIN ENERGY :  9.569094E-01
 LOADCASE        2 ; RESIDUAL :  2.049844E-16 ; STRAIN ENERGY :  2.392273E-01
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    5
 CIRCULAR RING


                   O L O A D   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1  2.5000E+03  2.5000E+03  0.0000E+00  0.0000E+00  0.0000E+00  2.7285E-12
      2  0.0000E+00  0.0000E+00  0.0000E+00 -1.2500E+03  1.2500E+03  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    6
 CIRCULAR RING


                 S P C F O R C E   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1 -2.5000E+03 -2.5000E+03  0.0000E+00  0.0000E+00  0.0000E+00 -2.9104E-11
```

```
     2  0.0000E+00  0.0000E+00  0.0000E+00  1.2500E+03 -1.2500E+03  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    7
 CIRCULAR RING


               M A X I M U M   A P P L I E D   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1        2     6.4705E+02  6.4705E+02  4.2633E-14  0.0000E+00
      2              0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    8
 CIRCULAR RING


                   M A X I M U M   S P C   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1        1     2.5000E+03  2.2737E-13 -2.5000E+03  0.0000E+00
      2        4     5.6843E-14  0.0000E+00  0.0000E+00 -5.6843E-14
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    9
 CIRCULAR RING


                  M A X I M U M   D I S P L A C E M E N T

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1        7     4.9296E-04  4.9296E-04  0.0000E+00  0.0000E+00
      2        1     2.5479E-18  0.0000E+00  0.0000E+00 -2.5479E-18
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   10
 CIRCULAR RING

                                                           LOADCASE        1

                       G R I D   D I S P L A C E M E N T S

  GRID ID            T1                 T2                 T3
                     R1                 R2                 R3

        1      4.929618E-04      0.000000E+00      0.000000E+00
               0.000000E+00      0.000000E+00      0.000000E+00

        2      4.929618E-04      1.057097E-18      0.000000E+00
               0.000000E+00      0.000000E+00     -2.303930E-19

        3      4.929618E-04      1.680513E-18      0.000000E+00
               0.000000E+00      0.000000E+00     -2.944887E-19

        4      4.929618E-04      1.783794E-18      0.000000E+00
               0.000000E+00      0.000000E+00     -1.848631E-19

        5      4.929618E-04      1.460556E-18      0.000000E+00
               0.000000E+00      0.000000E+00     -1.151965E-19
```

```
       6      4.929618E-04      8.233160E-19      0.000000E+00
              0.000000E+00      0.000000E+00      2.232235E-23

       7      4.929618E-04      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   11
 CIRCULAR RING

                                                            LOADCASE         2

                      G R I D   D I S P L A C E M E N T S

  GRID ID             T1                  T2                  T3
                      R1                  R2                  R3

       1      0.000000E+00      0.000000E+00     -2.547875E-18
              0.000000E+00      2.464809E-04      0.000000E+00

       2      0.000000E+00      0.000000E+00     -1.882099E-18
              1.236668E-19      2.464809E-04      0.000000E+00

       3      0.000000E+00      0.000000E+00     -8.030259E-19
              1.846532E-19      2.464809E-04      0.000000E+00

       4      0.000000E+00      0.000000E+00      0.000000E+00
              1.777602E-19      2.464809E-04      0.000000E+00

       5      0.000000E+00      0.000000E+00      1.192622E-18
              1.389134E-19      2.464809E-04      0.000000E+00

       6      0.000000E+00      0.000000E+00      2.250570E-18
              5.844527E-20      2.464809E-04      0.000000E+00

       7      0.000000E+00      0.000000E+00      2.263272E-18
              0.000000E+00      2.464809E-04      0.000000E+00

1                            ***** END OF OUTPUT *****
```

2.5 Wide Column/Wide Beam Frame

Example ID

A005

Analysis Data Used

GRID, GRDSET, CBAR, PBAR, MAT1, LOAD, FORCE, SPC, SPC1, DISP, FORCE.

Special Features Used

Utilization of offset capabilities of bar elements to model rigid connections of wide columns with wide beams.

Problem Statement

Find the nodal displacements and the element forces for the wide column/wide beam frame shown in **Figure 2-5**.

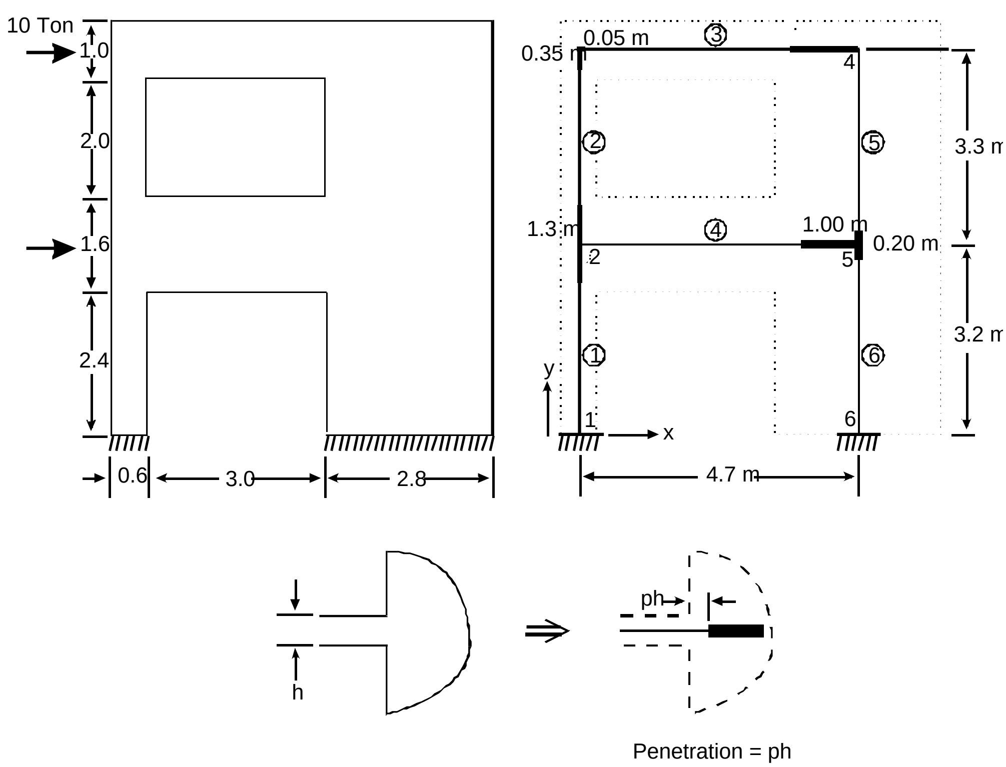


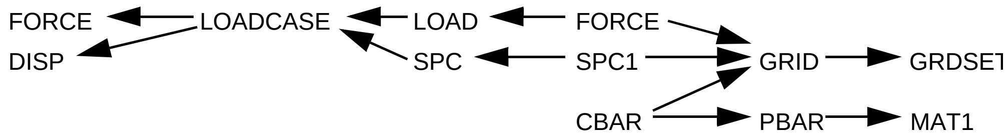
Figure 2-5

Structural Analysis Model

1. Six CBAR elements with offsets.

2. Dimensions: thickness=0.2m
3. Materials: Concrete E=3.0E+6 T/m^2
4. One load case: Two nodal forces. P1=10 T and P2=5 T.

Analysis Data Relationships



Special Modeling Techniques

The analysis of the facade of the figure below is done through a simplified model of a 6 bar frame. The model includes shear deformation and rigid segments. The rigid segments, which are generated with the offsets of the beam, are use to model the intersections of elements in massive nodes. The lengths of the rigid segments are obtained by subtracting the distance of the model axes and the penetration of each element in the massive node. The penetration of each element can be calculated by the product of Muto's penetration factor (p=0.25) and the elements' height (see the figure).
Note that the offsets are specified in the general coordinate system (displacement and constraint output coordinate system); not in the basic coordinate system. When no specification of displacement coordinate system is supplied (in field 7 of GRID entries), the general coordinate system is the basic coordinate system by default. In this example, the general coordinate system is the basic coordinate system.

Reference Solution

NONE

2.5.1 Input Data

```
ID A005
SOL COMPAT1
CEND
TITLE= ONE BAY, TWO STORY WIDE COLUMN/WIDE BEAM FRAME
SUBTITLE=SIX BAR MODEL WITH RIGID OFFSETS
ECHO=NONE
LINE=64,80
    LOAD=100
    SPC =100
    DISP=ALL
    FORCE=ALL
BEGIN BULK
$
$   GRID DATA
$
GRDSET                                                  345
GRID    1               0.0     0.0     0.0
GRID    2               0.0     3.2     0.0
GRID    3               0.0     6.5     0.0
GRID    4               4.7     6.5     0.0
GRID    5               4.7     3.2     0.0
GRID    6               4.7     0.0     0.0
$
$   BOUNDARY CONDITIONS
$
SPC1    100     123456  1       6
$
$   ELEMENT DATA
$
CBAR    1       12      1       2       0.0     0.0     -1.0
+                       0.0     0.0     0.0     0.0     -0.65   0.0
CBAR    2       12      2       3       0.0     0.0     -1.0
+                       0.0     0.65    0.0     0.0     -0.35   0.0
CBAR    3       3       3       4       0.0     0.0     -1.0
+                       0.05    0.0     0.0     -1.15   0.00    0.0
CBAR    4       4       2       5       0.0     0.0     -1.0
+                       0.0     0.0     0.0     -1.0    0.00    0.0
CBAR    5       56      5       4       0.0     0.0     -1.0
+                       0.0     0.1     0.0     0.0     0.00    0.0
CBAR    6       56      6       5       0.0     0.0     -1.0
+                       0.0     0.0     0.0     0.0     -0.10   0.0
$
$   PROPERTY DEFINITIONS
$
PBAR    12      1       .12     .0004   .0036
+       0.1     0.3     0.1     -0.3    -0.1    -0.3    -0.1    0.3
+       0.8333330.8333330.0
PBAR    3       1       .20     .00067  .01667
+       0.1     0.5     0.1     -0.5    -0.1    -0.5    -0.1    0.5
+       0.8333330.8333330.0
PBAR    4       1       .32     .00107  .06827
+       0.1     0.8     0.1     -0.8    -0.1    -0.8    -0.1    0.8
```

```
+       0.8333330.8333330.0
PBAR    56      1       .56     .00187  .3659
+       0.1     1.4     0.1     -1.4    -0.1    -1.4    -0.1    1.4
+       0.8333330.8333330.0
$
$   MATERIAL DATA
$
MAT1    1       3.0+6   1.2+6
$
$   LOAD DATA
$
FORCE   100     3               10.0    1.0     0.0     0.0
FORCE   100     2               5.0     1.0     0.0     0.0
$
ENDDATA
```

2.5.2 Output

```
1






              GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
             G        E       NN  N   E       S          I     S
             G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
             G    G   E       N  NN   E            S     I          S
              GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                 STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                              COPYRIGHT, 1991-2002

                   VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                        ALL RIGHTS RESERVED, WORLDWIDE

                                 VERSION 7.2

                           BUILD CODE 200212131048



     PROJECT NAME: A005
     RUN STARTED:  Dec 13, 2002 12:49
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    1
 ONE BAY, TWO STORY WIDE COLUMN/WIDE BEAM FRAME
 SIX BAR MODEL WITH RIGID OFFSETS

                           ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                       6
                   NUMBER OF CBAR ELEMENTS:                     6
                   TOTAL NUMBER OF NON RIGID ELEMENTS:          6
```

```
                      NUMBER OF ELEMENT PROPERTIES:              4
                      NUMBER OF MATERIALS:                       1
                      NUMBER OF DEGREES OF FREEDOM:             12


                                  LOAD CASES SUMMARY

                     NUMBER OF STATIC LOAD CASES:                  1
                     TOTAL NUMBER OF LOAD CASES:                   1

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    2
 ONE BAY, TWO STORY WIDE COLUMN/WIDE BEAM FRAME
 SIX BAR MODEL WITH RIGID OFFSETS

                 ********************************************
                 *  D E S I G N  C Y C L E      0 (ANALYSIS)*
                 ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    3
 ONE BAY, TWO STORY WIDE COLUMN/WIDE BEAM FRAME
 SIX BAR MODEL WITH RIGID OFFSETS

                       M A S S / V O L U M E   S U M M A R Y

                       SYSTEM MASS             0.000000E+00
                       SYSTEM VOLUME           5.994000E+00
                       SYSTEM MASS/VOLUME      0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    4
 ONE BAY, TWO STORY WIDE COLUMN/WIDE BEAM FRAME
 SIX BAR MODEL WITH RIGID OFFSETS

                      S O L U T I O N   R E S I D U A L S

 LOADCASE        1 ; RESIDUAL :  7.085516E-16 ; STRAIN ENERGY :  3.451449E-03
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    5
 ONE BAY, TWO STORY WIDE COLUMN/WIDE BEAM FRAME
 SIX BAR MODEL WITH RIGID OFFSETS

                        O L O A D   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1  1.5000E+01  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00 -8.1000E+01
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    6
 ONE BAY, TWO STORY WIDE COLUMN/WIDE BEAM FRAME
 SIX BAR MODEL WITH RIGID OFFSETS

                      S P C F O R C E   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1 -1.5000E+01  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  8.1000E+01
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    7
 ONE BAY, TWO STORY WIDE COLUMN/WIDE BEAM FRAME
 SIX BAR MODEL WITH RIGID OFFSETS
```

```
              M A X I M U M   A P P L I E D   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1        3     1.0000E+01  1.0000E+01  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    8
 ONE BAY, TWO STORY WIDE COLUMN/WIDE BEAM FRAME
 SIX BAR MODEL WITH RIGID OFFSETS

                  M A X I M U M   S P C   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1        6     1.5470E+01 -1.3640E+01  7.2974E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    9
 ONE BAY, TWO STORY WIDE COLUMN/WIDE BEAM FRAME
 SIX BAR MODEL WITH RIGID OFFSETS

                 M A X I M U M   D I S P L A C E M E N T

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1        3     5.7427E-04  5.7043E-04  6.6263E-05  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   10
 ONE BAY, TWO STORY WIDE COLUMN/WIDE BEAM FRAME
 SIX BAR MODEL WITH RIGID OFFSETS
                                                          LOADCASE        1

                      G R I D   D I S P L A C E M E N T S

  GRID ID           T1                T2                T3
                    R1                R2                R3

       1      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

       2      2.397111E-04      5.169027E-05      0.000000E+00
              0.000000E+00      0.000000E+00     -1.915512E-05

       3      5.704342E-04      6.626258E-05      0.000000E+00
              0.000000E+00      0.000000E+00     -2.782742E-05

       4      5.252333E-04     -1.781007E-05      0.000000E+00
              0.000000E+00      0.000000E+00     -8.167393E-05

       5      2.170035E-04     -1.346553E-05      0.000000E+00
              0.000000E+00      0.000000E+00     -6.705721E-05

       6      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   11
 ONE BAY, TWO STORY WIDE COLUMN/WIDE BEAM FRAME
 SIX BAR MODEL WITH RIGID OFFSETS
```

LOADCASE 1

F O R C E S   I N   B A R   E L E M E N T S

BAR ID	END	BENDING MOMENT 1 SHEAR FORCE 1	BENDING MOMENT 2 SHEAR FORCE 2	AXIAL FORCE TORQUE
1	A	0.000000E+00	-1.814576E+00	7.297449E+00
		0.000000E+00	-1.359567E+00	0.000000E+00
	B	0.000000E+00	1.652321E+00	7.297449E+00
		0.000000E+00	-1.359567E+00	0.000000E+00
2	A	0.000000E+00	-2.629698E+00	2.280884E+00
		0.000000E+00	-2.251283E+00	0.000000E+00
	B	0.000000E+00	2.548253E+00	2.280884E+00
		0.000000E+00	-2.251283E+00	0.000000E+00
3	A	0.000000E+00	3.222158E+00	-7.748717E+00
		0.000000E+00	2.280884E+00	0.000000E+00
	B	0.000000E+00	-4.760937E+00	-7.748717E+00
		0.000000E+00	2.280884E+00	0.000000E+00
4	A	0.000000E+00	6.629071E+00	-5.891716E+00
		0.000000E+00	5.016565E+00	0.000000E+00
	B	0.000000E+00	-1.193222E+01	-5.891716E+00
		0.000000E+00	5.016565E+00	0.000000E+00
5	A	0.000000E+00	-1.741194E+01	-2.280884E+00
		0.000000E+00	-7.748717E+00	0.000000E+00
	B	0.000000E+00	7.383955E+00	-2.280884E+00
		0.000000E+00	-7.748717E+00	0.000000E+00
6	A	0.000000E+00	-4.488741E+01	-7.297449E+00
		0.000000E+00	-1.364043E+01	0.000000E+00
	B	0.000000E+00	-2.602070E+00	-7.297449E+00
		0.000000E+00	-1.364043E+01	0.000000E+00

1 ***** END OF OUTPUT *****

2.6 Deformed Beam

Example ID

A006

Analysis Data Used

GRID, CBAR, PBAR, MAT1, LOADCASE, LOAD, SPC, SPCD, SPC1, STRESS.

Special Features Used

This problem shows the capabilities of *GENESIS* to analyze structures with enforced displacements.

Problem Statement

The beam in **Figure 2-6** has an enforced displacement of 1 inch in the z direction. Neglecting shear deformation find the tensile stresses at the corners of the beam.

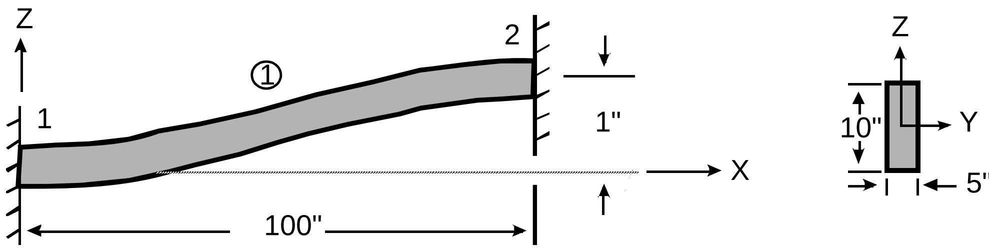


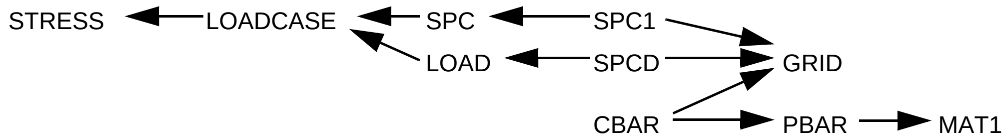
Figure 2-6

Structural Analysis Model

1. One CBAR element in the x-z plane.
2. The relevant section properties are: Area=50 in^2, I2=416.7 in^4
3. Material E=1.0E7 psi.
4. One displacement load case u_z = 1.0 in.

The enforced displacement is specified with a SPCD data entry. In addition, it is necessary to constrain the degree of freedom. Degrees of freedom are constrained with SPC1 data entries.

Analysis Data Relationships



Special Modeling Techniques

NONE

Reference Solution

The analytical solution for the stresses in the corner of the beam neglecting shear deformation are:

$$\sigma = \pm\frac{Mh}{2I}$$

where M is the moment, I the area moment of inertia and h the total height. The moment can be calculated using the following relationship:

$$M = \frac{6EI}{L^2}$$

where E is the Young's modulus and L is the length of the beam.
Therefore

$$\sigma = \mp 30{,}000.0 \text{ psi}$$

Calculated Solution

$$\sigma = \mp 30{,}000 \text{ psi}$$

Comparison Between Calculated Solution and Reference Solution

There are no differences between analytical solutions and the *GENESIS* solution.

2.6.1 Input Data

```
ID A006
SOL COMPAT1
CEND
TITLE= DEFORMEND BEAM
ECHO=NONE
LINE=64,80
LOADCASE 1
     LOAD=71
     SPC=81
     STRESS=ALL
BEGIN BULK
$
$   GRID DATA
$
GRID    1               0.0     0.0     0.0             123456
GRID    2               100.0   0.      0.              12456
$
$   ELEMENT DEFINITIONS
$
CBAR    1       1       1       2       0.      1.0     0.
+                       0.      .0      0.0     0.0     0.0     0.0
$
$   PROPERTY DEFINITIONS
$
PBAR    1       1       50.0    104.2   416.7   288.5   0.0
+       2.5     5.0     2.5     -5.0    -2.5    -5.0    -2.5    5.0
$
$   MATERIAL DATA
$
MAT1    1       10.0+6          0.3     0.0     0.0     25.0
$
$   ENFORCED DISPLACEMENT DATA
$
SPCD    71      2       3       1.0
SPC1    81      3       2
$
ENDDATA
```

2.6.2 Output

```
1

               GGGG     EEEEE    N   N    EEEEE     SSSSS    IIIII     SSSSS
              G         E        NN  N    E        S           I      S
              G   GG    EEEE     N N N    EEEE      SSSS       I       SSSS
              G    G    E        N  NN    E             S      I           S
               GGGG     EEEEE    N   N    EEEEE    SSSSS     IIIII    SSSSS


                   STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                                COPYRIGHT, 1991-2002

                     VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                          ALL RIGHTS RESERVED, WORLDWIDE

                                   VERSION 7.2

                              BUILD CODE 200212131048



     PROJECT NAME: A006
     RUN STARTED:  Dec 13, 2002 12:49
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    1
 DEFORMEND BEAM


                              ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                      2
                   NUMBER OF CBAR ELEMENTS:                    1
                   TOTAL NUMBER OF NON RIGID ELEMENTS:         1
```

```
                   NUMBER OF ELEMENT PROPERTIES:               1
                   NUMBER OF MATERIALS:                        1
                   NUMBER OF DEGREES OF FREEDOM:               1


                               LOAD CASES SUMMARY

                  NUMBER OF STATIC LOAD CASES:                   1
                  TOTAL NUMBER OF LOAD CASES:                    1

1GENESIS   VERSION  7.2                 DATE 12-13-2002  TIME 12:49  PAGE    2
 DEFORMEND BEAM


               ********************************************
               *  D E S I G N  C Y C L E      0 (ANALYSIS)*
               ********************************************
1GENESIS   VERSION  7.2                 DATE 12-13-2002  TIME 12:49  PAGE    3
 DEFORMEND BEAM


                    M A S S / V O L U M E   S U M M A R Y

                    SYSTEM MASS              0.000000E+00
                    SYSTEM VOLUME            5.000000E+03
                    SYSTEM MASS/VOLUME       0.000000E+00
1GENESIS   VERSION  7.2                 DATE 12-13-2002  TIME 12:49  PAGE    4
 DEFORMEND BEAM


                   S O L U T I O N   R E S I D U A L S

 LOADCASE        1 ; RESIDUAL :  0.000000E+00 ; STRAIN ENERGY :  2.500200E+04
1GENESIS   VERSION  7.2                 DATE 12-13-2002  TIME 12:49  PAGE    5
 DEFORMEND BEAM


                     O L O A D   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                 DATE 12-13-2002  TIME 12:49  PAGE    6
 DEFORMEND BEAM


                   S P C F O R C E   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                 DATE 12-13-2002  TIME 12:49  PAGE    7
 DEFORMEND BEAM
```

```
              M A X I M U M   A P P L I E D   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1              0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                 DATE 12-13-2002  TIME 12:49  PAGE    8
 DEFORMEND BEAM


                  M A X I M U M   S P C   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1        1     5.0004E+04  0.0000E+00  0.0000E+00 -5.0004E+04
1GENESIS   VERSION  7.2                 DATE 12-13-2002  TIME 12:49  PAGE    9
 DEFORMEND BEAM


                 M A X I M U M   D I S P L A C E M E N T

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1        2     1.0000E+00  0.0000E+00  0.0000E+00  1.0000E+00
1GENESIS   VERSION  7.2                 DATE 12-13-2002  TIME 12:49  PAGE   10
 DEFORMEND BEAM

                                                               LOADCASE        1

             S T R E S S E S   I N   B A R   E L E M E N T S

   BAR ID  END     STRESS-C       STRESS-D       STRESS-E       STRESS-F

       1    A  -3.000000E+04   3.000000E+04   3.000000E+04  -3.000000E+04
            B   3.000000E+04  -3.000000E+04  -3.000000E+04   3.000000E+04

1                            ***** END OF OUTPUT *****
```

2.7 Two Bar Symmetric Frame

Example ID

A007

Analysis Data Used

GRID, CBAR, PBAR, MAT1, LOADCASE, LOADCOM, LOADSEQ, LOAD, FORCE, SPC, SPC1, DISPLACEMENT, STRESS

Special Features Used

Utilization of multi-point constraints (MPC) to break a symmetric structure into a half model under two load conditions.

Problem Statement

Find nodal displacements of the structure shown in **Figure 2-7**.

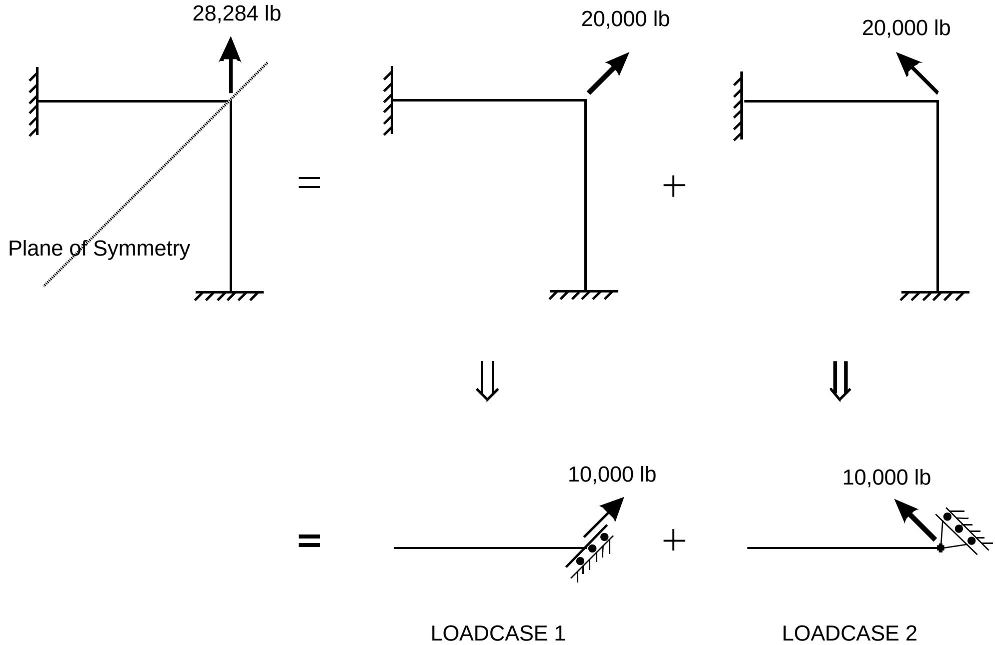


Figure 2-7

Structural Analysis Model

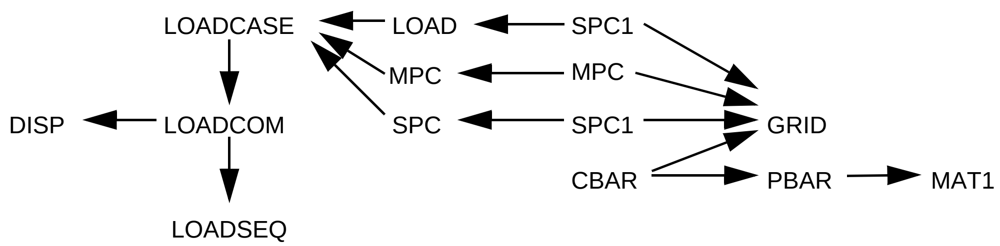
1. One beam structure in the X-Z plane (half model, CBAR element)
2. Section properties: Area=50 in^2, I2=416.7 in^4
3. Material E=1.0E7 psi.
4. Two load cases: each of them has different boundary conditions

   B.C. 1: Ux-Uz=0 (MPC=1), Uy=0, $\theta_x = \theta_y = \theta_z = 0$.

   B.C. 2: Ux+Uz=0 (MPC=2), Uy=0, $\theta_x = \theta_z = 0$.

5. One load combination that represent the solution of the left part of the structure.

Analysis Data Relationships



Special Modeling Techniques

Utilization of Symmetry: First the load is divided in the sum of its symmetric and antisymmetric components. Then, each of the forces is applied to the structure as a separate load case. Third, the structure in each load case is broken in half by considering suitable boundary conditions and load. Finally, the solution of the left part of the structure is recovered by adding the solutions of the symmetric and antisymmetric load case.

Reference Solution

The reference solution was constructed using the full model.

Calculated Solution

The *GENESIS* solution is presented in the output.

Comparison Between Calculated Solution and Reference

No differences between the full model and half model were found.

2.7.1 Input Data

```
ID A007
SOL COMPAT1
CEND
TITLE= TWO BAR SYMMETRIC FRAME
ECHO=NONE
LINE=64,80
LOADCASE 1
    LOAD=1
    MPC=1
    SPC=1
LOADCASE 2
    LOAD=2
    MPC=2
    SPC=2
LOADCOM 3
LOADSEQ 1.0,1.0
    DISPLACEMENT=ALL
BEGIN BULK
$
$   GRID DATA
$
GRID    1               0.0     0.0     0.0             123456
GRID    2               100.0   0.      0.              246
$
$   ELEMENT DEFINITIONS
$
CBAR    1       1       1       2       0.      1.0     0.
+                       0.      .0      0.0     0.0     0.0     0.0
$
$   PROPERTY DEFINITIONS
$
PBAR    1       1       50.0    104.2   416.7   288.5   0.0
+       2.5     5.0     2.5     -5.0    -2.5    -5.0    -2.5    5.0
+                       0.0
$
$   MATERIAL DATA
$
MAT1    1       10.0+6          0.3     0.0     0.0     25.0
$
$   LOAD DATA
$
FORCE   1       2               1.0+4   .707    0.0     0.707
FORCE   2       2               1.0+4   -.707   0.0     0.707
$
$   BOUNDARY CONDITIONS
$
MPC     1       2       1       1.0     2       3       -1.0
MPC     2       2       1       1.0     2       3       1.0
SPC1    1       2456    2
SPC1    2       246     2
$
ENDDATA
```

2.7.2 Output

```
1

                GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
               G        E       NN  N   E       S          I     S
               G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
               G    G   E       N  NN   E            S     I          S
                GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS

                    STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE

                                 COPYRIGHT, 1991-2002

                       VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                            ALL RIGHTS RESERVED, WORLDWIDE

                                      VERSION 7.2

                               BUILD CODE 200212131048

     PROJECT NAME: A007
     RUN STARTED:  Dec 13, 2002 12:49
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000

     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    1
 TWO BAR SYMMETRIC FRAME

                               ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                        2
                   NUMBER OF CBAR ELEMENTS:                      1
                   TOTAL NUMBER OF NON RIGID ELEMENTS:           1
```

```
                    NUMBER OF ELEMENT PROPERTIES:              1
                    NUMBER OF MATERIALS:                       1
                    NUMBER OF DEGREES OF FREEDOM:              3


                                LOAD CASES SUMMARY

                   NUMBER OF STATIC LOAD CASES:                  2
                   NUMBER OF STATIC LOADCOM LOAD CASES:          1
                   TOTAL NUMBER OF LOAD CASES:                   3

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    2
 TWO BAR SYMMETRIC FRAME


                 *********************************************
                 *  D E S I G N  C Y C L E     0 (ANALYSIS)*
                 *********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    3
 TWO BAR SYMMETRIC FRAME


                     M A S S / V O L U M E   S U M M A R Y

                     SYSTEM MASS                0.000000E+00
                     SYSTEM VOLUME              5.000000E+03
                     SYSTEM MASS/VOLUME         0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    4
 TWO BAR SYMMETRIC FRAME


                    S O L U T I O N   R E S I D U A L S

 LOADCASE        1 ; RESIDUAL :  2.572828E-16 ; STRAIN ENERGY :  1.979598E+01
 LOADCASE        2 ; RESIDUAL :  1.286414E-16 ; STRAIN ENERGY :  1.994410E+01
 LOADCOM         3 ;                            STRAIN ENERGY :  3.974008E+01
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    5
 TWO BAR SYMMETRIC FRAME


                     O L O A D   R E S U L T A N T S

 LOADCASE     T1          T2          T3          R1          R2          R3

      1  7.0700E+03  0.0000E+00  7.0700E+03  0.0000E+00 -7.0700E+05  0.0000E+00
      2 -7.0700E+03  0.0000E+00  7.0700E+03  0.0000E+00 -7.0700E+05  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    6
 TWO BAR SYMMETRIC FRAME


                    S P C F O R C E   R E S U L T A N T S

 LOADCASE     T1          T2          T3          R1          R2          R3
```

```
     1 -1.4000E+04  0.0000E+00 -1.4001E+02  0.0000E+00  1.4001E+04  0.0000E+00
     2  1.4105E+04  0.0000E+00 -3.5265E+01  0.0000E+00  3.5265E+03  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    7
 TWO BAR SYMMETRIC FRAME


               M A X I M U M   A P P L I E D   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1        2     9.9985E+03  7.0700E+03  0.0000E+00  7.0700E+03
      2        2     9.9985E+03 -7.0700E+03  0.0000E+00  7.0700E+03
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    8
 TWO BAR SYMMETRIC FRAME


                   M A X I M U M   S P C   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1        1     1.4001E+04 -1.4000E+04  0.0000E+00 -1.4001E+02
      2        1     1.4105E+04  1.4105E+04  0.0000E+00 -3.5265E+01
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    9
 TWO BAR SYMMETRIC FRAME


                  M A X I M U M   D I S P L A C E M E N T

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1        2     3.9598E-03  2.8000E-03  0.0000E+00  2.8000E-03
      2        2     3.9894E-03 -2.8209E-03  0.0000E+00  2.8209E-03
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   10
 TWO BAR SYMMETRIC FRAME

                                                            LOADCASE        3

                      G R I D   D I S P L A C E M E N T S

  GRID ID             T1                 T2                 T3
                      R1                 R2                 R3

       1      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

       2     -2.094929E-05      0.000000E+00      5.620945E-03
              0.000000E+00     -4.231421E-05      0.000000E+00

1                            ***** END OF OUTPUT *****
```

2.8 Three Story Facade with a Panel - A

Example ID

A008

Analysis Data Used

GRID, GRDSET, RBE2, CBAR, PBAR, MAT1, LOAD, FORCE, SPC, SPC1, DISP.

Special Features Used

Utilization of rigid body elements (RBE2) to model a panel zone in a frame.

Problem Statement

Considering shear deformation find the nodal displacements of the facade of **Figure 2-8**.

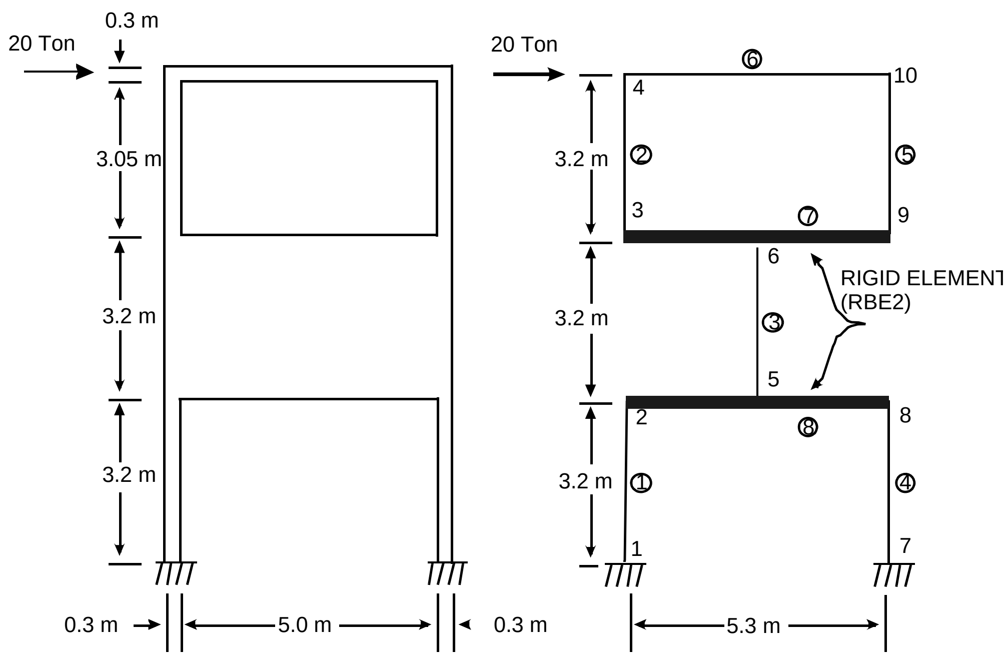
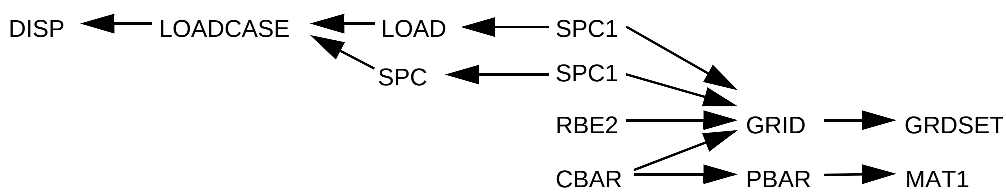


Figure 2-8

Structural Analysis Model

1. Analysis of a two dimensional structure with a simplified model of 6 bar elements (CBAR) and 2 rigid body elements (RBE2).
2. Section properties of flexible beams: Area=0.06 m^2, I2=0.0045 m^4, AS2=0.05 m^2
3. Section properties of modeled beam: Area=1.6 m^2, I2=3.2614 m^4, AS2=1.248 m^2
4. Material: E=3.0+6 T/m^2, G=1.2+6 T/m^2.
5. One load case. Loading: 20.0 T.

Analysis Data Relationships



Special Modeling Techniques

The analysis of the facade is performed using a stick model. Panel zones, as in this problem, can be modeled using two rigid elements and one beam element with modified properties. In the figure below, a detail of the panel model is given. These rigid elements, that are parallel to the horizontal force, cause that planes that they are located in to remain plane after deformation. Shear deformation is included in all beam elements.
The properties of the equivalent column is:

$$A = \frac{at}{1-\nu}$$

$$I = \frac{a^3 t}{12(1-\nu^2)}\left[1 + \frac{1-\nu}{2}\left(\frac{b}{a}\right)^2\right]$$

$$AS = \frac{A}{(1-\nu)\left[1 + \frac{1-\nu}{2}\left(\frac{b}{a}\right)^2\right]}$$

where t is the thickness of the panel.

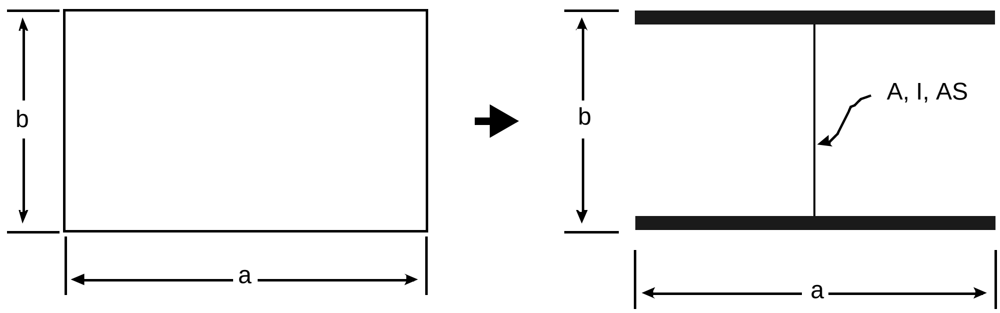


Figure 2-9

Reference Solutions

See Example **A009**. The horizontal displacements of the facades at nodes 2,3 and 4 are:

U2 = 0.02076 m

U3 = 0.02110 m

U4 = 0.05596 m

Calculated Solutions

The horizontal displacements of the facades at nodes 2,3 and 4 are:

U2 = 0.02108 m

U3 = 0.02183 m

U4 = 0.05675 m

Comparison Between Calculated Solutions and Reference Solutions

The differences between reference solution and *GENESIS* solutions are:

U2: -2%

U3: -3%

U4: -1%

2.8.1 Input Data

```
ID A008
SOL COMPAT1
CEND
TITLE=THREE STORY FACADE WITH A PANEL - I
SUBTITLE=SIX BAR MODEL WITH TWO RIGID BODY ELEMENTS
ECHO=NONE
LINE=64,80
    LOAD=100
    SPC =100
    DISP=ALL
BEGIN BULK
$
$   GRID DATA
$
GRDSET                                                  246
$
GRID    1               0.0     0.0     0.0
GRID    2               0.0     0.0     3.2
GRID    3               0.0     0.0     6.4
GRID    4               0.0     0.0     9.6
GRID    5               2.8     0.0     3.2
GRID    6               2.8     0.0     6.4
GRID    7               5.3     0.0     0.0
GRID    8               5.3     0.0     3.2
GRID    9               5.3     0.0     6.4
GRID    10              5.3     0.0     9.6
$
$   BOUNDARY CONDITIONS
$
SPC1    100     123456  1       7
$
$   ELEMENT DEFINITIONS
$
BAROR           1                       0.0     1.0     0.0
CBAR    1       1       1       2       0.0     1.0     0.0
CBAR    2       1       3       4       0.0     1.0     0.0
CBAR    4       1       7       8       0.0     1.0     0.0
CBAR    5       1       9       10      0.0     1.0     0.0
CBAR    6       1       4       10      0.0     1.0     0.0
$
$   PANEL MODELED AS A BEAM DATA
$
CBAR    3       100     5       6       0.0     1.0     0.0
$
$   RIGID ELEMENTS DATA
$
RBE2    7       6       135     3       9
RBE2    8       5       135     2       8
$
$   PROPERTY DEFINITIONS
$
PBAR    1       1       0.06    0.0002  0.00045
```

```
+       0.1     0.15    0.1     -0.15   -0.1    -0.15   -0.1    0.15
+       0.8333330.8333330.00
PBAR    100     1       1.6     0.0037  3.2614
+       0.1     2.8     0.1     -2.8    -0.1    -2.8    -0.1    2.8
+       0.8333330.8333330.0
$
$   MATERIAL DATA
$
MAT1    1       3.0+6   1.2+6
$
$   LOAD DATA
$
FORCE   100     4               20.0    1.0     0.0     0.0
$
ENDDATA
```

2.8.2 Output

```
1






                GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
               G        E       NN  N   E       S          I     S
               G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
               G    G   E       N  NN   E            S     I          S
                GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                  STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE



                               COPYRIGHT, 1991-2002

                    VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                       ALL RIGHTS RESERVED, WORLDWIDE

                                VERSION 7.2

                          BUILD CODE 200212131048




     PROJECT NAME: A008
     RUN STARTED:  Dec 13, 2002 12:49
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    1
 THREE STORY FACADE WITH A PANEL - I
 SIX BAR MODEL WITH TWO RIGID BODY ELEMENTS

                          ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                     10
                   NUMBER OF CBAR ELEMENTS:                    6
                   TOTAL NUMBER OF NON RIGID ELEMENTS:         6
```

```
                   NUMBER OF RBE2 ELEMENTS:                    2
                   NUMBER OF ELEMENT PROPERTIES:               2
                   NUMBER OF MATERIALS:                        1
                   NUMBER OF DEGREES OF FREEDOM:              24


                               LOAD CASES SUMMARY

                  NUMBER OF STATIC LOAD CASES:                    1
                  TOTAL NUMBER OF LOAD CASES:                     1

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    2
 THREE STORY FACADE WITH A PANEL - I
 SIX BAR MODEL WITH TWO RIGID BODY ELEMENTS

               *********************************************
               *  D E S I G N  C Y C L E     0 (ANALYSIS)*
               *********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    3
 THREE STORY FACADE WITH A PANEL - I
 SIX BAR MODEL WITH TWO RIGID BODY ELEMENTS

                    M A S S / V O L U M E   S U M M A R Y

                    SYSTEM MASS             0.000000E+00
                    SYSTEM VOLUME           6.206000E+00
                    SYSTEM MASS/VOLUME      0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    4
 THREE STORY FACADE WITH A PANEL - I
 SIX BAR MODEL WITH TWO RIGID BODY ELEMENTS

                   S O L U T I O N   R E S I D U A L S

 LOADCASE        1 ; RESIDUAL :  1.684547E-13 ; STRAIN ENERGY :  5.674781E-01
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    5
 THREE STORY FACADE WITH A PANEL - I
 SIX BAR MODEL WITH TWO RIGID BODY ELEMENTS

                     O L O A D   R E S U L T A N T S

 LOADCASE     T1          T2          T3          R1          R2          R3

      1  2.0000E+01  0.0000E+00  0.0000E+00  0.0000E+00  1.9200E+02  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    6
 THREE STORY FACADE WITH A PANEL - I
 SIX BAR MODEL WITH TWO RIGID BODY ELEMENTS

                   S P C F O R C E   R E S U L T A N T S

 LOADCASE     T1          T2          T3          R1          R2          R3

      1 -2.0000E+01  0.0000E+00  8.8818E-16  0.0000E+00 -1.9200E+02  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    7
 THREE STORY FACADE WITH A PANEL - I
```

```
 SIX BAR MODEL WITH TWO RIGID BODY ELEMENTS

              M A X I M U M   A P P L I E D   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1        4     2.0000E+01  2.0000E+01  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    8
 THREE STORY FACADE WITH A PANEL - I
 SIX BAR MODEL WITH TWO RIGID BODY ELEMENTS

                  M A X I M U M   S P C   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1        1     3.1771E+01 -1.0000E+01  0.0000E+00 -3.0156E+01
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    9
 THREE STORY FACADE WITH A PANEL - I
 SIX BAR MODEL WITH TWO RIGID BODY ELEMENTS

                 M A X I M U M   D I S P L A C E M E N T

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1        4     5.6752E-02  5.6748E-02  0.0000E+00  7.0790E-04
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   10
 THREE STORY FACADE WITH A PANEL - I
 SIX BAR MODEL WITH TWO RIGID BODY ELEMENTS
                                                            LOADCASE        1

                    G R I D   D I S P L A C E M E N T S

  GRID ID           T1                T2                T3
                    R1                R2                R3

       1      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

       2      2.108419E-02      0.000000E+00      5.361151E-04
              0.000000E+00      2.023076E-04      0.000000E+00

       3      2.182739E-02      0.000000E+00      6.240282E-04
              0.000000E+00      2.337051E-04      0.000000E+00

       4      5.674781E-02      0.000000E+00      7.079012E-04
              0.000000E+00      8.576776E-03      0.000000E+00

       5      2.108419E-02      0.000000E+00     -3.034614E-05
              0.000000E+00      2.023076E-04      0.000000E+00

       6      2.182739E-02      0.000000E+00     -3.034614E-05
              0.000000E+00      2.337051E-04      0.000000E+00

       7      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00
```

```
         8      2.108419E-02      0.000000E+00     -5.361151E-04
                0.000000E+00      2.023076E-04      0.000000E+00

         9      2.182739E-02      0.000000E+00     -6.146090E-04
                0.000000E+00      2.337051E-04      0.000000E+00

        10      5.645426E-02      0.000000E+00     -6.984819E-04
                0.000000E+00      8.472251E-03      0.000000E+00

1                              ***** END OF OUTPUT *****
```

2.9 Three Story Facade with a Panel - B

Example ID

A009

Analysis Data Used

GRID, GRDSET, CQUAD4, CBAR, PBAR, PSHELL, MAT1, LOAD, FORCE, SPC, SPC1, DISP

Special Features Used

NONE

Problem Statement

Considering shear deformation find the nodal displacements of the facade of **Figure 2-10**.

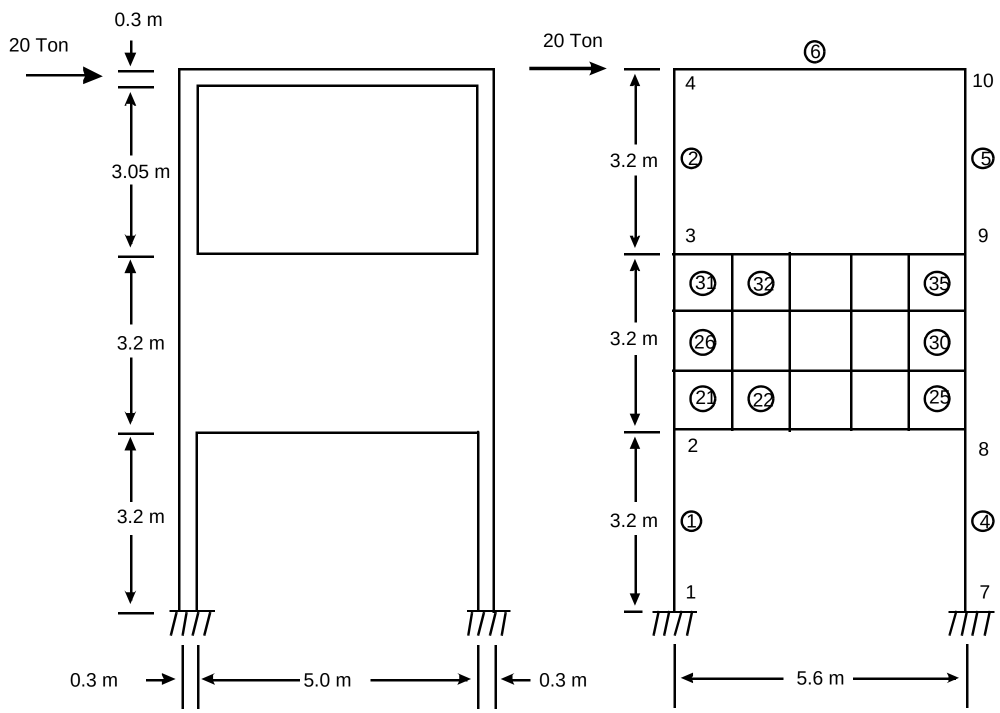


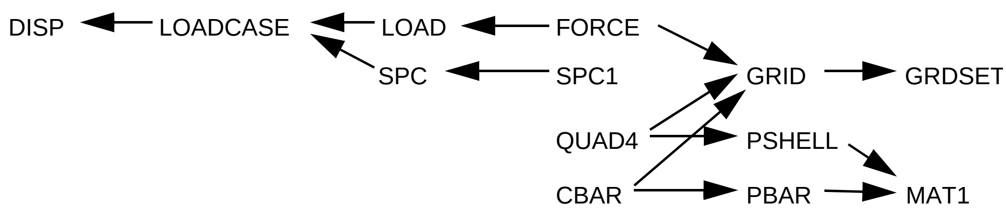
Figure 2-10

Structural Analysis Model

1. Five beam elements (CBAR) and 15 shell elements (CQUAD4), thickness = 0.2 m.
2. Section properties: Area=0.06m^2, I2=0.00045 m^4, AS2=0.05 m^2.
3. Material: E=3.0+6 T/m^2, G=1.2+6 T/m^2.
4. One load case. Loading: P= 20.0 T.

Quad elements and beam elements are incompatible elements. To overcome this incompatibility in this example nodes 2, 8, 3 and 9 were restricted to not rotate in plane. The last restriction is considered an adequate assumption because the points in the panel can not rotate much. The points of the panel do not rotate much because the columns do not deform much in the axial direction and the panel is very rigid, compared to the columns.

Analysis Data Relationships



Special Modeling Techniques

NONE

Reference Solutions

NONE

2.9.1 Input Data

```
ID A009
SOL COMPAT1
CEND
TITLE=THREE STORY FACADE WITH A PANEL-II
ECHO=NONE
LINE=64,80
    LOAD=100
    SPC =200
    DISP=ALL
BEGIN BULK
$
$   GRID DATA
$
$
GRDSET                                                          246
GRID    1               0.0     0.0     0.0
GRID    2               0.0     0.0     3.2
GRID    3               0.0     0.0     6.4
GRID    4               0.0     0.0     9.6
GRID    7               5.6     0.0     0.0
GRID    8               5.6     0.0     3.2
GRID    9               5.6     0.0     6.4
GRID    10              5.6     0.0     9.6
$
GRID    20              1.1     0.0     3.2                     2456
GRID    21              2.2     0.0     3.2                     2456
GRID    22              3.4     0.0     3.2                     2456
GRID    23              4.5     0.0     3.2                     2456
$
GRID    24              0.0     0.0     4.3                     2456
GRID    25              1.1     0.0     4.3                     2456
GRID    26              2.2     0.0     4.3                     2456
GRID    27              3.4     0.0     4.3                     2456
GRID    28              4.5     0.0     4.3                     2456
GRID    29              5.6     0.0     4.3                     2456
$
GRID    30              0.0     0.0     5.3                     2456
GRID    31              1.1     0.0     5.3                     2456
GRID    32              2.2     0.0     5.3                     2456
GRID    33              3.4     0.0     5.3                     2456
GRID    34              4.5     0.0     5.3                     2456
GRID    35              5.6     0.0     5.3                     2456
$
GRID    36              1.1     0.0     6.4                     2456
GRID    37              2.2     0.0     6.4                     2456
GRID    38              3.4     0.0     6.4                     2456
GRID    39              4.5     0.0     6.4                     2456
$
$   BOUNDARY CONDITIONS
$
SPC1    200     123456  1       7
SPC1    200     2456    2       3       8       9
```

```
$
$   ELEMENT DATA
$
BAROR           1                       0.0     1.0     0.0
CBAR    1       1       1       2       0.0     1.0     0.0
CBAR    2       1       3       4       0.0     1.0     0.0
CBAR    4       1       7       8       0.0     1.0     0.0
CBAR    5       1       9       10      0.0     1.0     0.0
CBAR    6       1       4       10      0.0     1.0     0.0
$
CQUAD4  21      2       2       20      25      24
CQUAD4  22      2       20      21      26      25
CQUAD4  23      2       21      22      27      26
CQUAD4  24      2       22      23      28      27
CQUAD4  25      2       23      8       29      28
$
CQUAD4  26      2       24      25      31      30
CQUAD4  27      2       25      26      32      31
CQUAD4  28      2       26      27      33      32
CQUAD4  29      2       27      28      34      33
CQUAD4  30      2       28      29      35      34
$
CQUAD4  31      2       30      31      36      3
CQUAD4  32      2       31      32      37      36
CQUAD4  33      2       32      33      38      37
CQUAD4  34      2       33      34      39      38
CQUAD4  35      2       34      35      9       39
$
$   PROPERTY DEFINITIONS
$
PBAR    1       1       0.06    0.0002  0.00045 0.1
+       0.1     0.15    0.1     -0.15   -0.1    -0.15   -0.1    0.15
+       0.8333330.8333330.00
PSHELL  2       1       .2
$
$   MATERIAL DATA
$
MAT1    1       3.0+6   1.2+6
$
$   LOAD DATA
$
FORCE   100     4               20.0    1.0     0.0     0.0
$
ENDDATA
```

2.9.2 Output

```
1










           GGGG     EEEEE    N    N    EEEEE     SSSSS    IIIII     SSSSS
          G         E        NN   N    E        S           I      S
          G   GG    EEEE     N N N     EEEE      SSSS       I       SSSS
          G    G    E        N   NN    E             S      I           S
           GGGG     EEEEE    N    N    EEEEE    SSSSS     IIIII    SSSSS


                 STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                              COPYRIGHT, 1991-2002

                    VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                         ALL RIGHTS RESERVED, WORLDWIDE

                                  VERSION 7.2

                            BUILD CODE 200212131048




     PROJECT NAME: A009
     RUN STARTED:  Dec 13, 2002 12:49
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    1
 THREE STORY FACADE WITH A PANEL-II


                            ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                    28
                   NUMBER OF CBAR ELEMENTS:                   5
                   NUMBER OF CQUAD4->PSHELL ELEMENTS:        15
```

```
                   TOTAL NUMBER OF NON RIGID ELEMENTS:        20
                   NUMBER OF ELEMENT PROPERTIES:               2
                   NUMBER OF MATERIALS:                        1
                   NUMBER OF DEGREES OF FREEDOM:              54



                               LOAD CASES SUMMARY

                  NUMBER OF STATIC LOAD CASES:                      1
                  TOTAL NUMBER OF LOAD CASES:                       1

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    2
 THREE STORY FACADE WITH A PANEL-II


               ********************************************
               *  D E S I G N  C Y C L E     0 (ANALYSIS)*
               ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    3
 THREE STORY FACADE WITH A PANEL-II


                    M A S S / V O L U M E   S U M M A R Y

                    SYSTEM MASS              0.000000E+00
                    SYSTEM VOLUME            4.688000E+00
                    SYSTEM MASS/VOLUME       0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    4
 THREE STORY FACADE WITH A PANEL-II


                   S O L U T I O N   R E S I D U A L S

 LOADCASE        1 ; RESIDUAL :  1.601635E-13 ; STRAIN ENERGY :  5.595812E-01
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    5
 THREE STORY FACADE WITH A PANEL-II


                     O L O A D   R E S U L T A N T S

 LOADCASE     T1          T2          T3          R1          R2          R3

      1  2.0000E+01  0.0000E+00  0.0000E+00  0.0000E+00  1.9200E+02  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    6
 THREE STORY FACADE WITH A PANEL-II


                   S P C F O R C E   R E S U L T A N T S

 LOADCASE     T1          T2          T3          R1          R2          R3

      1 -2.0000E+01  0.0000E+00 -1.9371E-12  0.0000E+00 -1.9200E+02  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    7
 THREE STORY FACADE WITH A PANEL-II
```

```
               M A X I M U M   A P P L I E D   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1        4     2.0000E+01  2.0000E+01  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    8
 THREE STORY FACADE WITH A PANEL-II


                   M A X I M U M   S P C   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1        7     1.3885E+01 -1.0000E+01  0.0000E+00  9.6332E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    9
 THREE STORY FACADE WITH A PANEL-II


                  M A X I M U M   D I S P L A C E M E N T

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1        4     5.5959E-02  5.5958E-02  0.0000E+00  3.2806E-04
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   10
 THREE STORY FACADE WITH A PANEL-II

                                                        LOADCASE        1

                     G R I D   D I S P L A C E M E N T S

  GRID ID            T1                 T2                 T3
                     R1                 R2                 R3

        1      0.000000E+00       0.000000E+00       0.000000E+00
               0.000000E+00       0.000000E+00       0.000000E+00

        2      2.076046E-02       0.000000E+00       1.712565E-04
               0.000000E+00       0.000000E+00       0.000000E+00

        3      2.110456E-02       0.000000E+00       2.498061E-04
               0.000000E+00       0.000000E+00       0.000000E+00

        4      5.595812E-02       0.000000E+00       3.280593E-04
               0.000000E+00       8.767236E-03       0.000000E+00

        7      0.000000E+00       0.000000E+00       0.000000E+00
               0.000000E+00       0.000000E+00       0.000000E+00

        8      2.076053E-02       0.000000E+00      -1.712565E-04
               0.000000E+00       0.000000E+00       0.000000E+00

        9      2.110408E-02       0.000000E+00      -2.496603E-04
               0.000000E+00       0.000000E+00       0.000000E+00
```

10	5.564799E-02	0.000000E+00	-3.279135E-04
	0.000000E+00	8.655570E-03	0.000000E+00
20	2.078759E-02	0.000000E+00	1.193432E-04
	0.000000E+00	0.000000E+00	0.000000E+00
21	2.079381E-02	0.000000E+00	4.170112E-05
	0.000000E+00	0.000000E+00	0.000000E+00
22	2.079383E-02	0.000000E+00	-4.183910E-05
	0.000000E+00	0.000000E+00	0.000000E+00
23	2.078765E-02	0.000000E+00	-1.194170E-04
	0.000000E+00	0.000000E+00	0.000000E+00
24	2.087139E-02	0.000000E+00	2.013616E-04
	0.000000E+00	0.000000E+00	0.000000E+00
25	2.086604E-02	0.000000E+00	1.153716E-04
	0.000000E+00	0.000000E+00	0.000000E+00
26	2.087417E-02	0.000000E+00	4.069888E-05
	0.000000E+00	0.000000E+00	0.000000E+00
27	2.087417E-02	0.000000E+00	-4.084917E-05
	0.000000E+00	0.000000E+00	0.000000E+00
28	2.086604E-02	0.000000E+00	-1.154484E-04
	0.000000E+00	0.000000E+00	0.000000E+00
29	2.087139E-02	0.000000E+00	-2.013474E-04
	0.000000E+00	0.000000E+00	0.000000E+00

1GENESIS VERSION 7.2 DATE 12-13-2002 TIME 12:49 PAGE 11
THREE STORY FACADE WITH A PANEL-II

LOADCASE 1

G R I D D I S P L A C E M E N T S

GRID ID	T1	T2	T3
	R1	R2	R3
30	2.095337E-02	0.000000E+00	2.204534E-04
	0.000000E+00	0.000000E+00	0.000000E+00
31	2.095794E-02	0.000000E+00	1.180255E-04
	0.000000E+00	0.000000E+00	0.000000E+00
32	2.095691E-02	0.000000E+00	3.814009E-05
	0.000000E+00	0.000000E+00	0.000000E+00
33	2.095688E-02	0.000000E+00	-3.829158E-05
	0.000000E+00	0.000000E+00	0.000000E+00

```
    34      2.095786E-02      0.000000E+00     -1.181204E-04
            0.000000E+00      0.000000E+00      0.000000E+00

    35      2.095330E-02      0.000000E+00     -2.203859E-04
            0.000000E+00      0.000000E+00      0.000000E+00

    36      2.105951E-02      0.000000E+00      1.179869E-04
            0.000000E+00      0.000000E+00      0.000000E+00

    37      2.104040E-02      0.000000E+00      4.000493E-05
            0.000000E+00      0.000000E+00      0.000000E+00

    38      2.104033E-02      0.000000E+00     -4.013590E-05
            0.000000E+00      0.000000E+00      0.000000E+00

    39      2.105930E-02      0.000000E+00     -1.180740E-04
            0.000000E+00      0.000000E+00      0.000000E+00

1                            ***** END OF OUTPUT *****
```

2.10 Vibration of a Skewed Beam

Example ID

A010

Analysis Data Used

GRID, CORD1R, CBAR, PBAR, MAT1, LOADCASE, METHOD, EIGR, SVECTOR

Special Features Used

Utilization of two different coordinate systems. The first one is the basic coordinate system and is used to define the grid coordinates. The second is a rotated coordinate system with its x-axis parallel to the cantilever beam. This coordinate system is used to describe the mode shapes of the beam.

Problem Statement

Find the first four natural frequencies and mode shapes of the cantilever beam shown in **Figure 2-11**. Neglect shear deformation and axial motion. Consider only the motion in the x-z plane.

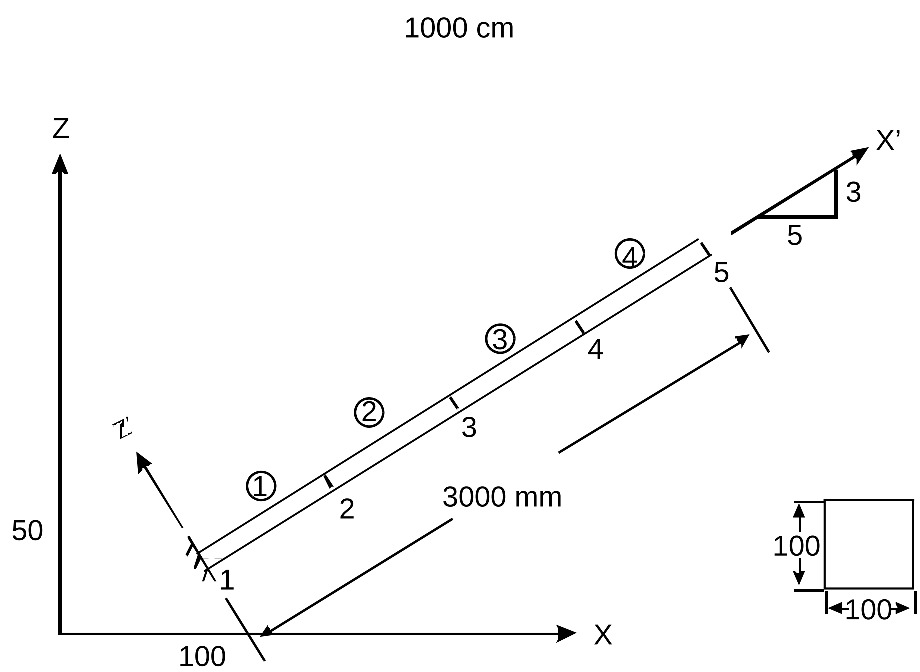
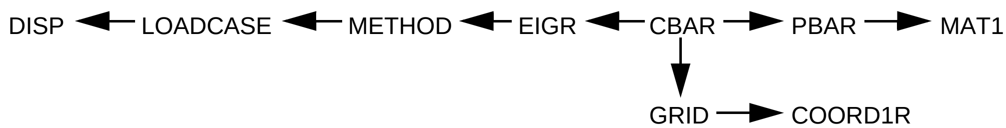


Figure 2-11

Structural Analysis Model

1. Four CBAR elements.
2. The section properties are: Area=10000 mm^2, I=8.3+6 mm^4.
3. Material: E=2.07+5 MPa, ρ =8.0-9 N-sec^2/mm^4.
4. One eigenvalue load case.

Analysis Data Relationships



Special Modeling Techniques

NONE

Reference Solutions

The analytical solutions for Bernulli-Euler beams for the first four modes are:

$$f1 = 0.5596\sqrt{\frac{EI}{\rho AL^2}} = 9.13 \text{ hz}$$

$$f2 = 3.5069\sqrt{\frac{EI}{\rho AL^2}} = 57.21 \text{ hz}$$

$$f3 = 9.8194\sqrt{\frac{EI}{\rho AL^2}} = 160.2 \text{ hz}$$

$$f4 = 19.257\sqrt{\frac{EI}{\rho AL^2}} = 314.19 \text{ hz}$$

where E the Young's modulus, A the cross section area, I the area moment of inertia, ρ the mass density and L the length.

Calculated Solutions

f1 = 9.128 hz

f2 = 57.20 hz

f3 = 160.87 hz

f4 = 316.39 hz

Comparison Between Calculated Solutions and Reference Solutions

The differences between analytical solutions and the *GENESIS* solutions are:

f1: 0.1%

f2: 0.1%

f3: 0.5%

f4: 1%

2.10.1 Input Data

```
ID A010
SOL COMPAT1
CEND
TITLE=VIBRATIONS OF CANTILEVER BEAM IN A SKEWED COORDINATE SYSTEM
LINE=64,80
$
LOADCASE 4
METHOD=4
SVECTOR=ALL
$
BEGIN BULK
$
$   COORDINATE SYSTEM
$
GRID    101             10.0    0.0     5.0     2       123456
GRID    102             7.0     0.0     10.0    2       123456
GRID    103             15.0    0.0     8.0     2       123456
CORD1R  2       101     102     103
$
$   GRID DATA
$
GRID    1               100.00  0.0     50.0    2       123456
GRID    2               743.11  0.      435.87  2       1246
GRID    3               1386.24 0.      821.74  2       1246
GRID    4               2029.36 0.      1207.62 2       1246
GRID    5               2672.48 0.      1593.48 2       1246
$
$   ELEMENT DEFINITIONS
$
CBAR    1       1       1       2       0.      1.0     0.
CBAR    2       1       2       3       0.      1.0     0.
CBAR    3       1       3       4       0.      1.0     0.
CBAR    4       1       4       5       0.      1.0     0.
$
$   PROPERTY DEFINITIONS
$
PBAR    1       1       1.0+4   8.333+6 8.333+6 0.0
$
$   MATERIAL DATA
$
MAT1    1       2.07+5          0.3     8.0-9
$
$   EIGENVALUES DATA
$
EIGR    4       SUB                             4       MAX
$
ENDDATA
```

2.10.2 Output

```
1

  GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
 G        E       NN  N   E       S          I     S
 G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
 G    G   E       N  NN   E            S     I          S
  GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS

          STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE

                      COPYRIGHT, 1991-2002

             VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                 ALL RIGHTS RESERVED, WORLDWIDE

                          VERSION 7.2

                    BUILD CODE 200212131048

     PROJECT NAME: A010
     RUN STARTED:  Dec 13, 2002 12:49
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000

     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    1
 VIBRATIONS OF CANTILEVER BEAM IN A SKEWED COORDINATE SYSTEM

                    ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                       8
                   NUMBER OF LOCAL COORDINATE SYSTEMS:          1
                   NUMBER OF CBAR ELEMENTS:                     4
```

```
                    TOTAL NUMBER OF NON RIGID ELEMENTS:        4
                    NUMBER OF ELEMENT PROPERTIES:              1
                    NUMBER OF MATERIALS:                       1
                    NUMBER OF DEGREES OF FREEDOM:              8


                            LOAD CASES SUMMARY

                   NUMBER OF USER FREQUENCY LOAD CASES:          1
                   TOTAL NUMBER OF LOAD CASES:                   1

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    2
 VIBRATIONS OF CANTILEVER BEAM IN A SKEWED COORDINATE SYSTEM


                *********************************************
                *  D E S I G N  C Y C L E     0 (ANALYSIS)*
                *********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    3
 VIBRATIONS OF CANTILEVER BEAM IN A SKEWED COORDINATE SYSTEM


                    M A S S / V O L U M E   S U M M A R Y

                    SYSTEM MASS              2.399998E-01
                    SYSTEM VOLUME            2.999997E+07
                    SYSTEM MASS/VOLUME       8.000000E-09
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    4
 VIBRATIONS OF CANTILEVER BEAM IN A SKEWED COORDINATE SYSTEM

                                                        LOADCASE         4

                           E I G E N V A L U E S

                                                          GENERALIZED   GENERALIZED
   MODE       CYCLES      EIGENVALUE     RADIANS             MASS        STIFFNESS

        1  9.128321E+00  3.289588E+03  5.735493E+01  6.001553E-02  1.974264E+02
        2  5.719729E+01  1.291548E+05  3.593812E+02  5.994689E-02  7.742430E+03
        3  1.608667E+02  1.021626E+06  1.010755E+03  5.897686E-02  6.025233E+04
        4  3.163879E+02  3.951841E+06  1.987924E+03  6.188160E-02  2.445463E+05
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    5
 VIBRATIONS OF CANTILEVER BEAM IN A SKEWED COORDINATE SYSTEM

                                                        LOADCASE         4
                           E I G E N V E C T O R

 EIGENVECTOR NUMBER        1      FREQUENCY (HZ) =  9.128321E+00
                                  EIGENVALUE     =  3.289588E+03


  GRID ID            T1                  T2                  T3
                     R1                  R2                  R3

        1      0.000000E+00      0.000000E+00      0.000000E+00
```

```
             0.000000E+00      0.000000E+00      0.000000E+00

        2    0.000000E+00      0.000000E+00      9.727488E-02
             0.000000E+00     -2.426782E-04      0.000000E+00

        3    0.000000E+00      0.000000E+00      3.395039E-01
             0.000000E+00     -3.876783E-04      0.000000E+00

        4    0.000000E+00      0.000000E+00      6.577331E-01
             0.000000E+00     -4.490414E-04      0.000000E+00

        5    0.000000E+00      0.000000E+00      1.000000E+00
             0.000000E+00     -4.588620E-04      0.000000E+00

      101    0.000000E+00      0.000000E+00      0.000000E+00
             0.000000E+00      0.000000E+00      0.000000E+00

      102    0.000000E+00      0.000000E+00      0.000000E+00
             0.000000E+00      0.000000E+00      0.000000E+00

      103    0.000000E+00      0.000000E+00      0.000000E+00
             0.000000E+00      0.000000E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    6
 VIBRATIONS OF CANTILEVER BEAM IN A SKEWED COORDINATE SYSTEM

                                                           LOADCASE         4
                                 E I G E N V E C T O R

 EIGENVECTOR NUMBER        2      FREQUENCY (HZ) =  5.719729E+01
                                  EIGENVALUE     =  1.291548E+05

  GRID ID          T1                T2                T3
                   R1                R2                R3

        1    0.000000E+00      0.000000E+00      0.000000E+00
             0.000000E+00      0.000000E+00      0.000000E+00

        2    0.000000E+00      0.000000E+00     -4.172720E-01
             0.000000E+00      7.624584E-04      0.000000E+00

        3    0.000000E+00      0.000000E+00     -7.141837E-01
             0.000000E+00     -1.502159E-04      0.000000E+00

        4    0.000000E+00      0.000000E+00     -1.358161E-01
             0.000000E+00     -1.297497E-03      0.000000E+00

        5    0.000000E+00      0.000000E+00      1.000000E+00
             0.000000E+00     -1.595286E-03      0.000000E+00

      101    0.000000E+00      0.000000E+00      0.000000E+00
             0.000000E+00      0.000000E+00      0.000000E+00

      102    0.000000E+00      0.000000E+00      0.000000E+00
             0.000000E+00      0.000000E+00      0.000000E+00
```

```
     103      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    7
 VIBRATIONS OF CANTILEVER BEAM IN A SKEWED COORDINATE SYSTEM

                                                             LOADCASE        4
                                E I G E N V E C T O R

 EIGENVECTOR NUMBER        3      FREQUENCY (HZ) =  1.608667E+02
                                  EIGENVALUE     =  1.021626E+06

  GRID ID            T1                T2                T3
                     R1                R2                R3

       1      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

       2      0.000000E+00      0.000000E+00      7.276161E-01
              0.000000E+00     -5.340301E-04      0.000000E+00

       3      0.000000E+00      0.000000E+00      2.429590E-02
              0.000000E+00      1.853566E-03      0.000000E+00

       4      0.000000E+00      0.000000E+00     -5.853796E-01
              0.000000E+00     -8.777811E-04      0.000000E+00

       5      0.000000E+00      0.000000E+00      1.000000E+00
              0.000000E+00     -2.631730E-03      0.000000E+00

     101      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     102      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     103      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    8
 VIBRATIONS OF CANTILEVER BEAM IN A SKEWED COORDINATE SYSTEM

                                                             LOADCASE        4
                                E I G E N V E C T O R

 EIGENVECTOR NUMBER        4      FREQUENCY (HZ) =  3.163879E+02
                                  EIGENVALUE     =  3.951841E+06

  GRID ID            T1                T2                T3
                     R1                R2                R3

       1      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00
```

```
      2      0.000000E+00      0.000000E+00     -7.221294E-01
             0.000000E+00     -1.095162E-03      0.000000E+00

      3      0.000000E+00      0.000000E+00      7.433052E-01
             0.000000E+00     -7.855713E-05      0.000000E+00

      4      0.000000E+00      0.000000E+00     -6.382017E-01
             0.000000E+00      9.580850E-04      0.000000E+00

      5      0.000000E+00      0.000000E+00      1.000000E+00
             0.000000E+00     -3.748253E-03      0.000000E+00

    101      0.000000E+00      0.000000E+00      0.000000E+00
             0.000000E+00      0.000000E+00      0.000000E+00

    102      0.000000E+00      0.000000E+00      0.000000E+00
             0.000000E+00      0.000000E+00      0.000000E+00

    103      0.000000E+00      0.000000E+00      0.000000E+00
             0.000000E+00      0.000000E+00      0.000000E+00

1                            ***** END OF OUTPUT *****
```

2.11 Beam with Temperature Load

Example ID:

A011

Analysis Feature Used:

GRID, CBAR, PBAR, MAT1, LINE,LOADCASE,LABEL, SPC, SPC1, TEMPD, TEMP, STRESS, DISP

Special Features Used:

Single point constraint.

Problem Statement:

The beam of **Figure 2-12** was installed free of stress with a temperature of 5 degrees. The temperature is then increased to 25 degrees.
For T=25 degrees:

1. Calculate the axial displacement of the beam at node 2 when node 2 is free.
2. Calculate the stresses that would be develop in the beam the axial displacement of node 2 is constrained.

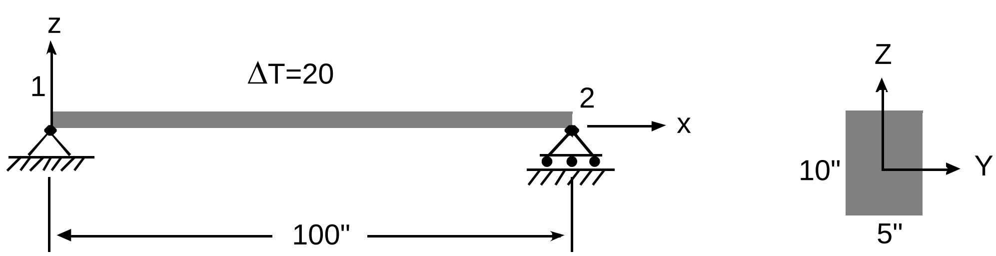


Figure 2-12

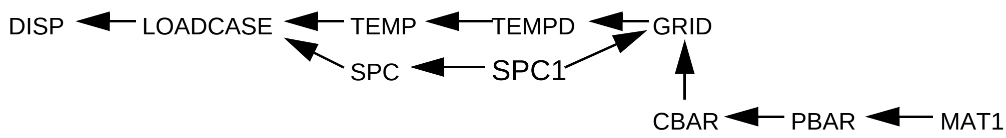
Structural Analysis Model:

1. One CBAR elements.
2. The section properties are: Area=50 in2. α =10E-6 in/degree.
3. Material: E=1.0E7 psi.

Two load cases:

1. Change of temperature.
1. Change of temperature and lateral constraint (SPC).

Analysis Data Relationships:



Special Modeling Techniques:

NONE

Reference Solutions:

The analytical solutions for a beam under change of temperature are:

$$U_x = \alpha L(T - T_0) = 0.02 \text{ in. (free to move)}$$

$$\sigma = -E\alpha(T - T_0) = -2000.0 \text{ psi (constrained to move)}$$

where E is Young's modulus, α is the thermal expansion coefficient, L is the length and (T-T_o) is the difference between the final temperature and initial temperature.
CALCULATED SOLUTIONS:

Ux = 0.02 in.

α = -2000.0 psi

Comparison Between Calculated Solutions and Reference Solutions:

There are no differences between analytical solutions and the *GENESIS* solutions.

2.11.1 Input Data

```
ID A011
SOL COMPAT1
CEND
TITLE= BEAM UNDER CHANGES OF TEMPERATURE
LINE=64,80
LOADCASE 1
LABEL= LOAD CASE 1: FREE RIGHT DISPLACEMENT
    TEMP=1
    DISPLACEMENT=ALL
LOADCASE 2
LABEL= LOAD CASE 2: CONSTRAIN RIGHT DISPLACEMENT
    TEMP=1
    SPC=1
    STRESS=ALL
BEGIN BULK
$
$   BOUNDARY CONDITIONS FOR LOAD CASE 2
$
SPC1    1       1       2
$
$   GRID DATA
$
GRID    1               0.0     0.0     0.0             12346
GRID    2               100.0   0.0     0.0             2346
$
$   ELEMENT DEFINITIONS
$
CBAR    1       1       1       2       0.      1.0     0.
+                       0.      .0      0.0     0.0     0.0     0.0
$
$   PROPERTY DEFINITIONS
$
PBAR    1       1       50.0    104.2   416.7   288.5   0.0
+       2.5     5.0     2.5     -5.0    -2.5    -5.0    -2.5    5.0
$
$   MATERIAL DATA
$
MAT1    1       10.0+6          0.3     0.0     10.-6   5.0
$
$   TEMPERATURE DATA
$
TEMPD   1       25.0
$
ENDDATA
```

2.11.2 Output

```
1

            GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
           G        E       NN  N   E       S          I     S
           G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
           G    G   E       N  NN   E            S     I          S
            GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                             COPYRIGHT, 1991-2002

                   VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                        ALL RIGHTS RESERVED, WORLDWIDE

                                 VERSION 7.2

                           BUILD CODE 200212131048



     PROJECT NAME: A011
     RUN STARTED:  Dec 13, 2002 12:49
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    1
 BEAM UNDER CHANGES OF TEMPERATURE


                           ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                      2
                   NUMBER OF CBAR ELEMENTS:                    1
                   TOTAL NUMBER OF NON RIGID ELEMENTS:         1
```

```
                  NUMBER OF ELEMENT PROPERTIES:              1
                  NUMBER OF MATERIALS:                       1
                  NUMBER OF DEGREES OF FREEDOM:              3


                              LOAD CASES SUMMARY

                 NUMBER OF STATIC LOAD CASES:                  2
                 TOTAL NUMBER OF LOAD CASES:                   2

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    2
 BEAM UNDER CHANGES OF TEMPERATURE


               *********************************************
               *  D E S I G N  C Y C L E      0 (ANALYSIS)*
               *********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    3
 BEAM UNDER CHANGES OF TEMPERATURE


                    M A S S / V O L U M E   S U M M A R Y

                    SYSTEM MASS              0.000000E+00
                    SYSTEM VOLUME            5.000000E+03
                    SYSTEM MASS/VOLUME       0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    4
 BEAM UNDER CHANGES OF TEMPERATURE


                  S O L U T I O N   R E S I D U A L S

 LOADCASE        1 ; RESIDUAL :  0.000000E+00 ; STRAIN ENERGY :  1.000000E+03
 LOADCASE        2 ; RESIDUAL :  0.000000E+00 ; STRAIN ENERGY :  0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    5
 BEAM UNDER CHANGES OF TEMPERATURE


                     O L O A D   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
      2  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    6
 BEAM UNDER CHANGES OF TEMPERATURE


                  S P C F O R C E   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
      2  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
```

```
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    7
 BEAM UNDER CHANGES OF TEMPERATURE


               M A X I M U M   A P P L I E D   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

       1        2     1.0000E+05  1.0000E+05  0.0000E+00  0.0000E+00
       2        2     1.0000E+05  1.0000E+05  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    8
 BEAM UNDER CHANGES OF TEMPERATURE


                   M A X I M U M   S P C   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

       1              0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
       2        1     1.0000E+05  1.0000E+05  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    9
 BEAM UNDER CHANGES OF TEMPERATURE


                  M A X I M U M   D I S P L A C E M E N T

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

       1        2     2.0000E-02  2.0000E-02  0.0000E+00  0.0000E+00
       2              0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   10
 BEAM UNDER CHANGES OF TEMPERATURE

 LOAD CASE 1: FREE RIGHT DISPLACEMENT                       LOADCASE        1

                      G R I D   D I S P L A C E M E N T S

  GRID ID            T1                 T2                 T3
                     R1                 R2                 R3

        1      0.000000E+00      0.000000E+00      0.000000E+00
               0.000000E+00      0.000000E+00      0.000000E+00

        2      2.000000E-02      0.000000E+00      0.000000E+00
               0.000000E+00      0.000000E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   11
 BEAM UNDER CHANGES OF TEMPERATURE

 LOAD CASE 2: CONSTRAIN RIGHT DISPLACEMENT                  LOADCASE        2

            S T R E S S E S   I N   B A R   E L E M E N T S

   BAR ID  END     STRESS-C       STRESS-D       STRESS-E       STRESS-F
```

```
        1     A  -2.000000E+03  -2.000000E+03  -2.000000E+03  -2.000000E+03
              B  -2.000000E+03  -2.000000E+03  -2.000000E+03  -2.000000E+03

1                               ***** END OF OUTPUT *****
```

2.12 Portal Frame with Flexible Nodes

Example ID:

A012

Analysis Data Used:

GRID, GRDSET, CBAR, CELAS1, PBAR,PELAS, MAT1, LOAD, FORCE, PLOADA, SPC, SPC1, MPC, MPC, FORCE, SPCFORCES

Special Features Used:

Utilization of multi-point constraints (MPC) and scalar springs (CELAS) to model a flexible node.

Problem Statement:

Find the internal forces and reaction forces of the portal frame with angular flexible nodes. Consider that the angular flexibility of the nodes is f=L/(12EI).

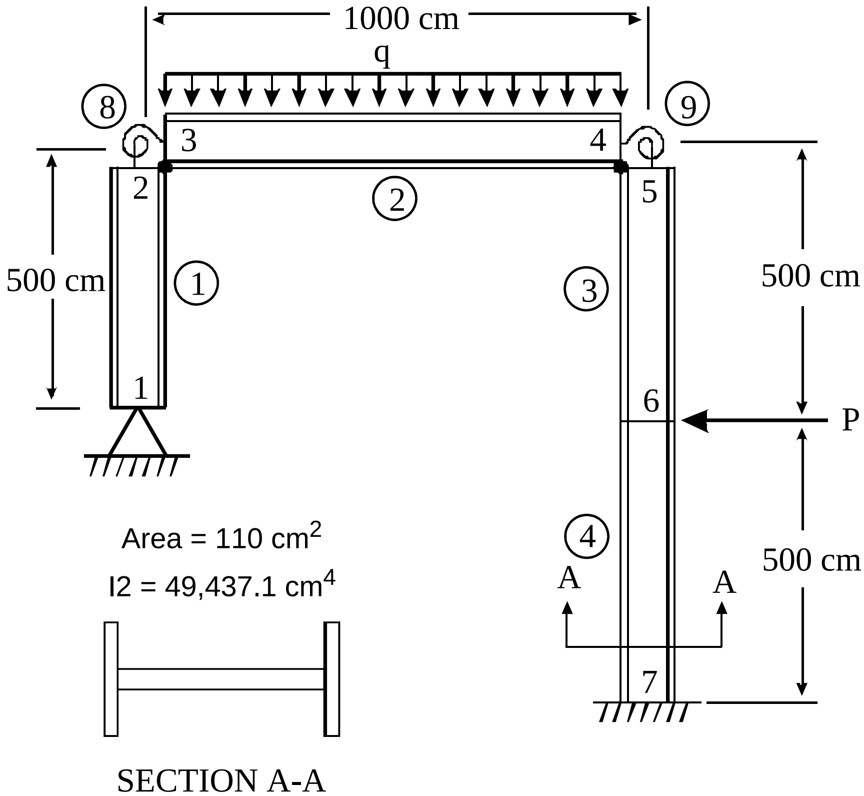
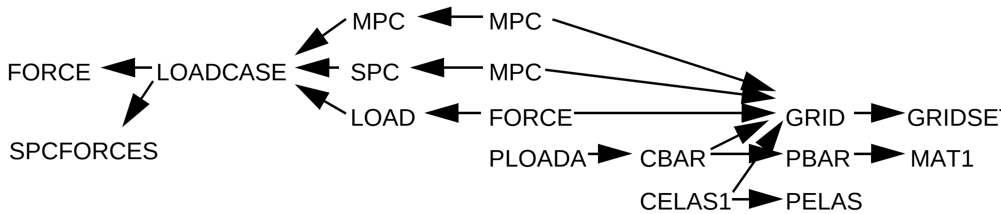


Figure 2-13

Structural Analysis Model:

1. Planar frame assembled with 4 CBAR elements and two CELAS elements.
2. Section properties of RAIL: Area=110.0cm^2, I2=49437.1 cm^4.
   of CELAS: $k = \frac{12EI}{L} = 4.188E+9$N-cm.
3. Material: Aluminum Alloy, E=7.06E+6 N/cm^2, ν=0.33.
4. One load case: P=10,000.0 N and q=10 N/cm.
5. Compatibility: Ux(GRID 2)-Ux(GRID 3)=0, Uy(GRID 2)-Uy(GRID 3)=0, Ux(GRID 4)-Ux(GRID 5)=0, Uy(GRID 4)-Uy(GRID 5)=0.

Analysis Data Relationships:



Special Modeling Techniques:

The angular flexibility of the upper left node was modeled by creating two grids for that node (GRID 2 and GRID 3). Then bars 1 and 2 were connected to the GRIDS 2 and 3 respectively. Then the CELAS element (EID=8) was connected to grid 2 and 3. Finally, to achieve displacement compatibilities, two MPC equations were written. The angular flexibility of the upper right node was modeled in a similar way.

Reference Solutions:

A solution of this problem was obtained using the manual force method.

M1a = 0.0

$$M1b = -\frac{LX_1}{2} = -1408935 \text{ N-cm}$$

$$M2a = -\frac{LX_1}{2} = -1408935 \text{ N-cm}$$

$$M2b = -\frac{LX_1}{2} + LX_2 - \frac{qL^2}{2} = -240550 \text{ N-cm}$$

$$M3a = -\frac{LX_1}{2} + LX_2 - \frac{qL^2}{2} = -240550 \text{ N-cm}$$

$$M4b = -\frac{LX_1}{2} + LX_2 - \frac{qL^2}{2} = -240550 \text{ N-cm}$$

X1 = 2817.87 N

X2 = 6168.38 N

To get this solution, P was written as P=qL. X1 and X2 were selected as the unknowns forces. These unknown forces correspond to the reaction forces at grid number 1.

Calculated Solutions:

M1a = 0.0 N-cm

M1b = -1407252 N-cm

M2a = -1407252 N-cm

M2b = -2393214 N-cm

M3a = -2393214 N-cm

M4b = -2424818 N-cm

X1 = 2814.50 N

X2 = 6167.93 N

Comparison Between Calculated Solutions and Reference Solutions:

The differences between analytical solutions and the *GENESIS* solutions are:

M1a: 0%

M1b: 0.1%

M2a: 0.1%

M2b: 0.5%

M3a: 0.5%

M4b: 0.1%

X1: 0.1%

X2: 0.01%

2.12.1 Input Data

```
ID A012
SOL COMPAT1
CEND
TITLE = PORTAL FRAME WITH FLEXIBLE NODES
$ECHO=NONE
LINE=64,80
SET 1000 =1,7
SUBCASE 1
        LOAD = 300
        SPC = 100
        MPC = 100
        LABEL = A FORCE AT NODE 3
        FORCE = ALL
        SPCFORCES = 1000
$
BEGIN BULK
$
$     BOUNDARY CONDITIONS
$
SPC1    100     12345   1
SPC1    100     123456  7
MPC     100     2       1       1.0     3       1       -1.0
MPC     100     2       2       1.0     3       2       -1.0
$
MPC     100     4       1       1.0     5       1       -1.0
MPC     100     4       2       1.0     5       2       -1.0
$
$     GRID POINTS
$
GRDSET                                                  345
GRID    1               0.0     500.    0.0
GRID    2               0.0     1000.   0.0
GRID    3               0.0     1000.   0.0
GRID    4               1000.   1000.   0.0
GRID    5               1000.   1000.   0.0
GRID    6               1000.   500.    0.0
GRID    7               1000.   0.0     0.0
$
$     ELEMENT DEFINITIONS
$
CBAR    1       1       1       2       0.0     0.0     -1.0
CBAR    2       1       3       4       0.0     0.0     -1.0
CBAR    3       1       5       6       0.0     0.0     -1.0
CBAR    4       1       6       7       0.0     0.0     -1.0
$
$     SCALAR SPRING
$
CELAS1  8       2       2       6       3       6
CELAS1  9       3       4       6       5       6
$
$     PROPERTY DEFINITIONS
$
```

```
PBAR    1       51      110.0   4504.0  49437.1                         +P1
+P1     15.0    26.0    0.0     26.0    0.0     0.0     0.00    -26.0
PELAS   2       4.188+9         1.0
PELAS   3       4.188+9         1.0
$PELAS  3       2.792+9         1.0
$
$     MATERIAL DEFINITIONS
$
MAT1    51      7.06E6          0.33
$
$     LOAD DEFINITIONS
$
FORCE   300     6               -10000.01.0     0.0     0.0
PLOADA  300     2               0.0     -1.0    0.0     10.0    10.0
$
ENDDATA
```

2.12.2 Output

```
1




             GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
            G        E       NN  N   E       S          I     S
            G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
            G    G   E       N  NN   E            S     I          S
             GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                             COPYRIGHT, 1991-2002

                   VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                        ALL RIGHTS RESERVED, WORLDWIDE

                                 VERSION 7.2

                           BUILD CODE 200212131048



     PROJECT NAME: A012
     RUN STARTED:  Dec 13, 2002 12:49
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    1
 PORTAL FRAME WITH FLEXIBLE NODES


                             ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                       7
                   NUMBER OF CBAR ELEMENTS:                     4
                   NUMBER OF CELAS1/2 ELEMENTS:                 2
```

```
                 TOTAL NUMBER OF NON RIGID ELEMENTS:         6
                 NUMBER OF ELEMENT PROPERTIES:               3
                 NUMBER OF MATERIALS:                        1
                 NUMBER OF DEGREES OF FREEDOM:              16


                             LOAD CASES SUMMARY

                NUMBER OF STATIC LOAD CASES:                   1
                TOTAL NUMBER OF LOAD CASES:                    1

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    2
 PORTAL FRAME WITH FLEXIBLE NODES


              ********************************************
              *  D E S I G N  C Y C L E     0 (ANALYSIS)*
              ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    3
 PORTAL FRAME WITH FLEXIBLE NODES


                  M A S S / V O L U M E   S U M M A R Y

                  SYSTEM MASS               0.000000E+00
                  SYSTEM VOLUME             2.750000E+05
                  SYSTEM MASS/VOLUME        0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    4
 PORTAL FRAME WITH FLEXIBLE NODES


                 S O L U T I O N   R E S I D U A L S

 LOADCASE        1 ; RESIDUAL :  5.403643E-14 ; STRAIN ENERGY :  2.231866E+03
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    5
 PORTAL FRAME WITH FLEXIBLE NODES


                   O L O A D   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1 -1.0000E+04 -1.0000E+04  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    6
 PORTAL FRAME WITH FLEXIBLE NODES


                 S P C F O R C E   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1  1.0000E+04  1.0000E+04  0.0000E+00  0.0000E+00  0.0000E+00 -9.3132E-10
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    7
 PORTAL FRAME WITH FLEXIBLE NODES
```

```
              M A X I M U M   A P P L I E D   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1           T2           T3

       1        6     1.0000E+04 -1.0000E+04  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    8
 PORTAL FRAME WITH FLEXIBLE NODES


                  M A X I M U M   S P C   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1           T2           T3

       1        7     8.1435E+03  7.1855E+03  3.8321E+03  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    9
 PORTAL FRAME WITH FLEXIBLE NODES


                 M A X I M U M   D I S P L A C E M E N T

 LOADCASE GRID ID      MAGNITUDE      T1           T2           T3

       1        4     6.3940E-01 -6.3938E-01 -4.9344E-03  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   10
 PORTAL FRAME WITH FLEXIBLE NODES

 A FORCE AT NODE 3                                                LOADCASE        1

                  R E A C T I O N   F O R C E S

       ID             F1                 F2                 F3
                      M1                 M2                 M3

        1      2.814503E+03      6.167930E+03      0.000000E+00
               0.000000E+00      0.000000E+00     -1.746230E-09

        7      7.185497E+03      3.832070E+03      0.000000E+00
               0.000000E+00      0.000000E+00     -2.424818E+06

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   11
 PORTAL FRAME WITH FLEXIBLE NODES

 A FORCE AT NODE 3                                                LOADCASE        1

                F O R C E S   I N   E L A S 1/2   E L E M E N T S

 ELAS1 ID                FORCE

        8            1.407252E+06
        9            2.393214E+05
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   12
 PORTAL FRAME WITH FLEXIBLE NODES
```

A FORCE AT NODE 3 LOADCASE 1

F O R C E S   I N   B A R   E L E M E N T S

BAR ID	END	BENDING MOMENT 1 SHEAR FORCE 1	BENDING MOMENT 2 SHEAR FORCE 2	AXIAL FORCE TORQUE
1	A	0.000000E+00	1.746230E-09	-6.167930E+03
		0.000000E+00	2.814503E+03	0.000000E+00
	B	0.000000E+00	-1.407252E+06	-6.167930E+03
		0.000000E+00	2.814503E+03	0.000000E+00
2	A	0.000000E+00	-1.407252E+06	-2.814503E+03
		0.000000E+00	-6.167930E+03	0.000000E+00
	B	0.000000E+00	-2.393214E+05	-2.814503E+03
		0.000000E+00	3.832070E+03	0.000000E+00
3	A	0.000000E+00	-2.393214E+05	-3.832070E+03
		0.000000E+00	-2.814503E+03	0.000000E+00
	B	0.000000E+00	1.167930E+06	-3.832070E+03
		0.000000E+00	-2.814503E+03	0.000000E+00
4	A	0.000000E+00	1.167930E+06	-3.832070E+03
		0.000000E+00	7.185497E+03	0.000000E+00
	B	0.000000E+00	-2.424818E+06	-3.832070E+03
		0.000000E+00	7.185497E+03	0.000000E+00

1 ***** END OF OUTPUT *****

2.13 Beam Supported by Springs

Example ID:

A013

Analysis Data Used:

GRID, GRDSET, CBAR, CELAS1, PBAR,PELAS, MAT1, LOADCASE, LOAD, FORCE, FORCE (SOLUTION CONTROL)

Special Features Used:

Utilization of scalar springs (CELAS).

Problem Statement:

Find the moment at the center of the beam of **Figure 2-14**. Consider the rigidity of the external springs as k=1.0E7 N/cm.

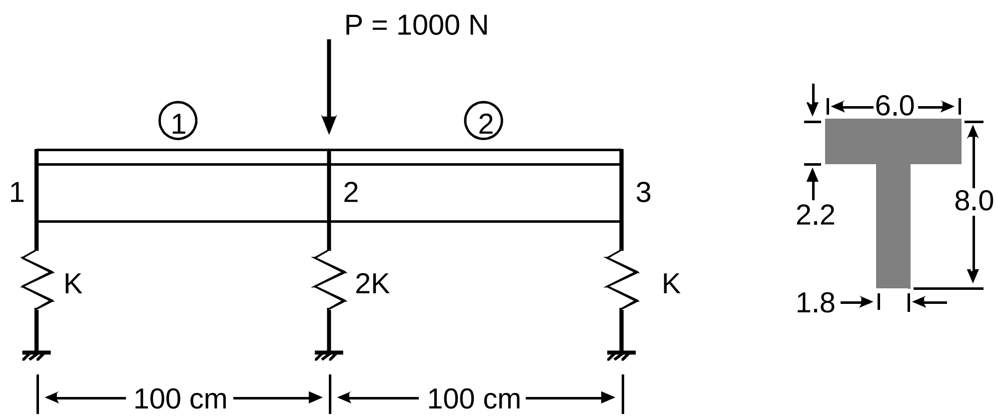
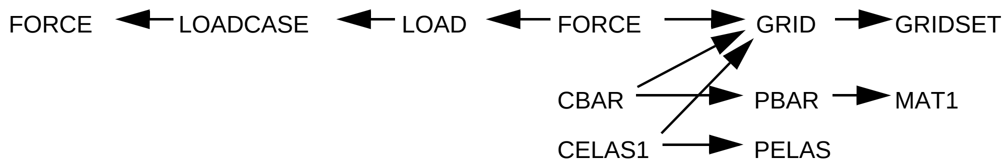


Figure 2-14

Structural Analysis Model:

1. Planar structure assembled with 2 CBAR elements and three CELAS1 elements.
2. Section properties of T BEAM: Area=23.64 cm^2, I_2=42.41 cm^4.
3. Stiffness of CELAS: k=1.0E+7 N/cm.
4. Material: Aluminum Alloy, E=7.06E+6 N/cm^2, ν =0.33.
5. One load case: P=1,000.0 N.

Analysis Data Relationships:



Special Modeling Techniques:

NONE

Reference Solutions:

The analytical solution for this problem is:

$$M = \frac{P}{2\left(6EI + \frac{KL^3}{8}\right)} = 4.5084 \text{ N-cm}$$

where P is the applied load, E is the Young's modulus, I the area moment of inertia, k is the spring stiffness and L is the total length of the beam.

Calculated Solutions:

M= 4.5084 N-cm

Comparison Between Calculated Solutions and Reference Solution:

There are no differences between the analytical solution and the *GENESIS* solution.

2.13.1 Input Data

```
ID A013
SOL COMPAT1
CEND
TITLE = BEAM SUPPORTED BY SPRINGS
LINE=64,80
LOADCASE 1
        LOAD = 300
        FORCE = ALL
$
BEGIN BULK
$
$     GRID POINTS
$
GRDSET                                                        345
$
GRID    1               0.0     0.      0.0
GRID    2               100.0   0.      0.0                   1345
GRID    3               200.0   0.      0.0
GRID    4               0.0     -1.     0.0                   123456
GRID    5               100.0   -1.     0.0                   123456
GRID    6               200.0   -1.     0.0                   123456
$
$     ELEMENT DEFINITIONS
CBAR    1       1       1       2       0.0     0.0     -1.0
CBAR    2       1       2       3       0.0     0.0     -1.0
$
$     SCALAR SPRING
$
CELAS1  3       2       4       2       1       2
CELAS1  4       3       5       2       2       2
CELAS1  5       2       6       2       3       2
$
$     PROPERTY DEFINITIONS
$
PBAR    1       51      23.64   10.44   127.74
PELAS   2       3.+7            1.0
PELAS   3       6.+7            1.0
$
$     MATERIAL DEFINITIONS
$
MAT1    51      7.06E6          0.33
$
$     LOAD DEFINITIONS
$
FORCE   300     2               -1000.0 0.0     1.0     0.0
$
ENDDATA
```

2.13.2 Output

```
1




                  GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
                 G        E       NN  N   E       S          I     S
                 G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
                 G    G   E       N  NN   E            S     I          S
                  GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                      STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                                   COPYRIGHT, 1991-2002

                         VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                              ALL RIGHTS RESERVED, WORLDWIDE

                                       VERSION 7.2

                                 BUILD CODE 200212131048



     PROJECT NAME: A013
     RUN STARTED:  Dec 13, 2002 12:49
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    1
 BEAM SUPPORTED BY SPRINGS


                                 ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                      6
                   NUMBER OF CBAR ELEMENTS:                    2
                   NUMBER OF CELAS1/2 ELEMENTS:                3
```

```
                     TOTAL NUMBER OF NON RIGID ELEMENTS:          5
                     NUMBER OF ELEMENT PROPERTIES:                3
                     NUMBER OF MATERIALS:                         1
                     NUMBER OF DEGREES OF FREEDOM:                8


                                 LOAD CASES SUMMARY

                    NUMBER OF STATIC LOAD CASES:                    1
                    TOTAL NUMBER OF LOAD CASES:                     1
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    2
 BEAM SUPPORTED BY SPRINGS


                ********************************************
                *  D E S I G N  C Y C L E     0 (ANALYSIS)*
                ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    3
 BEAM SUPPORTED BY SPRINGS


                     M A S S / V O L U M E   S U M M A R Y

                     SYSTEM MASS               0.000000E+00
                     SYSTEM VOLUME             4.728000E+03
                     SYSTEM MASS/VOLUME        0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    4
 BEAM SUPPORTED BY SPRINGS


                    S O L U T I O N   R E S I D U A L S

 LOADCASE        1 ; RESIDUAL : -2.273204E-16 ; STRAIN ENERGY :  8.332582E-03
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    5
 BEAM SUPPORTED BY SPRINGS


                      O L O A D   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1  0.0000E+00 -1.0000E+03  0.0000E+00  0.0000E+00  0.0000E+00 -1.0000E+05
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    6
 BEAM SUPPORTED BY SPRINGS


                    S P C F O R C E   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1  0.0000E+00  1.0000E+03  0.0000E+00  0.0000E+00  0.0000E+00  1.0000E+05
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    7
 BEAM SUPPORTED BY SPRINGS
```

```
              M A X I M U M   A P P L I E D   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1        2     1.0000E+03  0.0000E+00 -1.0000E+03  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    8
 BEAM SUPPORTED BY SPRINGS


                  M A X I M U M   S P C   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1        5     9.9991E+02  0.0000E+00  9.9991E+02  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    9
 BEAM SUPPORTED BY SPRINGS


                 M A X I M U M   D I S P L A C E M E N T

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1        2     1.6665E-05  0.0000E+00 -1.6665E-05  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   10
 BEAM SUPPORTED BY SPRINGS

                                                         LOADCASE        1

                 F O R C E S   I N   E L A S 1/2   E L E M E N T S

 ELAS1 ID              FORCE

       3            4.508409E-02
       4            9.999098E+02
       5            4.508409E-02
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   11
 BEAM SUPPORTED BY SPRINGS

                                                         LOADCASE        1

                 F O R C E S   I N   B A R   E L E M E N T S

   BAR ID  END     BENDING MOMENT 1   BENDING MOMENT 2     AXIAL FORCE
                    SHEAR FORCE 1      SHEAR FORCE 2         TORQUE


       1    A       0.000000E+00       0.000000E+00       0.000000E+00
                    0.000000E+00      -4.508409E-02       0.000000E+00
            B       0.000000E+00       4.508409E+00       0.000000E+00
                    0.000000E+00      -4.508409E-02       0.000000E+00


       2    A       0.000000E+00       4.508409E+00       0.000000E+00
```

```
                  0.000000E+00      4.508409E-02      0.000000E+00
        B         0.000000E+00      1.776357E-15      0.000000E+00
                  0.000000E+00      4.508409E-02      0.000000E+00

1                        ***** END OF OUTPUT *****
```

2.14 Planar Grillage with Internal Pin

Example ID:

A014

Analysis Data Used:

GRID, CBAR, PBAR, MAT1, LOADCASE, LOAD, FORCE, MOMENT, DISP

Special Features Used:

Utilization of PIN FLAGS of CBAR elements to represent an internal pin in the planar grillage.

Problem Statement:

Find the angular displacement and internal moments of the elements of the planar grillage shown in **Figure 2-15**.

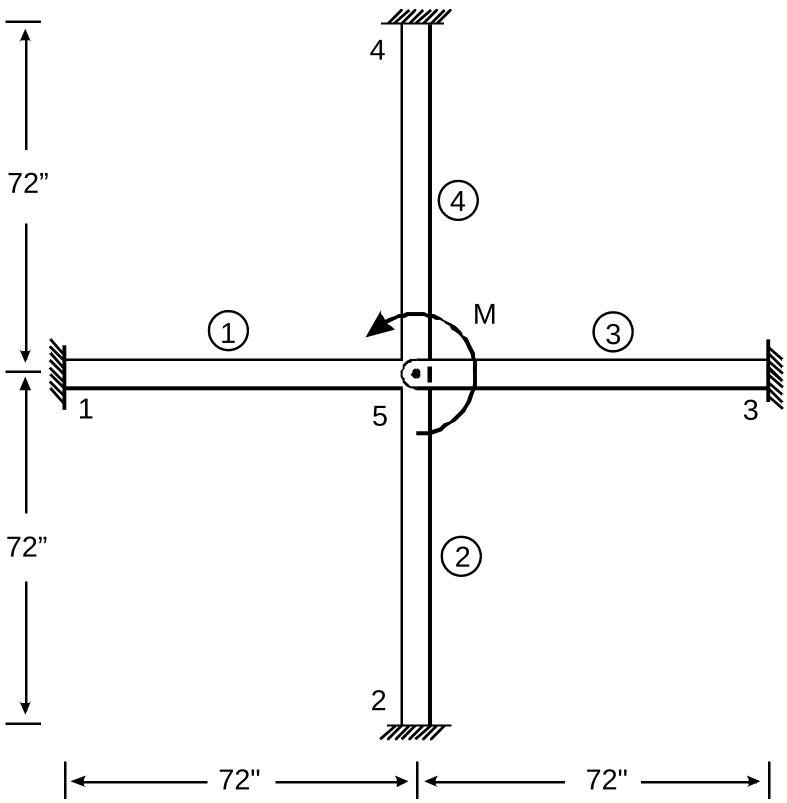
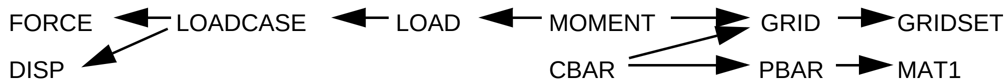


Figure 2-15

Structural Analysis Model:

1. Planar grillage assembled with 4 CBAR elements.
2. Section properties of BEAMS: Area=1.0 in^2, I2=0.0833 in^4.
3. Material: E=6.902E+6 psi.
4. One Load cases: M=10,000.0 in-lb.

Analysis Date Relationships:



Special Modeling Techniques:

The internal pin of the grillage is represented in the CBAR (EID=3) data as PA=5. Notice that the degree of freedom being condensed is in the element coordinate system (not in the general coordinate system, nor in the basic coordinate system).

Reference Solutions:

The analytical solutions for this problem are:

$$\theta = \frac{ML}{12EI} = 0.1043 \text{ Rad}$$

$$M1a = M2a = M4a = -\frac{4EI\theta}{L} = \text{-3333.3 in-lb}$$

$$M1b = M2b = M4b = -\frac{2EI\theta}{L} = \text{-1666.7 in-lb}$$

$$M3a = M3b = 0.0$$

where: M is the applied load, E is the Young's modulus, I the area moment of inertia and L is the total length of each of the elements.

Calculated Solution:

The *GENESIS* solution is:

$$\theta = 0.1043 \text{ Rad}$$

$$M1a = M2a = M4a = -3333.3 \text{ in-lb}$$

$$M1b = M2b = M4b = -1666.7 \text{ in-lb}$$

$$M3a = M3b = 0.0$$

Comparison Between Calculated Solutions and Reference Solution:

There are no differences between the analytical solution and the *GENESIS* solution.

2.14.1 Input Data

```
ID A014
SOL COMPAT1
CEND
TITLE = PLANAR GRILLAGE WITH INTERNAL PIN
ECHO=NONE
SET 5=5
LINE=64,80
LOADCASE 1
        LOAD = 100
        DISP=5
        FORCE = ALL
BEGIN BULK
$
$     GRID POINTS
$
GRID    1               -72.0   0.      0.0             123456
GRID    2               0.0     -72.    0.0             123456
GRID    3               72.0    0.      0.0             123456
GRID    4               0.      72.     0.0             123456
GRID    5               0.      0.      0.0             12345
$
$     ELEMENT DEFINITIONS
$
CBAR    1       1       5       1       0.0     0.0     -1.0
CBAR    2       1       5       2       0.0     0.0     -1.0
CBAR    3       1       5       3       0.0     0.0     -1.0
+       5
CBAR    4       1       5       4       0.0     0.0     -1.0
$
$     PROPERTY DEFINITIONS
$
PBAR    1       51      1.0     .08333  0.08333
$
$     MATERIAL DEFINITIONS
$
MAT1    51      6.902+6         0.33    1.6636-4
$
$     LOAD DEFINITIONS
$
MOMENT  100     5                10000.00.0     0.0     1.0
$
ENDDATA
```

2.14.2 Output

```
1

        GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
       G        E       NN  N   E       S          I     S
       G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
       G    G   E       N  NN   E            S     I          S
        GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


             STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                          COPYRIGHT, 1991-2002

                VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                     ALL RIGHTS RESERVED, WORLDWIDE

                              VERSION 7.2

                        BUILD CODE 200212131048



     PROJECT NAME: A014
     RUN STARTED:  Dec 13, 2002 12:49
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    1
 PLANAR GRILLAGE WITH INTERNAL PIN


                         ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                       5
                   NUMBER OF CBAR ELEMENTS:                     4
                   TOTAL NUMBER OF NON RIGID ELEMENTS:          4
```

```
                    NUMBER OF ELEMENT PROPERTIES:             1
                    NUMBER OF MATERIALS:                      1
                    NUMBER OF DEGREES OF FREEDOM:             1


                                LOAD CASES SUMMARY

                   NUMBER OF STATIC LOAD CASES:                  1
                   TOTAL NUMBER OF LOAD CASES:                   1

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    2
 PLANAR GRILLAGE WITH INTERNAL PIN


                ********************************************
                *  D E S I G N  C Y C L E     0 (ANALYSIS)*
                ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    3
 PLANAR GRILLAGE WITH INTERNAL PIN


                    M A S S / V O L U M E   S U M M A R Y

                    SYSTEM MASS               4.791168E-02
                    SYSTEM VOLUME             2.880000E+02
                    SYSTEM MASS/VOLUME        1.663600E-04
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    4
 PLANAR GRILLAGE WITH INTERNAL PIN


                   S O L U T I O N   R E S I D U A L S

 LOADCASE        1 ; RESIDUAL :  0.000000E+00 ; STRAIN ENERGY :  5.216088E+02
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    5
 PLANAR GRILLAGE WITH INTERNAL PIN


                     O L O A D   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  1.0000E+04
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    6
 PLANAR GRILLAGE WITH INTERNAL PIN


                   S P C F O R C E   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00 -1.0000E+04
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    7
 PLANAR GRILLAGE WITH INTERNAL PIN
```

```
             M A X I M U M   A P P L I E D   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1              0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    8
 PLANAR GRILLAGE WITH INTERNAL PIN


                 M A X I M U M   S P C   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1        1     6.9444E+01  0.0000E+00  6.9444E+01  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    9
 PLANAR GRILLAGE WITH INTERNAL PIN


                M A X I M U M   D I S P L A C E M E N T

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1              0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   10
 PLANAR GRILLAGE WITH INTERNAL PIN

                                                        LOADCASE         1

                    G R I D   D I S P L A C E M E N T S

  GRID ID            T1                 T2                 T3
                     R1                 R2                 R3

       5      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      1.043218E-01

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   11
 PLANAR GRILLAGE WITH INTERNAL PIN

                                                        LOADCASE         1

               F O R C E S   I N   B A R   E L E M E N T S

   BAR ID  END     BENDING MOMENT 1   BENDING MOMENT 2     AXIAL FORCE
                    SHEAR FORCE 1      SHEAR FORCE 2         TORQUE


       1    A       0.000000E+00      -3.333333E+03       0.000000E+00
                    0.000000E+00      -6.944444E+01       0.000000E+00
            B       0.000000E+00       1.666667E+03       0.000000E+00
                    0.000000E+00      -6.944444E+01       0.000000E+00


       2    A       0.000000E+00      -3.333333E+03       0.000000E+00
```

```
               0.000000E+00     -6.944444E+01      0.000000E+00
          B    0.000000E+00      1.666667E+03      0.000000E+00
               0.000000E+00     -6.944444E+01      0.000000E+00


     3    A    0.000000E+00      0.000000E+00      0.000000E+00
               0.000000E+00      0.000000E+00      0.000000E+00
          B    0.000000E+00      0.000000E+00      0.000000E+00
               0.000000E+00      0.000000E+00      0.000000E+00


     4    A    0.000000E+00     -3.333333E+03      0.000000E+00
               0.000000E+00     -6.944444E+01      0.000000E+00
          B    0.000000E+00      1.666667E+03      0.000000E+00
               0.000000E+00     -6.944444E+01      0.000000E+00

1                        ***** END OF OUTPUT *****
```

2.15 Rod Modeled with Tetra Elements

Example ID:

A015

Analysis Data Used:

GRID, CTETRA, PSOLID, MAT1, LOADCASE, LOAD, FORCE, SPC, SPC1, STRESS, DISP

Special Features Used:

NONE. This example shows how to assemble a brick using CTETRA elements

Problem Statement:

Find the tip displacements and the stresses at the root of a cantilever rod loaded in its free end with a tension load of 4800 lb.

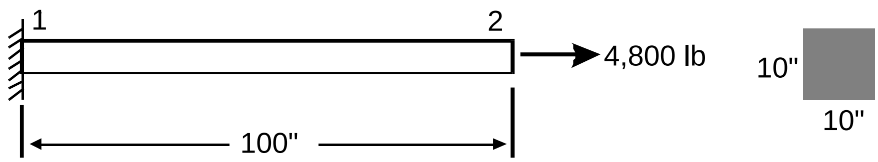


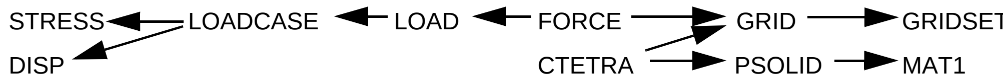
Figure 2-16

Structural Analysis Model:

1. Tridimensional model of the rod assembled with 30 CTETRA elements.
2. Material: E=1.0E+7psi.
3. One Load cases: P=4800lb.

The stresses for solid elements are printed out in the material coordinate system. In this case the material coordinate system is the basic coordinate system (the default). Other coordinate system can be used as the material coordinate system. See the description of the PSOLID element in Volume II for more details.

Analysis Data Relationships:



In this example the solution control commands SET 5=21,22,23,24 and SET 6=1,2,3,4,5,6 were used to limit the output.

Special Modeling Techniques:

It is important to correctly model the boundary conditions. In this problem they have to globally prevent the structure from moving in the six degrees of freedoms of the fixed boundary condition (see figure below). Please note that if all 4 nodes 1,2,3 and 4 were constrained against all movement, slightly different answers will be obtained. Also it is important to load the structure with the correct consistent load vector. Please also note, that if the structure were loaded with 4 loads of 1200 lb in each of the free end corners, incorrect answers would be obtained.

The procedure to assemble a brick with 6 CTETRA elements are shown in **Figure 2-17**. There are alternative ways to do this; another way is to divide the brick in 5 CTETRA elements. See the Design Capabilities discussion (Ch. 4) in Volume I.

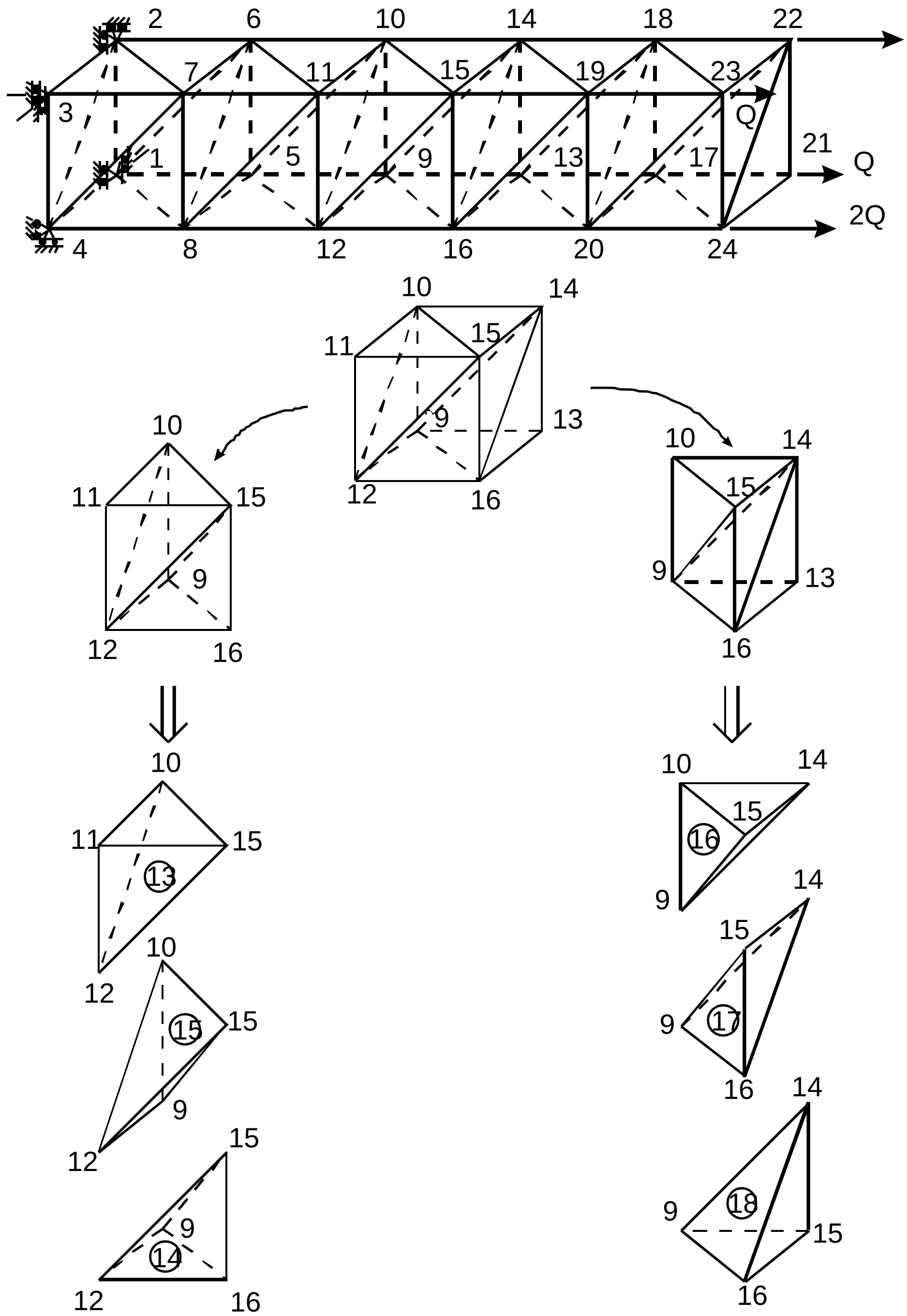


Figure 2-17

Reference Solutions:

The analytical solutions for this problem are:

$$U_x = \frac{PL}{EA} = 0.00048 \text{ in}$$

$$\sigma = \frac{P}{A} = 48 \text{ psi}$$

where: P is the applied load, E is the Young's modulus, A the area and L is the total length of the beam.

Calculated Solution:

The *GENESIS* solution is:

$$U_x = 0.00048 \text{ in}$$

$$\sigma = \frac{P}{A} = 48 \text{ psi}$$

Comparison Between Calculated Solution and Reference Solution:

There are no differences between the analytical solution and the *GENESIS* solution.

2.15.1 Input Data

```
ID A015
SOL COMPAT1
CEND
TITLE = TENSION ROD ASSEMBLED WITH TETRA ELEMENTS
LINE=64,80
SET 5=21,22,23,24
SET 6=1,2,3,4,5,6
LOADCASE 1
        LOAD = 42
        FORCE = ALL
        SPC=77
        DISPLACEMENT=5
        STRESS=6
$
BEGIN BULK
$
$     BOUNDARY CONDITIONS
$
SPC1    77      12      1
SPC1    77      13      2
SPC1    77      12      3
SPC1    77      13      4
$
$     GRID POINTS
$
GRID    1               0.0     10.     0.0
GRID    2               0.0     10.     10.0
GRID    3               0.0     0.0     10.0
GRID    4               0.0     0.0     0.0
$
GRID    5               20.0    10.     0.0
GRID    6               20.0    10.     10.0
GRID    7               20.0    0.0     10.0
GRID    8               20.0    0.0     0.0
$
GRID    9               40.0    10.     0.0
GRID    10              40.0    10.     10.0
GRID    11              40.0    0.0     10.0
GRID    12              40.0    0.0     0.0
$
GRID    13              60.0    10.     0.0
GRID    14              60.0    10.     10.0
GRID    15              60.0    0.0     10.0
GRID    16              60.0    0.0     0.0
$
GRID    17              80.0    10.     0.0
GRID    18              80.0    10.     10.0
GRID    19              80.0    0.0     10.0
GRID    20              80.0    0.0     0.0
$
GRID    21              100.0   10.     0.0
GRID    22              100.0   10.     10.0
```

```
GRID    23              100.0   0.0     10.0
GRID    24              100.0   0.0     0.0
$
$     ELEMENT DEFINITIONS
$
CTETRA  1       1       3       7       2       4
CTETRA  2       1       4       8       1       7
CTETRA  3       1       2       7       1       4
CTETRA  4       1       2       6       7       1
CTETRA  5       1       7       6       8       1
CTETRA  6       1       8       5       1       6
$
CTETRA  7       1       7       11      6       8
CTETRA  8       1       8       12      5       11
CTETRA  9       1       6       11      5       8
CTETRA  10      1       6       10      11      5
CTETRA  11      1       11      10      12      5
CTETRA  12      1       12      9       5       10
$
CTETRA  13      1       11      15      10      12
CTETRA  14      1       12      16      9       15
CTETRA  15      1       10      15      9       12
CTETRA  16      1       10      14      15      9
CTETRA  17      1       15      14      16      9
CTETRA  18      1       16      13      9       14
$
CTETRA  19      1       15      19      14      16
CTETRA  20      1       16      20      13      19
CTETRA  21      1       14      19      13      16
CTETRA  22      1       14      18      19      13
CTETRA  23      1       19      18      20      13
CTETRA  24      1       20      17      13      18
$
CTETRA  25      1       19      23      18      20
CTETRA  26      1       20      24      17      23
CTETRA  27      1       18      23      17      20
CTETRA  28      1       18      22      23      17
CTETRA  29      1       23      22      24      17
CTETRA  30      1       24      21      17      22
$
$     PROPERTY DEFINITIONS
$
PSOLID  1       51
$
$     MATERIAL DEFINITIONS
$
MAT1    51      10.0E6          0.3
$
$     LOAD DEFINITIONS
$
FORCE   42      21              800.0   1.0     0.0     0.0
FORCE   42      22              1600.0  1.0     0.0     0.0
FORCE   42      23              800.0   1.0     0.0     0.0
FORCE   42      24              1600.0  1.0     0.0     0.0
$
```

```
ENDDATA
```

2.15.2 Output

```
1

           GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
          G        E       NN  N   E       S          I     S
          G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
          G    G   E       N  NN   E            S     I          S
           GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                 STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                              COPYRIGHT, 1991-2002

                    VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                         ALL RIGHTS RESERVED, WORLDWIDE

                                  VERSION 7.2

                            BUILD CODE 200212131048



     PROJECT NAME: A015
     RUN STARTED:  Dec 13, 2002 12:49
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    1
 TENSION ROD ASSEMBLED WITH TETRA ELEMENTS


                            ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                     24
                   NUMBER OF CTETRA ELEMENTS:                 30
                   TOTAL NUMBER OF NON RIGID ELEMENTS:        30
```

```
                NUMBER OF ELEMENT PROPERTIES:            1
                NUMBER OF MATERIALS:                     1
                NUMBER OF DEGREES OF FREEDOM:           64


                            LOAD CASES SUMMARY

               NUMBER OF STATIC LOAD CASES:                  1
               TOTAL NUMBER OF LOAD CASES:                   1

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    2
 TENSION ROD ASSEMBLED WITH TETRA ELEMENTS


             ********************************************
             *  D E S I G N  C Y C L E      0 (ANALYSIS)*
             ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    3
 TENSION ROD ASSEMBLED WITH TETRA ELEMENTS


                M A S S / V O L U M E   S U M M A R Y

                SYSTEM MASS              0.000000E+00
                SYSTEM VOLUME            1.000000E+04
                SYSTEM MASS/VOLUME       0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    4
 TENSION ROD ASSEMBLED WITH TETRA ELEMENTS


               S O L U T I O N   R E S I D U A L S

 LOADCASE         1 ; RESIDUAL :  1.590384E-15 ; STRAIN ENERGY :  1.152000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    5
 TENSION ROD ASSEMBLED WITH TETRA ELEMENTS


                O L O A D   R E S U L T A N T S

 LOADCASE     T1          T2          T3          R1          R2          R3

      1  4.8000E+03  0.0000E+00  0.0000E+00  0.0000E+00  2.4000E+04 -2.4000E+04
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    6
 TENSION ROD ASSEMBLED WITH TETRA ELEMENTS


               S P C F O R C E   R E S U L T A N T S

 LOADCASE     T1          T2          T3          R1          R2          R3

      1 -4.8000E+03 -1.2830E-12  3.0340E-12  4.4646E-11 -2.4000E+04  2.4000E+04
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    7
 TENSION ROD ASSEMBLED WITH TETRA ELEMENTS
```

```
              M A X I M U M   A P P L I E D   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

       1       22     1.6000E+03  1.6000E+03  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    8
 TENSION ROD ASSEMBLED WITH TETRA ELEMENTS


                  M A X I M U M   S P C   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

       1        2     1.6000E+03 -1.6000E+03  1.2790E-13  1.4381E-11
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    9
 TENSION ROD ASSEMBLED WITH TETRA ELEMENTS


                 M A X I M U M   D I S P L A C E M E N T

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

       1       22     4.8022E-04  4.8000E-04 -1.4400E-05 -1.2455E-17
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   10
 TENSION ROD ASSEMBLED WITH TETRA ELEMENTS

                                                         LOADCASE         1

                     G R I D   D I S P L A C E M E N T S

  GRID ID            T1                 T2                 T3
                     R1                 R2                 R3

      21      4.800000E-04     -7.175809E-17      1.440000E-05
              0.000000E+00      0.000000E+00      0.000000E+00

      22      4.800000E-04     -1.440000E-05     -1.245477E-17
              0.000000E+00      0.000000E+00      0.000000E+00

      23      4.800000E-04     -7.123208E-17     -1.440000E-05
              0.000000E+00      0.000000E+00      0.000000E+00

      24      4.800000E-04      1.440000E-05     -1.197027E-17
              0.000000E+00      0.000000E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   11
 TENSION ROD ASSEMBLED WITH TETRA ELEMENTS

                                                         LOADCASE         1

             S T R E S S E S   I N   T E T R A   E L E M E N T S

 TETRA ID       NORMAL            SHEAR            PRINCIPAL
                VON MISES         OCTAHEDRAL       MAX SHEAR        PRESSURE
```

```
1  X  4.800000E+01  XY -8.401915E-13  1  4.800000E+01
   Y -7.283063E-14  YZ  1.262405E-13  2  6.750156E-14
   Z  6.750156E-14  ZX -1.258333E-13  3 -7.283063E-14
      4.800000E+01      2.262742E+01     2.400000E+01    -1.600000E+01

2  X  4.800000E+01  XY -8.091608E-13  1  4.800000E+01
   Y  2.451372E-13  YZ  2.083375E-13  2  2.451372E-13
   Z -9.592327E-14  ZX  2.932037E-13  3 -9.592327E-14
      4.800000E+01      2.262742E+01     2.400000E+01    -1.600000E+01

3  X  4.800000E+01  XY -7.423755E-13  1  4.800000E+01
   Y  3.961276E-13  YZ  7.492984E-14  2  3.961276E-13
   Z -1.421085E-13  ZX -5.375401E-14  3 -1.421085E-13
      4.800000E+01      2.262742E+01     2.400000E+01    -1.600000E+01

4  X  4.800000E+01  XY  4.235165E-13  1  4.800000E+01
   Y  1.829648E-13  YZ -1.588187E-13  2  3.375078E-13
   Z  3.375078E-13  ZX -1.708319E-13  3  1.829648E-13
      4.800000E+01      2.262742E+01     2.400000E+01    -1.600000E+01

5  X  4.800000E+01  XY  3.534734E-13  1  4.800000E+01
   Y  3.197442E-14  YZ -2.606255E-14  2  3.836931E-13
   Z  3.836931E-13  ZX  1.787728E-13  3  3.197442E-14
      4.800000E+01      2.262742E+01     2.400000E+01    -1.600000E+01

6  X  4.800000E+01  XY  7.506015E-13  1  4.800000E+01
   Y  4.956036E-13  YZ  7.330093E-15  2  4.956036E-13
   Z  2.557954E-13  ZX -7.818766E-14  3  2.557954E-13
      4.800000E+01      2.262742E+01     2.400000E+01    -1.600000E+01

1                             ***** END OF OUTPUT *****
```

2.16 Rod Modeled with Penta Elements

Example ID:

A016

Analysis Data:

GRID, CPENTA, PSOLID, MAT1, LOADCASE, LOAD, FORCE, SPC, SPC1, STRESS, DISPLACEMENT

Special Features Used:

NONE. This example shows how to assemble a brick using CPENTA elements.

Problem Statement:

Find the tip displacements and the stresses at the root of a cantilever rod loaded in its free end with a tension load of 4800 lb.

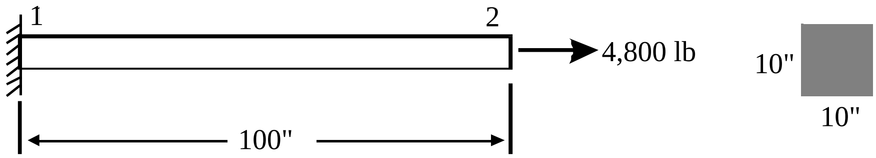


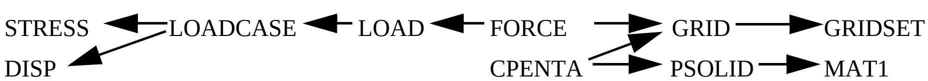
Figure 2-18

Structural Data Relationships:

1. Tridimensional model of the rod assembled with 10 CPENTA elements.
2. Material: E=1.0E+7psi.
3. One Load cases: P=4800lb.

The stresses for solid elements are printed out in the material coordinate system. In this case the material coordinate system is the basic coordinate system (the default). Other coordinate systems can be used as the material coordinate system. See the description of the PSOLID element in Volume II for more details.

Analysis Data Relationships:



In this example the solution control commands SET 5=21,22,23,24 and SET 6=1,2,3,4,5,6 were used to limit the output.

Special Modeling Techniques:

It is important to correctly model the boundary conditions. In this problem the structure is globally prevented from moving in the six rigid body degrees of freedom at the fixed boundary. Please note that if all four boundary nodes (1, 2, 3 and 4) are fully constrained, slightly different answers will be obtained. Also it is important to load the structure with the correct consistent load vector (i.e., if the structure is loaded with 4 loads of 1200 lb in each of the free end corners, incorrect answers will be obtained).

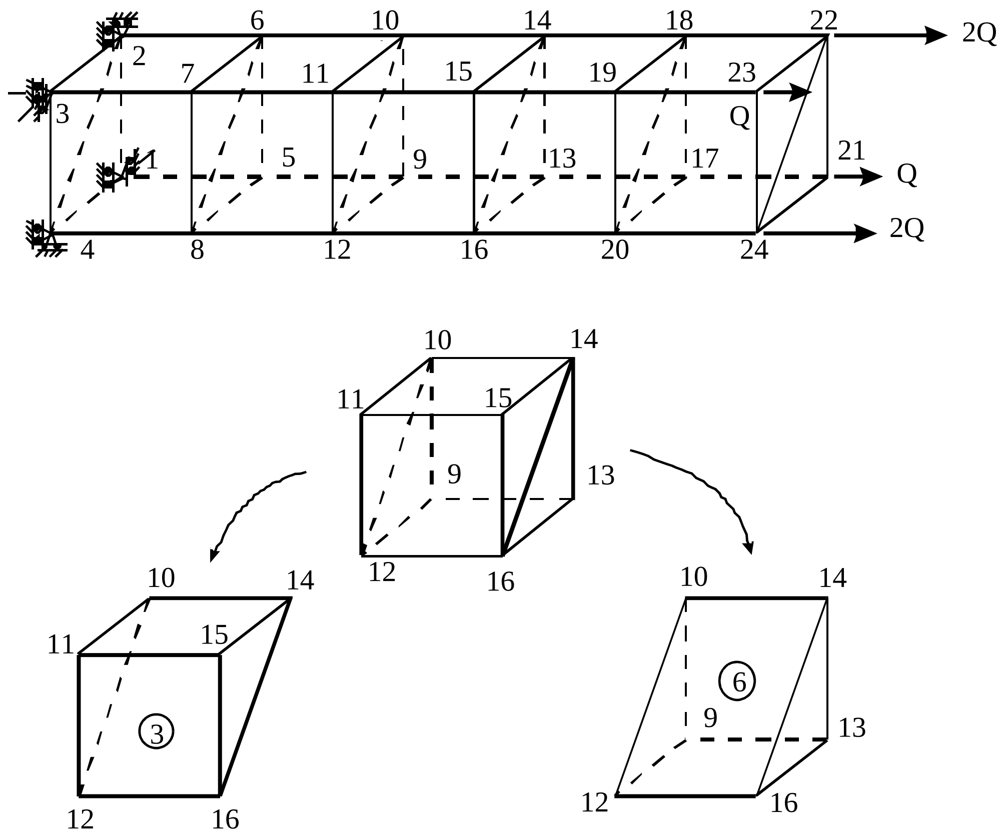


Figure 2-19

Reference Solution:

The analytical solution for this problem is:

$$U_x = \frac{PL}{EA} = 0.00048 \text{ IN}$$

$$\sigma = \frac{P}{A} = 48 \text{ psi}$$

where: P is the applied load, E is the Young's modulus, A the area and L is the total length of the beam.

Calculated Solution:

The *GENESISGENESIS* solution is:

$$U_x = 0.00048 \text{ IN}$$

$$\sigma = \frac{P}{A} = 48 \text{ psi}$$

Comparison Between Calculated Solution and Reference:

There are no differences between the analytical solution and the *GENESIS* solution.

2.16.1 Input Data

```
ID A016
SOL COMPAT1
CEND
TITLE = TENSION ROD ASSEMBLED WITH PENTA ELEMENTS
LINE=64,80
SET 5=21,22,23,24
SET 6=1,2,3,4,5,6
LOADCASE 1
        LOAD = 42
        FORCE = ALL
        SPC=77
        DISPLACEMENT=5
        STRESS=6
$
BEGIN BULK
$
$     BOUNDARY CONDITIONS
$
SPC1    77      12      1
SPC1    77      13      2
SPC1    77      12      3
SPC1    77      13      4
$
$     GRID POINTS
$
GRID    1               0.0     10.     0.0
GRID    2               0.0     10.     10.0
GRID    3               0.0     0.0     10.0
GRID    4               0.0     0.0     0.0
$
GRID    5               20.0    10.     0.0
GRID    6               20.0    10.     10.0
GRID    7               20.0    0.0     10.0
GRID    8               20.0    0.0     0.0
$
GRID    9               40.0    10.     0.0
GRID    10              40.0    10.     10.0
GRID    11              40.0    0.0     10.0
GRID    12              40.0    0.0     0.0
$
GRID    13              60.0    10.     0.0
GRID    14              60.0    10.     10.0
GRID    15              60.0    0.0     10.0
GRID    16              60.0    0.0     0.0
$
GRID    17              80.0    10.     0.0
GRID    18              80.0    10.     10.0
GRID    19              80.0    0.0     10.0
GRID    20              80.0    0.0     0.0
$
GRID    21              100.0   10.     0.0
GRID    22              100.0   10.     10.0
```

```
GRID    23              100.0   0.0     10.0
GRID    24              100.0   0.0     0.0
$
$     ELEMENT DEFINITIONS
$
CPENTA  1       1       2       3       4       6       7       8
CPENTA  3       1       6       7       8       10      11      12
CPENTA  5       1       10      11      12      14      15      16
CPENTA  7       1       14      15      16      18      19      20
CPENTA  9       1       18      19      20      22      23      24
$
CPENTA  2       1       4       1       2       8       5       6
CPENTA  4       1       8       5       6       12      9       10
CPENTA  6       1       12      9       10      16      13      14
CPENTA  8       1       16      13      14      20      17      18
CPENTA  10      1       20      17      18      24      21      22
$
$     PROPERTY DEFINITIONS
$
PSOLID  1       51
$
$     MATERIAL DEFINITIONS
$
MAT1    51      10.0E6          0.3
$
$     LOAD DEFINITIONS
$
FORCE   42      21              800.0   1.0     0.0     0.0
FORCE   42      22              1600.0  1.0     0.0     0.0
FORCE   42      23              800.0   1.0     0.0     0.0
FORCE   42      24              1600.0  1.0     0.0     0.0
$
ENDDATA
```

2.16.2 Output

```
1








                 GGGG     EEEEE    N   N    EEEEE     SSSSS    IIIII     SSSSS
                G         E        NN  N    E        S           I      S
                G   GG    EEEE     N N N    EEEE      SSSS       I       SSSS
                G    G    E        N  NN    E             S      I           S
                 GGGG     EEEEE    N   N    EEEEE    SSSSS     IIIII    SSSSS


                       STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE



                                    COPYRIGHT, 1991-2002

                          VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                               ALL RIGHTS RESERVED, WORLDWIDE

                                        VERSION 7.2

                                   BUILD CODE 200212131048




     PROJECT NAME: A016
     RUN STARTED:  Dec 13, 2002 12:49
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    1
 TENSION ROD ASSEMBLED WITH PENTA ELEMENTS


                                   ANALYSIS PROBLEM SUMMARY

                    NUMBER OF GRID POINTS:                    24
                    NUMBER OF CPENTA ELEMENTS:                10
                    TOTAL NUMBER OF NON RIGID ELEMENTS:       10
```

```
                NUMBER OF ELEMENT PROPERTIES:              1
                NUMBER OF MATERIALS:                       1
                NUMBER OF DEGREES OF FREEDOM:             64


                            LOAD CASES SUMMARY

               NUMBER OF STATIC LOAD CASES:                     1
               TOTAL NUMBER OF LOAD CASES:                      1

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    2
 TENSION ROD ASSEMBLED WITH PENTA ELEMENTS


              *********************************************
              *  D E S I G N  C Y C L E     0 (ANALYSIS)*
              *********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    3
 TENSION ROD ASSEMBLED WITH PENTA ELEMENTS


                    M A S S / V O L U M E   S U M M A R Y

                    SYSTEM MASS              0.000000E+00
                    SYSTEM VOLUME            1.000000E+04
                    SYSTEM MASS/VOLUME       0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    4
 TENSION ROD ASSEMBLED WITH PENTA ELEMENTS


                S O L U T I O N   R E S I D U A L S

 LOADCASE        1 ; RESIDUAL :  1.162389E-14 ; STRAIN ENERGY :  1.152000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    5
 TENSION ROD ASSEMBLED WITH PENTA ELEMENTS


                 O L O A D   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1  4.8000E+03  0.0000E+00  0.0000E+00  0.0000E+00  2.4000E+04 -2.4000E+04
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    6
 TENSION ROD ASSEMBLED WITH PENTA ELEMENTS


                S P C F O R C E   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1 -4.8000E+03  4.8885E-12  6.3345E-12  2.6326E-11 -2.4000E+04  2.4000E+04
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    7
 TENSION ROD ASSEMBLED WITH PENTA ELEMENTS
```

```
              M A X I M U M   A P P L I E D   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1           T2           T3

      1       22     1.6000E+03  1.6000E+03  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    8
 TENSION ROD ASSEMBLED WITH PENTA ELEMENTS


                  M A X I M U M   S P C   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1           T2           T3

      1        4     1.6000E+03 -1.6000E+03  5.9716E-13 -1.1340E-07
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    9
 TENSION ROD ASSEMBLED WITH PENTA ELEMENTS


                 M A X I M U M   D I S P L A C E M E N T

 LOADCASE GRID ID      MAGNITUDE      T1           T2           T3

      1       23     4.8022E-04  4.8000E-04  2.4490E-14 -1.4400E-05
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   10
 TENSION ROD ASSEMBLED WITH PENTA ELEMENTS

                                                                 LOADCASE         1

                     G R I D   D I S P L A C E M E N T S

  GRID ID            T1                 T2                 T3
                     R1                 R2                 R3

       21      4.800000E-04     -2.422770E-14      1.440000E-05
               0.000000E+00      0.000000E+00      0.000000E+00

       22      4.800000E-04     -1.440000E-05      5.115088E-15
               0.000000E+00      0.000000E+00      0.000000E+00

       23      4.800000E-04      2.448960E-14     -1.440000E-05
               0.000000E+00      0.000000E+00      0.000000E+00

       24      4.800000E-04      1.440000E-05     -4.959690E-15
               0.000000E+00      0.000000E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   11
 TENSION ROD ASSEMBLED WITH PENTA ELEMENTS

                                                                 LOADCASE         1

            S T R E S S E S   I N   P E N T A   E L E M E N T S

 PENTA ID        NORMAL            SHEAR            PRINCIPAL
                 VON MISES         OCTAHEDRAL       MAX SHEAR        PRESSURE
```

```
     1  X  4.800000E+01  XY -6.895663E-09  1  4.800000E+01
        Y -1.695472E-09  YZ  1.190896E-09  2  1.395897E-10
        Z  1.395897E-10  ZX  6.570976E-09  3 -1.695472E-09
           4.800000E+01      2.262742E+01     2.400000E+01    -1.600000E+01

     2  X  4.800000E+01  XY  6.895747E-09  1  4.800000E+01
        Y -1.696007E-09  YZ  1.190805E-09  2  1.396039E-10
        Z  1.396039E-10  ZX -6.570875E-09  3 -1.696007E-09
           4.800000E+01      2.262742E+01     2.400000E+01    -1.600000E+01

     3  X  4.800000E+01  XY  9.713318E-09  1  4.800000E+01
        Y  3.494018E-09  YZ -1.768138E-09  2  3.494018E-09
        Z  1.725656E-09  ZX -9.432481E-09  3  1.725656E-09
           4.800000E+01      2.262742E+01     2.400000E+01    -1.600000E+01

     4  X  4.800000E+01  XY -9.713227E-09  1  4.800000E+01
        Y  3.493644E-09  YZ -1.768237E-09  2  3.493644E-09
        Z  1.725653E-09  ZX  9.432581E-09  3  1.725653E-09
           4.800000E+01      2.262742E+01     2.400000E+01    -1.600000E+01

     5  X  4.800000E+01  XY -1.660786E-08  1  4.800000E+01
        Y -6.780555E-09  YZ  3.142942E-09  2 -3.710976E-09
        Z -3.710976E-09  ZX  1.620281E-08  3 -6.780555E-09
           4.800000E+01      2.262742E+01     2.400000E+01    -1.600000E+01

     6  X  4.800000E+01  XY  1.660801E-08  1  4.800000E+01
        Y -6.780787E-09  YZ  3.142863E-09  2 -3.711008E-09
        Z -3.711008E-09  ZX -1.620275E-08  3 -6.780787E-09
           4.800000E+01      2.262742E+01     2.400000E+01    -1.600000E+01

1                            ***** END OF OUTPUT *****
```

2.17 Anisotropic Plate with Thermal Load - A

Example ID:

A017

Analysis Data Used:

GRID, CQUAD4, PSHELL, MAT8, LOADCASE, TEMP, TEMPD, SPC, SPC, SPC1, FORCE, STRESS, STRAIN, DISP

Special Features Used:

Utilization of orthotropic material MAT8

Problem Statement:

Find the elements forces, stresses and strains of the anisotropic plate shown in **Figure 2-20**. The plate has its four sides clamped and the material is orthotropic with its principal axis rotated in 21.7 degrees from the element coordinate system.

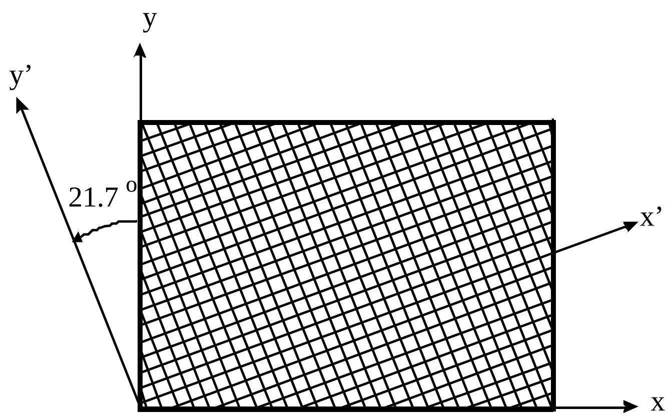
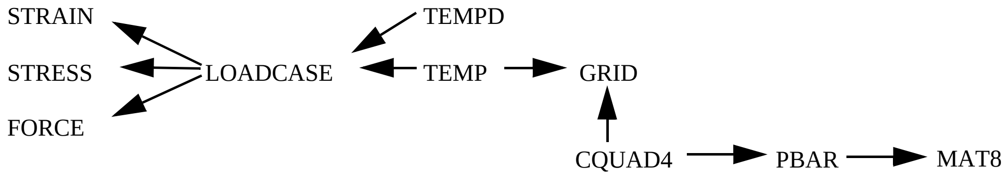


Figure 2-20

Structural Analysis Model:

1. Plate assembled with 4 CQUAD4 elements.
2. Section properties of the plate: thickness=2.0.
3. Material: E1=7.8E6, E2=2.6E6, ν_{12}=0.25, G=1.3E6, A1=3.5E-6, A2=11.4E-6, A3=0.0 (Data is in the material coordinate system).
4. One temperature Load case: T-T0=20.0 degrees.

Analysis Data Relationships:



Special Modeling Techniques:

NONE.

Reference Solutions:

The analytical solution for this problem can be obtained by using the stress-strain relationship in the element coordinate system.
The strains are zero because the plate is constrained to move.
Stresses:

$$\sigma_x = -701.2$$

$$\sigma_y = -659.7$$

$$\tau_{xy} = -19.6$$

Element forces:

$$N_x = 2.0\sigma_x = -1402.3$$

$$N_y = 2.0\sigma_y = -1319.4$$

$$N_{xy} = 2.0\tau_{xy} = -39.2$$

Calculated Solutions:

$$\varepsilon_{xx} = \varepsilon_{yy} = \gamma_{xy} = 0.0$$

$$\sigma_x = -701.2$$

$$\sigma_y = -659.7$$

$$\tau_{xy} = -19.6$$

$$N_x = -1402.3$$

$$N_y = -1319.4$$

$$N_{xy} = -39.2$$

Comparison Between Calculated Solutions and Reference Solutions:

There are no differences between the analytical solutions and the *GENESIS* solutions.

2.17.1 Input Data

```
ID A017
SOL COMPAT1
CEND
TITLE=ANISOTROPIC PLANTE WITH TEMPERATURE LOAD-I
SUBTITLE=USE OF MAT8
ECHO=NONE
LINE=64,80
LOADCASE 1
        TEMP = 1
        STRESS=ALL
        STRAIN=ALL
        FORCE=ALL
$
BEGIN BULK
$
$     GRID POINTS
$
GRID    1               0.0     0.0     0.0             123456
GRID    2               10.0    0.0     0.0             123456
GRID    3               20.0    0.0     0.0             123456
$
GRID    12              0.0     0.0     5.0             123456
GRID    13              10.0    0.0     5.0
GRID    14              20.0    0.0     5.0             123456
$
GRID    23              0.0     0.0     10.0            123456
GRID    24              10.0    0.0     10.0            123456
GRID    25              20.0    0.0     10.0            123456
$
$     ELEMENT DEFINITIONS
$
CQUAD4  1       1       1       2       13      12      21.7
CQUAD4  2       1       2       3       14      13      21.7
CQUAD4  3       1       12      13      24      23      21.7
CQUAD4  4       1       13      14      25      24      21.7
$
$     PROPERTY DEFINITIONS
$
PSHELL  1       1       2.0     1                               0.0
$
$     MATERIAL DEFINITIONS
$
MAT8    1       7.8+6   2.6+6   0.25    1.3+6
+       3.50-6  11.40-6 80.0
$
$    TEMPERATURE DEFINITION
$
TEMPD   1       100.0
$
ENDDATA
```

2.17.2 Output

```
1

               GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
              G        E       NN  N   E       S          I     S
              G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
              G    G   E       N  NN   E            S     I          S
               GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                  STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                              COPYRIGHT, 1991-2002

                    VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                         ALL RIGHTS RESERVED, WORLDWIDE

                                  VERSION 7.2

                           BUILD CODE 200212131048



     PROJECT NAME: A017
     RUN STARTED:  Dec 13, 2002 12:49
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    1
 ANISOTROPIC PLANTE WITH TEMPERATURE LOAD-I
 USE OF MAT8

                            ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                      9
                   NUMBER OF CQUAD4->PSHELL ELEMENTS:          4
                   TOTAL NUMBER OF NON RIGID ELEMENTS:         4
```

```
                    NUMBER OF ELEMENT PROPERTIES:              1
                    NUMBER OF MATERIALS:                       1
                    NUMBER OF DEGREES OF FREEDOM:              6


                            LOAD CASES SUMMARY

                   NUMBER OF STATIC LOAD CASES:                  1
                   TOTAL NUMBER OF LOAD CASES:                   1

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    2
 ANISOTROPIC PLANTE WITH TEMPERATURE LOAD-I
 USE OF MAT8

               ********************************************
               *  D E S I G N  C Y C L E      0 (ANALYSIS)*
               ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    3
 ANISOTROPIC PLANTE WITH TEMPERATURE LOAD-I
 USE OF MAT8

                    M A S S / V O L U M E   S U M M A R Y

                    SYSTEM MASS              0.000000E+00
                    SYSTEM VOLUME            4.000000E+02
                    SYSTEM MASS/VOLUME       0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    4
 ANISOTROPIC PLANTE WITH TEMPERATURE LOAD-I
 USE OF MAT8

                   S O L U T I O N    R E S I D U A L S

 LOADCASE        1 ; RESIDUAL : -1.999995E+00 ; STRAIN ENERGY :  2.512098E-32
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    5
 ANISOTROPIC PLANTE WITH TEMPERATURE LOAD-I
 USE OF MAT8

                     O L O A D    R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1  0.0000E+00  0.0000E+00  1.8190E-12  0.0000E+00 -4.3656E-11  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    6
 ANISOTROPIC PLANTE WITH TEMPERATURE LOAD-I
 USE OF MAT8

                   S P C F O R C E    R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1  0.0000E+00  0.0000E+00 -4.5475E-12  0.0000E+00  5.8208E-11  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    7
 ANISOTROPIC PLANTE WITH TEMPERATURE LOAD-I
 USE OF MAT8
```

```
                M A X I M U M   A P P L I E D   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

       1       13     9.0949E-13  0.0000E+00  0.0000E+00  9.0949E-13
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    8
 ANISOTROPIC PLANTE WITH TEMPERATURE LOAD-I
 USE OF MAT8

                    M A X I M U M   S P C   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

       1       24     1.3200E+04 -3.9225E+02  0.0000E+00 -1.3194E+04
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE    9
 ANISOTROPIC PLANTE WITH TEMPERATURE LOAD-I
 USE OF MAT8

                   M A X I M U M   D I S P L A C E M E N T

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

       1       13     5.6171E-20 -1.0177E-20  0.0000E+00  5.5241E-20
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   10
 ANISOTROPIC PLANTE WITH TEMPERATURE LOAD-I
 USE OF MAT8
                                                                LOADCASE        1

                  F O R C E S   I N   Q U A D 4   E L E M E N T S

 QUAD4 ID        - NX -           - NY -          - NXY -
                 - MX -           - MY -          - MXY -

        1   -1.402331E+03   -1.319371E+03   -3.922539E+01
             0.000000E+00    0.000000E+00    0.000000E+00

        2   -1.402331E+03   -1.319371E+03   -3.922539E+01
             0.000000E+00    0.000000E+00    0.000000E+00

        3   -1.402331E+03   -1.319371E+03   -3.922539E+01
             0.000000E+00    0.000000E+00    0.000000E+00

        4   -1.402331E+03   -1.319371E+03   -3.922539E+01
             0.000000E+00    0.000000E+00    0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   11
 ANISOTROPIC PLANTE WITH TEMPERATURE LOAD-I
 USE OF MAT8
                                                                LOADCASE        1

              S T R E S S E S   I N   Q U A D 4   E L E M E N T S

 QUAD4 ID  SURFACE  MAX SHEAR      VON MISES       MAJOR          MINOR
                     SIGMA X        SIGMA Y        TAU XY
```

```
       1     1    2.854468E+01   6.822194E+02  -6.518809E+02  -7.089702E+02
                 -7.011654E+02  -6.596857E+02  -1.961269E+01
             2    2.854468E+01   6.822194E+02  -6.518809E+02  -7.089702E+02
                 -7.011654E+02  -6.596857E+02  -1.961269E+01

       2     1    2.854468E+01   6.822194E+02  -6.518809E+02  -7.089702E+02
                 -7.011654E+02  -6.596857E+02  -1.961269E+01
             2    2.854468E+01   6.822194E+02  -6.518809E+02  -7.089702E+02
                 -7.011654E+02  -6.596857E+02  -1.961269E+01

       3     1    2.854468E+01   6.822194E+02  -6.518809E+02  -7.089702E+02
                 -7.011654E+02  -6.596857E+02  -1.961269E+01
             2    2.854468E+01   6.822194E+02  -6.518809E+02  -7.089702E+02
                 -7.011654E+02  -6.596857E+02  -1.961269E+01

       4     1    2.854468E+01   6.822194E+02  -6.518809E+02  -7.089702E+02
                 -7.011654E+02  -6.596857E+02  -1.961269E+01
             2    2.854468E+01   6.822194E+02  -6.518809E+02  -7.089702E+02
                 -7.011654E+02  -6.596857E+02  -1.961269E+01

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:49  PAGE   12
 ANISOTROPIC PLANTE WITH TEMPERATURE LOAD-I
 USE OF MAT8
                                                           LOADCASE         1

                 S T R A I N S   I N   Q U A D 4   E L E M E N T S

 QUAD4 ID  SURFACE   MAX SHEAR     VON MISES      MAJOR        MINOR
                     EPSILON X     EPSILON Y     GAMMA XY
                    (EPSILON-X)   (EPSILON-Y)   (GAMMA-XY)    (KAPPA-X)
                     (KAPPA-Y)    (KAPPA-XY)

       1    1      6.27271E-21   3.98814E-21   5.64168E-21  -6.31026E-22
                  -5.07315E-22   5.51797E-21   1.74435E-21
            2      6.27271E-21   3.98814E-21   5.64168E-21  -6.31026E-22
                  -5.07315E-22   5.51797E-21   1.74435E-21
            0    (-5.07315E-22)( 5.51797E-21)( 1.74435E-21)( 0.00000E+00)
                 ( 0.00000E+00)( 0.00000E+00)

       2    1      6.28629E-21   4.15004E-21   6.16196E-21  -1.24326E-22
                   5.07315E-22   5.53032E-21  -3.77979E-21
            2      6.28629E-21   4.15004E-21   6.16196E-21  -1.24326E-22
                   5.07315E-22   5.53032E-21  -3.77979E-21
            0    ( 5.07315E-22)( 5.53032E-21)(-3.77979E-21)( 0.00000E+00)
                 ( 0.00000E+00)( 0.00000E+00)

       3    1      6.27396E-21   4.14232E-21   1.22792E-22  -6.15117E-21
                  -5.10403E-22  -5.51797E-21   3.77979E-21
            2      6.27396E-21   4.14232E-21   1.22792E-22  -6.15117E-21
                  -5.10403E-22  -5.51797E-21   3.77979E-21
            0    (-5.10403E-22)(-5.51797E-21)( 3.77979E-21)( 0.00000E+00)
                 ( 0.00000E+00)( 0.00000E+00)

       4    1      6.28754E-21   3.99721E-21   6.33810E-22  -5.65373E-21
```

```
                 5.10403E-22  -5.53032E-21  -1.74435E-21
          2      6.28754E-21   3.99721E-21   6.33810E-22  -5.65373E-21
                 5.10403E-22  -5.53032E-21  -1.74435E-21
          0    ( 5.10403E-22)(-5.53032E-21)(-1.74435E-21)( 0.00000E+00)
               ( 0.00000E+00)( 0.00000E+00)

1                            ***** END OF OUTPUT *****
```

2.18 Anisotropic Plate with Thermal Load - B

Example ID:

A018

Analysis Data Used:

GRID, CQUAD4, PSHELL, MAT2, LOADCASE, TEMP, TEMPD, SPC, SPC, SPC1, FORCE, STRESS, STRAIN, DISP

Special Features Used:

Utilization of anisotropic material MAT2.

Problem Statement:

Find the elements forces, stresses and strains of the anisotropic plate shown in **Figure 2-21**. The plate has its four sides clamped and the material is orthotropic with principal axis rotated in 21.7 degrees from the element coordinate system. The mechanical properties are given below and are in the element coordinate system.

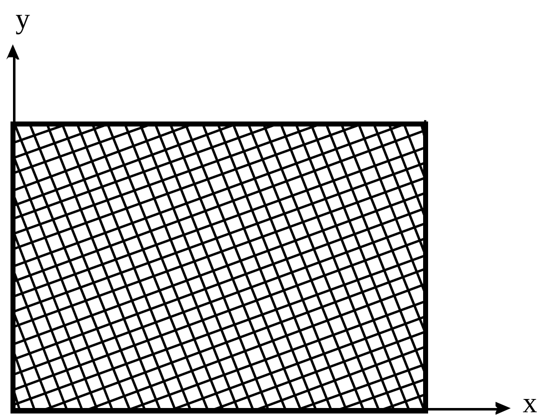
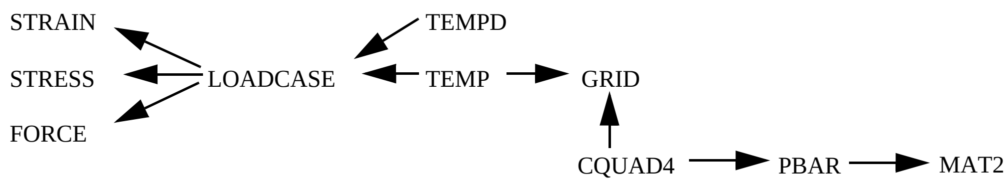


Figure 2-21

Structural Analysis Model:

1. Plate assembled with 4 CQUAD4 elements.
2. Section properties of plate: thickness=2.0.
3. Material:
   G11=6.756E6, G12=1.147E6, G13=1.423E6
   G22=2.898E6, G23=4.013E5, G33=1.783E6
   A1=4.58E-6, A2=10.32E-6, A12=-5.428E-6
   (Data is in the element coordinate system and corresponds to the orthotropic material used in A017.)
4. One temperature Load case: T-T0=20.0 degrees.

Analysis Data Relationships:



Special Modeling Techniques:

NONE. Since the mechanical properties of the plate are given in the element coordinate system, the angle 21.7 should not be included in the CQUAD4 data.

Reference Solutions:

Same as problem **A017**.

Calculated Solutions:

$$\varepsilon_{xx} = \varepsilon_{yy} = \gamma_{xy} = 0.0$$

$$\sigma_x = -701.2$$

$$\sigma_y = -659.7$$

$$\tau_{xy} = -19.6$$

$$N_x = -1402.3$$

$$N_y = -1319.4$$

$$N_{xy} = -39.2$$

Comparison Between Calculated Solutions and Reference Solutions:

There is no difference between the analytical solutions and the *GENESIS* solutions.

2.18.1 Input Data

```
ID A018
SOL COMPAT1
CEND
TITLE=ANISOTROPIC PLANTE WITH TEMPERATURE LOAD-II
SUBTITLE=USE OF MAT2
ECHO=NONE
LINE=64,80
LOADCASE 1
        TEMP = 1
        STRESS=ALL
        STRAIN=ALL
        FORCE=ALL
$
BEGIN BULK
$
$     GRID POINTS
$
GRID    1               0.0     0.0     0.0             123456
GRID    2               10.0    0.0     0.0             123456
GRID    3               20.0    0.0     0.0             123456
$
GRID    12              0.0     0.0     5.0             123456
GRID    13              10.0    0.0     5.0
GRID    14              20.0    0.0     5.0             123456
$
GRID    23              0.0     0.0     10.0            123456
GRID    24              10.0    0.0     10.0            123456
GRID    25              20.0    0.0     10.0            123456
$
$     ELEMENT DEFINITIONS
$
CQUAD4  1       1       1       2       13      12
CQUAD4  2       1       2       3       14      13
CQUAD4  3       1       12      13      24      23
CQUAD4  4       1       13      14      25      24
$
$     PROPERTY DEFINITIONS
$
PSHELL  1       1       2.0     1                               0.0
$
$     MATERIAL DEFINITIONS
$
$1------2-------3-------4-------5-------6-------7-------8-------9
MAT2    1       6756788.1146968.1423123.2898213.401314. 1783138.
+       4.58-6  10.32-6 -5.428-6 80.0.0
$
$    TEMPERATURE DEFINITION
$
TEMPD   1       100.0
$
ENDDATA
```

2.18.2 Output

```
1

  GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
 G        E       NN  N   E       S          I     S
 G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
 G    G   E       N  NN   E            S     I          S
  GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


      STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                 COPYRIGHT, 1991-2002

     VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

          ALL RIGHTS RESERVED, WORLDWIDE

                    VERSION 7.2

              BUILD CODE 200212131048



     PROJECT NAME: A018
     RUN STARTED:  Dec 13, 2002 12:50
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    1
 ANISOTROPIC PLANTE WITH TEMPERATURE LOAD-II
 USE OF MAT2

                               ANALYSIS PROBLEM SUMMARY

                    NUMBER OF GRID POINTS:                      9
                    NUMBER OF CQUAD4->PSHELL ELEMENTS:          4
                    TOTAL NUMBER OF NON RIGID ELEMENTS:         4
```

```
                    NUMBER OF ELEMENT PROPERTIES:              1
                    NUMBER OF MATERIALS:                       1
                    NUMBER OF DEGREES OF FREEDOM:              6


                                LOAD CASES SUMMARY

                   NUMBER OF STATIC LOAD CASES:                  1
                   TOTAL NUMBER OF LOAD CASES:                   1

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    2
 ANISOTROPIC PLANTE WITH TEMPERATURE LOAD-II
 USE OF MAT2

              ********************************************
              *  D E S I G N  C Y C L E      0 (ANALYSIS)*
              ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    3
 ANISOTROPIC PLANTE WITH TEMPERATURE LOAD-II
 USE OF MAT2

                    M A S S / V O L U M E   S U M M A R Y

                    SYSTEM MASS              0.000000E+00
                    SYSTEM VOLUME            4.000000E+02
                    SYSTEM MASS/VOLUME       0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    4
 ANISOTROPIC PLANTE WITH TEMPERATURE LOAD-II
 USE OF MAT2

                   S O L U T I O N    R E S I D U A L S

 LOADCASE        1 ; RESIDUAL : -1.999665E+00 ; STRAIN ENERGY :  2.512512E-32
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    5
 ANISOTROPIC PLANTE WITH TEMPERATURE LOAD-II
 USE OF MAT2

                     O L O A D   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1  0.0000E+00  0.0000E+00 -9.0949E-13  0.0000E+00 -4.3656E-11  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    6
 ANISOTROPIC PLANTE WITH TEMPERATURE LOAD-II
 USE OF MAT2

                   S P C F O R C E   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1  0.0000E+00  0.0000E+00 -1.8190E-12  0.0000E+00  1.4552E-11  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    7
 ANISOTROPIC PLANTE WITH TEMPERATURE LOAD-II
 USE OF MAT2
```

```
              M A X I M U M   A P P L I E D   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1       13     9.0949E-13  0.0000E+00  0.0000E+00  9.0949E-13
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    8
 ANISOTROPIC PLANTE WITH TEMPERATURE LOAD-II
 USE OF MAT2

                  M A X I M U M   S P C   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1        2     1.3200E+04  3.9224E+02  0.0000E+00  1.3194E+04
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    9
 ANISOTROPIC PLANTE WITH TEMPERATURE LOAD-II
 USE OF MAT2

                 M A X I M U M   D I S P L A C E M E N T

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1       13     5.6171E-20 -1.0177E-20  0.0000E+00  5.5241E-20
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   10
 ANISOTROPIC PLANTE WITH TEMPERATURE LOAD-II
 USE OF MAT2
                                                              LOADCASE        1

                 F O R C E S   I N   Q U A D 4   E L E M E N T S

 QUAD4 ID       - NX -          - NY -         - NXY -
                - MX -          - MY -         - MXY -

       1   -1.402323E+03   -1.319374E+03   -3.922363E+01
            0.000000E+00    0.000000E+00    0.000000E+00

       2   -1.402323E+03   -1.319374E+03   -3.922363E+01
            0.000000E+00    0.000000E+00    0.000000E+00

       3   -1.402323E+03   -1.319374E+03   -3.922363E+01
            0.000000E+00    0.000000E+00    0.000000E+00

       4   -1.402323E+03   -1.319374E+03   -3.922363E+01
            0.000000E+00    0.000000E+00    0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   11
 ANISOTROPIC PLANTE WITH TEMPERATURE LOAD-II
 USE OF MAT2
                                                              LOADCASE        1

             S T R E S S E S   I N   Q U A D 4   E L E M E N T S

 QUAD4 ID  SURFACE  MAX SHEAR      VON MISES       MAJOR          MINOR
                     SIGMA X        SIGMA Y        TAU XY
```

```
       1     1    2.854236E+01   6.822178E+02  -6.518819E+02  -7.089666E+02
                 -7.011617E+02  -6.596868E+02  -1.961182E+01
             2    2.854236E+01   6.822178E+02  -6.518819E+02  -7.089666E+02
                 -7.011617E+02  -6.596868E+02  -1.961182E+01

       2     1    2.854236E+01   6.822178E+02  -6.518819E+02  -7.089666E+02
                 -7.011617E+02  -6.596868E+02  -1.961182E+01
             2    2.854236E+01   6.822178E+02  -6.518819E+02  -7.089666E+02
                 -7.011617E+02  -6.596868E+02  -1.961182E+01

       3     1    2.854236E+01   6.822178E+02  -6.518819E+02  -7.089666E+02
                 -7.011617E+02  -6.596868E+02  -1.961182E+01
             2    2.854236E+01   6.822178E+02  -6.518819E+02  -7.089666E+02
                 -7.011617E+02  -6.596868E+02  -1.961182E+01

       4     1    2.854236E+01   6.822178E+02  -6.518819E+02  -7.089666E+02
                 -7.011617E+02  -6.596868E+02  -1.961182E+01
             2    2.854236E+01   6.822178E+02  -6.518819E+02  -7.089666E+02
                 -7.011617E+02  -6.596868E+02  -1.961182E+01

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   12
 ANISOTROPIC PLANTE WITH TEMPERATURE LOAD-II
 USE OF MAT2
                                                             LOADCASE         1

                  S T R A I N S   I N   Q U A D 4   E L E M E N T S

 QUAD4 ID  SURFACE   MAX SHEAR     VON MISES      MAJOR        MINOR
                     EPSILON X     EPSILON Y     GAMMA XY
                    (EPSILON-X)   (EPSILON-Y)   (GAMMA-XY)    (KAPPA-X)
                     (KAPPA-Y)    (KAPPA-XY)

       1    1      6.22081E-21   3.95641E-21   5.59952E-21  -6.21292E-22
                  -4.96507E-22   5.47474E-21   1.74435E-21
            2      6.22081E-21   3.95641E-21   5.59952E-21  -6.21292E-22
                  -4.96507E-22   5.47474E-21   1.74435E-21
            0    (-4.96507E-22)( 5.47474E-21)( 1.74435E-21)( 0.00000E+00)
                 ( 0.00000E+00)( 0.00000E+00)

       2    1      6.32955E-21   4.17713E-21   6.19981E-21  -1.29745E-22
                   4.96507E-22   5.57355E-21  -3.77979E-21
            2      6.32955E-21   4.17713E-21   6.19981E-21  -1.29745E-22
                   4.96507E-22   5.57355E-21  -3.77979E-21
            0    ( 4.96507E-22)( 5.57355E-21)(-3.77979E-21)( 0.00000E+00)
                 ( 0.00000E+00)( 0.00000E+00)

       3    1      6.23091E-21   4.11534E-21   1.17481E-22  -6.11343E-21
                  -5.21212E-22  -5.47474E-21   3.77979E-21
            2      6.23091E-21   4.11534E-21   1.17481E-22  -6.11343E-21
                  -5.21212E-22  -5.47474E-21   3.77979E-21
            0    (-5.21212E-22)(-5.47474E-21)( 3.77979E-21)( 0.00000E+00)
                 ( 0.00000E+00)( 0.00000E+00)

       4    1      6.33948E-21   4.02896E-21   6.43566E-22  -5.69591E-21
```

```
                5.21212E-22  -5.57355E-21  -1.74435E-21
         2      6.33948E-21   4.02896E-21   6.43566E-22  -5.69591E-21
                5.21212E-22  -5.57355E-21  -1.74435E-21
         0    ( 5.21212E-22)(-5.57355E-21)(-1.74435E-21)( 0.00000E+00)
              ( 0.00000E+00)( 0.00000E+00)

1                          ***** END OF OUTPUT *****
```

2.19 Straight Uniform Fin Analysis

Example ID:

A019

Analysis Data Used:

GRID, CROD, CHBDY (LINE AND POINT), PROD, PHBDY, MAT4, MAT1(DUMMY), LOADCASE, HEAT, SPCD, THERMAL, SPC and SPC1.

Special Features Used:

Convection using boundary elements LINE and POINT.

Problem Statement:

Find the temperature distribution in the fin shown in the figure below. Consider convection through the perimeter and through the tip.

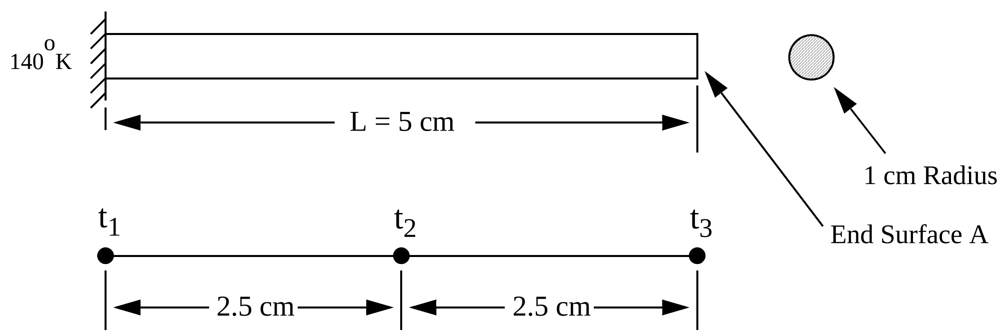


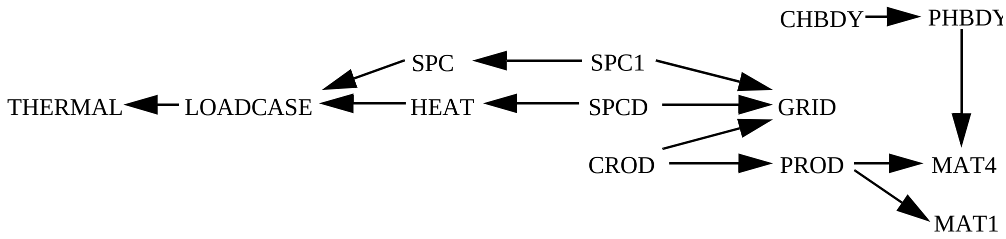
Figure 2-22

Heat Transfer Analysis Model:

1. Fin structure assembled with 2 conductive rod elements and 3 CHBDY boundary elements (2 LINE and 1 POINT).
2. Section properties: Area=3.141592cm^2.
3. Materials:
   - k=70 Watts/cm-^{o}K (conduction)
   - h=5 Watts/cm^2-^{o}K (convection)

   In addition, dummy structural material MAT1 is included in the input data. Structural material data is necessary to run *GENESIS*.
4. One load case: Convection due to an ambient temperature of 40 ^{o}K, and an enforced temperature of 140.0 ^{o}K at the root.

Analysis Data Relationships:



Special Modeling Techniques:

The convection through the perimeter is modeled using two CHBDY (LINE) boundary elements. In this case the AREA FACTOR parameter corresponds to the circular perimeter. The convection through the tip is modeled with one POINT boundary element.

Reference Solutions:

Rao,S.S, "The Finite Element Method In Engineering." Pergamon Press, second edition, page 452. 1989.

Grid	Temperature
1	140.00
2	80.44
3	63.36

Calculated Solutions:.

Grid	Temperature
1	140.00
2	80.45
3	63.32

Comparison Between Calculated Solutions and Reference Solutions:

The calculated solution and the reference solution are very similar. The reason for the small difference is that the number of digits used in both solutions are different.

2.19.1 Input Data

```
ID A019
SOL COMPAT1
CEND
summary=no
TITLE = STRAIGHT UNIFORM FIN ANALYSIS.
LINE=64,80
ECHO=NONE
LOADCASE 1
LABEL=  CONVECTION FIN ANALYSIS USING 1 POINT-CHBDY  & 2 LINE-CHBDYS.
SPC=101
HEAT=101
THERMAL=ALL
$
BEGIN BULK
$
$    HEAT TRANSFER BOUNDARY CONDITIONS
$
SPC1    101             1
SPCD    101     1               140.0
$
$    AMBIENT TEMPERATURE
$
SPC1    101             999
SPCD    101     999             40.0
GRID    999     0       0.0     0.0     3.0
$
$   GRID DATA
$
GRID    1       0       0.0     0.0     0.0     0       123456
GRID    2       0       2.5     0.0     0.0     0       0
GRID    3       0       5.0     0.0     0.0     0       0
$
$   ELEMENT DEFINITIONS
$
CROD    1       22      1       2
CROD    2       22      2       3
CHBDY   11      109     LINE    1       2
+       999     999                     1.0     0.0     0.0
CHBDY   12      109     LINE    2       3
+       999     999                     1.0     0.0     0.0
CHBDY   13      309     POINT   3
+       999                             1.0     0.0     0.0
$
$   PROPERTY DEFINITIONS
$
PROD    22      70      3.141592
PHBDY   109     5       6.283185        1.0
PHBDY   309     5       3.141592        1.0
$
$
$   MATERIAL DATA
$
```

```
MAT1    70      1.0+7           0.30
MAT4    70      70.0
$
MAT1    5       1.0+7           0.30
MAT4    5       5.0
$
ENDDATA
```

2.19.2 Output

```
1





              GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
             G        E       NN  N   E       S          I     S
             G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
             G    G   E       N  NN   E            S     I          S
              GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                  STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                              COPYRIGHT, 1991-2002

                    VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                         ALL RIGHTS RESERVED, WORLDWIDE

                                  VERSION 7.2

                            BUILD CODE 200212131048



     PROJECT NAME: A019
     RUN STARTED:  Dec 13, 2002 12:50
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    1
 STRAIGHT UNIFORM FIN ANALYSIS.


               ********************************************
               *  D E S I G N  C Y C L E     0 (ANALYSIS)*
               ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    2
 STRAIGHT UNIFORM FIN ANALYSIS.
```

```
                    M A S S / V O L U M E   S U M M A R Y

                    SYSTEM MASS              0.000000E+00
                    SYSTEM VOLUME            1.570796E+01
                    SYSTEM MASS/VOLUME       0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    3
 STRAIGHT UNIFORM FIN ANALYSIS.


              H E A T   S O L U T I O N   R E S I D U A L S

 LOADCASE        1 ; RESIDUAL :  0.000000E+00 ;   HEAT ENERGY 8.929663E+05
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    4
 STRAIGHT UNIFORM FIN ANALYSIS.

 CONVECTION FIN ANALYSIS USING 1 POINT-CHBDY  & 2 LINE-CHBDYS LOADCASE        1

                     G R I D   T E M P E R A T U R E S

  GRID ID          TEMP

        1      1.400000E+02
        2      8.044754E+01
        3      6.332257E+01
      999      4.000000E+01
1                           ***** END OF OUTPUT *****
```

2.20 Square Plate With Volume Heat Generation and Enforced Temperature

Example ID:

A020

Analysis Data Used:

GRID, CTRIA3, PSHELL, MAT4, MAT1(DUMMY), LOADCASE, HEAT, QVOL, SPCD, THERMAL, SPC and SPC1.

Special Features Used:

Enforced temperature.

Problem Statement:

Find the temperature distribution in the square plate with uniform energy generation as shown in the figure bellow. Assume there is no variation of the temperature in the z direction. Consider k = 30 watts/cm-^{o}K, L =10.0 cm., T=50^{o}K at boundaries defined by (L,y) and (x,L). Consider Qv = 100 Watt/cm^3.

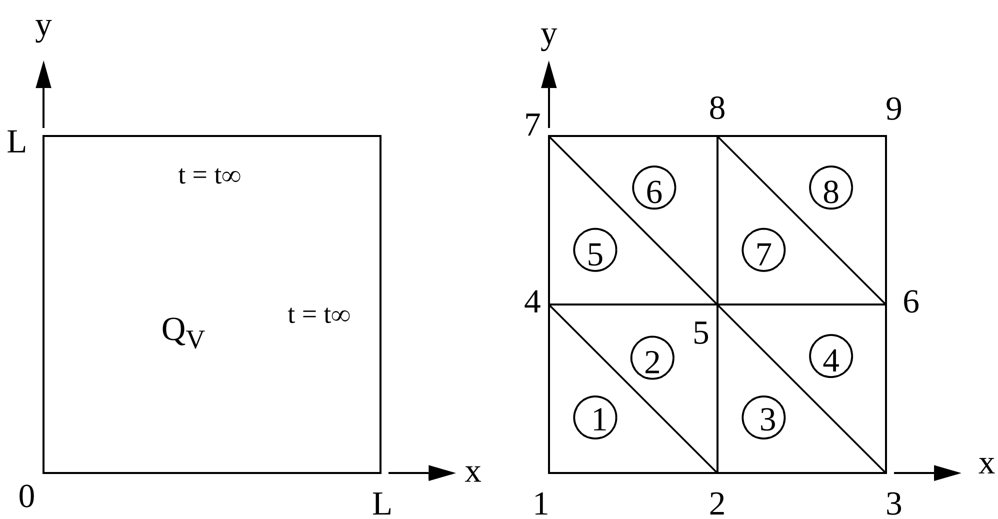


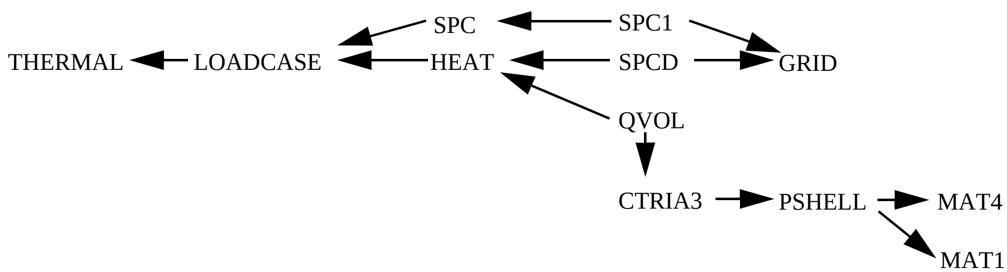
Figure 2-23

Heat Transfer Analysis Model:

1. Plate structure assembled with 8 conductive CTRIA3 elements.
2. Section properties: PSHELL: thickness=1.0 cm.
3. Materials:
   - k=30 Watts/cm-^{o}K (conduction).
   In addition, dummy structural material MAT1 is included in the input data.
   Structural material data is necessary to run *GENESIS*.
4. One load case: Conduction due to volume energy generation Qv=100.0 Watt/cm^3.
   - boundary conditions: enforced temperature T = 50 ^{o}K at (L,y) and (x,L).

The enforced temperature are specified with SPCD data statements. In addition, it is necessary to constrain the corresponding grids. The grids are constrained with SPC1 data statements.

Analysis Data Relationships:



Special Modeling Techniques:

NONE

Reference Solutions:

Rao,S.S, “The Finite Element Method In Engineering Pergamon Press, second edition, page 477. 1989.

Grid ID	Temperature
1	133.3
2	119.4
3	50.0
4	119.4
5	105.6
6	50.0
7	50.0
8	50.0
9	50.0

Calculated Solutions:.

Grid ID	Temperature
1	133.3
2	119.4
3	50.0
4	119.4
5	105.6
6	50.0
7	50.0
8	50.0
9	50.0

Comparison Between Calculated Solution And Reference Solution:

There is no difference between the calculated solution and the reference solution.

2.20.1 Input Data

```
ID A020
SOL COMPAT1
CEND
TITLE= SQUARE PLATE WITH VOLUME HEAT GENERATION AND ENFORCED TEMPERATURE.
LINE=64,80
ECHO=NONE
LOADCASE 1
LABEL= REF. T=(133.3,119.4,50,119.4,105.6,50.0,50.0,50,50.0 CELSIUS)
$    REFERENCE SOLUTION: Rao,S.S, “The Finite Element Method In Eng.”
$                        Pergamon Press,second edition, pag.477. 1989.
     HEAT=200
     SPC=22
     THERMAL=ALL
BEGIN BULK
$
$   BOUNDARY CONDITIONS
$   ENFORCED TEMERATURE DATA
$
SPCD    200     3               50.0
SPCD    200     6               50.0
SPCD    200     7               50.0
SPCD    200     8               50.0
SPCD    200     9               50.0
$
SPC1    22              7       8       9
SPC1    22              3       6
$
$    GRID DATA
$
GRID    1       0       0.      0.      0.0     0
GRID    2       0       5.0     0.      0.0     0
GRID    3       0       10.     0.      0.0     0
GRID    4       0       0.      5.0     0.0     0
GRID    5       0       5.0     5.0     0.0     0
GRID    6       0       10.     5.0     0.0     0
GRID    7       0       0.      10.     0.0     0
GRID    8       0       5.0     10.     0.0     0
GRID    9       0       10.     10.     0.0     0
$
$   ELEMENT DEFINITIONS
$
CTRIA3  1       22      1       2       4
CTRIA3  2       22      4       2       5
CTRIA3  3       22      2       3       5
CTRIA3  4       22      5       3       6
CTRIA3  5       22      4       5       7
CTRIA3  6       22      7       5       8
CTRIA3  7       22      5       6       8
CTRIA3  8       22      8       6       9
$
$   PROPERTY DEFINITIONS
$
```

```
PSHELL  22      33      1.
$
$   MATERIAL DATA
$
MAT1    33      1.0+6           0.25
MAT4    33      30.0
$
$   HEAT TRANSFER LOADS
$
QVOL    200     100.0   1       2       3       4
QVOL    200     100.0   5       6       7       8
$
ENDDATA
```

2.20.2 Output

```
1









                    GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
                   G        E       NN  N   E       S          I     S
                   G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
                   G    G   E       N  NN   E            S     I          S
                    GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                        STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                                    COPYRIGHT, 1991-2002

                          VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                               ALL RIGHTS RESERVED, WORLDWIDE

                                        VERSION 7.2

                                   BUILD CODE 200212131048




     PROJECT NAME: A020
     RUN STARTED:  Dec 13, 2002 12:50
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    1
 SQUARE PLATE WITH VOLUME HEAT GENERATION AND ENFORCED TEMPERATURE.


                                 ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                      9
                   NUMBER OF CTRIA3->PSHELL ELEMENTS:          8
                   TOTAL NUMBER OF NON RIGID ELEMENTS:         8
```

```
                         NUMBER OF ELEMENT PROPERTIES:               1
                         NUMBER OF MATERIALS:                        1
                         NUMBER OF THERMAL DEGREES OF FREEDOM:       9


                                  LOAD CASES SUMMARY

                        NUMBER OF HEAT TRANSFER LOAD CASES:            1
                        TOTAL NUMBER OF LOAD CASES:                    1

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    2
 SQUARE PLATE WITH VOLUME HEAT GENERATION AND ENFORCED TEMPERATURE.


                     ********************************************
                     *  D E S I G N  C Y C L E      0 (ANALYSIS)*
                     ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    3
 SQUARE PLATE WITH VOLUME HEAT GENERATION AND ENFORCED TEMPERATURE.


                          M A S S / V O L U M E   S U M M A R Y

                          SYSTEM MASS             0.000000E+00
                          SYSTEM VOLUME           1.000000E+02
                          SYSTEM MASS/VOLUME      0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    4
 SQUARE PLATE WITH VOLUME HEAT GENERATION AND ENFORCED TEMPERATURE.


                    H E A T   S O L U T I O N   R E S I D U A L S

 LOADCASE        1 ; RESIDUAL :  2.263114E-15 ;   HEAT ENERGY 1.736111E+05
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    5
 SQUARE PLATE WITH VOLUME HEAT GENERATION AND ENFORCED TEMPERATURE.

 REF. T=(133.3,119.4,50,119.4,105.6,50.0,50.0,50,50.0 CELSIUS LOADCASE       1

                            G R I D   T E M P E R A T U R E S

  GRID ID          TEMP

        1      1.333333E+02
        2      1.194444E+02
        3      5.000000E+01
        4      1.194444E+02
        5      1.055556E+02
        6      5.000000E+01
        7      5.000000E+01
        8      5.000000E+01
        9      5.000000E+01
1                            ***** END OF OUTPUT *****
```

2.21 Conduction on an Elliptical Bar Heated by a Distant Source

Example ID:

A021

Analysis Data Used:

GRID, CBAR, CHBDY (ELCYL), PBAR, PHBDY, MAT4, MAT1(DUMMY), LOADCASE, HEAT, QVECT, THERMAL, SPC and SPC1.

Special Features Used:

Utilization of boundary element ELCYL and vector flux loading.

Problem Statement:

Find the temperature distribution in the bar shown in the figure below. Consider only conduction through the bar, neglecting convection.

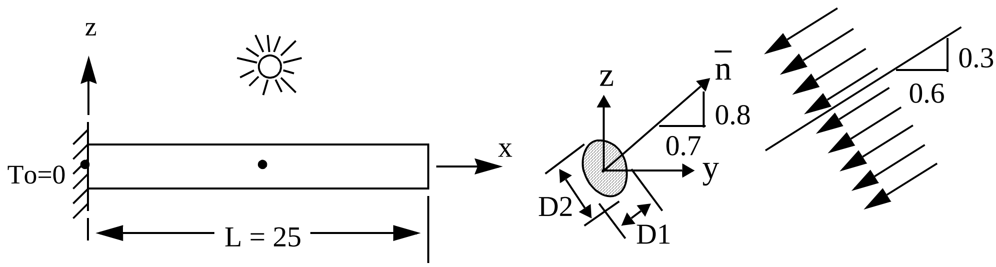
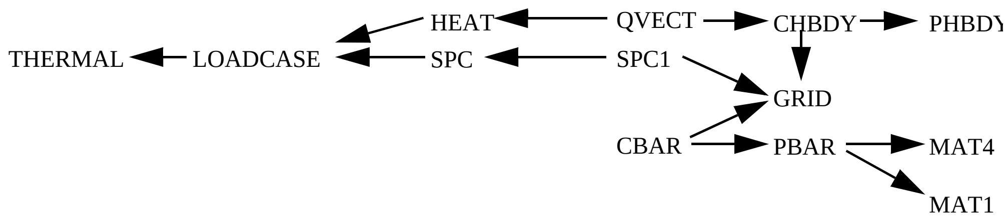


Figure 2-24

Heat Transfer Analysis Model:

1. Bar structure assembled with 2 conductive CBAR elements and 2 CHBDY (ELCYL) boundary elements.
2. Section properties:
   PBAR: AREA=2.945243,
   PHBDY: D1=1.5, D2=2.5, ALPHA = 1.0
3. Materials:
   -k=70 Watts/cm-^{o}K (conduction).
   In addition, structural material MAT1 is included in the input data.
   Structural material data is necessary to run *GENESIS*.
4. One load case: Conduction due to vector flux Q=100*(0.0,0.6,0.3). Boundary condition is zero temperature at root.

Analysis Data Relationships:



Special Modeling Techniques:

The CHBDY (ELCYL) elements are used to compute the heat loading only. Their properties do no reference any material, in this way convection is not considered in this problem.

Reference Solutions:

$$T(X) = \frac{qv \bullet X\left(L - \frac{X}{2}\right)}{k}$$

where;
qv = Power/volume
Power = 2611.0 (calculated using analytical integration)
volume = 2.9452*25.0:

X	**Temperature**
0.0	0.0
12.5	118.7
25.0	158.3

Calculated Solutions:

X	**Temperature**
0.0	0.0
12.5	118.7
25.0	158.3

Comparison Between Calculated Solution And Reference Solution:

There is no difference between the calculated solution and the analytical solution.

2.21.1 Input Data

```
ID A021
SOL COMPAT1
CEND
TITLE= CONDUCTION ON AN ELLIPTICAL BAR HEATED BY A DISTANT SOURCE.
LINE=64,80
ECHO=NONE
LOADCASE 1
   LABEL=  CONDUCTION USING 2 BAR. LOADING USING 2 CHBDY (ELCYL) and 2 QVECT.
   SPC=101
   HEAT=102
   THERMAL=ALL
BEGIN BULK
$
$    HEAT TRANSFER BOUNDARY CONDITIONS
$
SPC1    101             1
$
$   GRID DATA
$
GRID    1       0       0.0     0.0     0.0     0
GRID    2       0       12.5    0.0     0.0     0
GRID    3       0       25.0    0.0     0.0     0
$
$   ELEMENT DEFINITIONS
$
CBAR    1       22      1       2       0.0     1.0     0.0
CBAR    2       22      2       3       0.0     1.0     0.0
CHBDY   11      109     ELCYL   1       2
+                                       0.0     0.7     0.8
CHBDY   12      109     ELCYL   2       3
+                                       0.0     0.7     0.8
$
$   PROPERTY DEFINITIONS: DUMMY INERTIAS.
$
PBAR    22      70      2.9452431.667E-56.667E-5
PHBDY   109                             1.0     1.5     2.5
$
$   MATERIAL DATA
$
MAT1    70      1.0+7           0.30
MAT4    70      70.0
$
$   HEAT LOADING:  HEAT FLUX VECTOR
$
QVECT   102     100.0    .0     0.6      0.3    11
QVECT   102     100.0    .0     0.6      0.3    12
$
ENDDATA
```

2.21.2 Output

```
1

            GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
           G        E       NN  N   E       S          I     S
           G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
           G    G   E       N  NN   E            S     I          S
            GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                 STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                              COPYRIGHT, 1991-2002

                    VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                         ALL RIGHTS RESERVED, WORLDWIDE

                                  VERSION 7.2

                             BUILD CODE 200212131048



     PROJECT NAME: A021
     RUN STARTED:  Dec 13, 2002 12:50
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    1
 CONDUCTION ON AN ELLIPTICAL BAR HEATED BY A DISTANT SOURCE.

                             ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                       3
                   NUMBER OF CBAR ELEMENTS:                     2
                   NUMBER OF CHBDY ELEMENTS:                    2
```

```
                      TOTAL NUMBER OF NON RIGID ELEMENTS:         4
                      NUMBER OF ELEMENT PROPERTIES:               2
                      NUMBER OF MATERIALS:                        1
                      NUMBER OF THERMAL DEGREES OF FREEDOM:       2


                                LOAD CASES SUMMARY

                     NUMBER OF HEAT TRANSFER LOAD CASES:            1
                     TOTAL NUMBER OF LOAD CASES:                    1

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    2
 CONDUCTION ON AN ELLIPTICAL BAR HEATED BY A DISTANT SOURCE.


               ********************************************
               *  D E S I G N  C Y C L E      0 (ANALYSIS)*
               ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    3
 CONDUCTION ON AN ELLIPTICAL BAR HEATED BY A DISTANT SOURCE.


                    M A S S / V O L U M E   S U M M A R Y

                    SYSTEM MASS              0.000000E+00
                    SYSTEM VOLUME            7.363107E+01
                    SYSTEM MASS/VOLUME       0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    4
 CONDUCTION ON AN ELLIPTICAL BAR HEATED BY A DISTANT SOURCE.


              H E A T   S O L U T I O N   R E S I D U A L S

 LOADCASE        1 ; RESIDUAL : -3.483986E-16 ;   HEAT ENERGY 1.291185E+05
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    5
 CONDUCTION ON AN ELLIPTICAL BAR HEATED BY A DISTANT SOURCE.

 CONDUCTION USING 2 BAR. LOADING USING 2 CHBDY (ELCYL) AND 2  LOADCASE        1

                      G R I D   T E M P E R A T U R E S

  GRID ID          TEMP

        1      0.000000E+00
        2      1.187069E+02
        3      1.582758E+02
1                            ***** END OF OUTPUT *****
```

2.22 Heat Conduction in an Anisotropic Plate

Example ID:

A022

Analysis Data Used:

GRID, CQUAD4, PSHELL, MAT5, MAT8(DUMMY), LOADCASE, SPC, SPC, SPC1, HEAT, QHBDY, THERMAL.

Special Features Used:

Utilization of anisotropic material MAT5 with PSHELL.

Problem Statement:

Find the temperature distribution in the anisotropic plate shown in the figure below. The plate is loaded in one edge with a constant flux load of 100.0 units. The boundary at the opposite edge of the loading has a constant temperature of zero degrees.

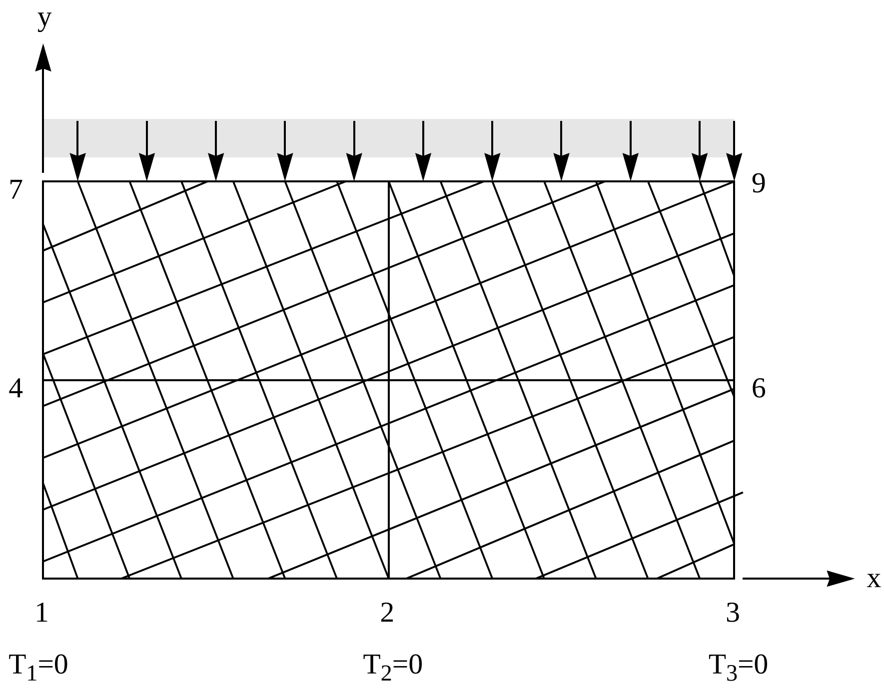


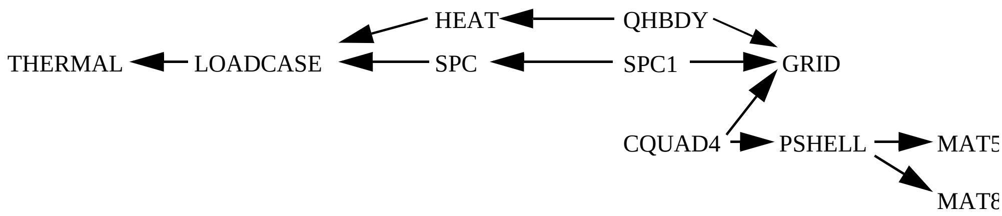
Figure 2-25

Heat Transfer Analysis Model:

1. Plate assembled with 4 QUAD4 elements.

2. Section properties of plate: thickness=2.0
3. Material:
   - KXX=65.215
   - KXY=12.0241
   - KYY=39.78501
   This material correspond to an orthotropic material of kxx=70 and kyy=35 rotated 21.7 degrees.
   In addition, dummy structural material MAT8 is included in the input data.
   Structural material data is necessary to run *GENESIS*.
4. One HEAT FLUX Load case: a) Q0 = 100.0 units.

Analysis Data Relationships:



Special Modeling Techniques:

NONE.

Reference Solutions:

See problem A023

Calculated Solutions:

Grid ID	Temperature
1	0.000
2	0.000
3	0.000
4	16.171
5	12.636
6	9.791
7	29.939
8	25.839
9	22.046

Comparison Between Calculated Solution And Reference Solution:

There are no differences between the reference solution and the *GENESIS* solution.

2.22.1 Input Data

```
ID A022
SOL COMPAT1
CEND
TITLE=HEAT CONDUCTION IN AN ANISOTROPIC PLATE.
SUBTITLE=USE OF 4 CONDUCTIVE QUAD4 AND 2 QHBDY(LINE). HEAT FLUX LOADING.
ECHO=NONE
LINE=64,80
LOADCASE 10
   HEAT = 1
   THERMAL=ALL
   SPC=1
$
BEGIN BULK
$
$     HEAT TRANSFER BOUNDARY CONDITIONS
$
SPC1    1               1       2       3
$     GRID POINTS
$
GRID    1               0.0     0.0     0.0
GRID    2               10.0    0.0     0.0
GRID    3               20.0    0.0     0.0
$
GRID    4               0.0     5.0     0.0
GRID    5               10.0    5.0     0.0
GRID    6               20.0    5.0     0.0
$
GRID    7               0.0     10.0     0.0
GRID    8               10.0    10.0     0.0
GRID    9               20.0    10.0     0.0
$
$     ELEMENT DEFINITIONS
$
CQUAD4  1       1       1       2       5       4
CQUAD4  2       1       2       3       6       5
CQUAD4  3       1       4       5       8       7
CQUAD4  4       1       5       6       9       8
$
$     PROPERTY DEFINITIONS
$
PSHELL  1       1       2.0
$
$     MATERIAL DEFINITIONS
$
MAT8    1       7.8+6   2.6+6   0.25    1.3+6
+       3.50-6  11.40-6 80.0
MAT5    1       65.215  12.0241 0.0     39.78501
$
$    HEAT FLUX LOADING DEFINITION
$
QHBDY   1       LINE    100.0   2.0     7       8
QHBDY   1       LINE    100.0   2.0     8       9
```

```
$
ENDDATA
```

2.22.2 Output

```
1









               GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
              G        E       NN  N   E       S          I     S
              G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
              G    G   E       N  NN   E            S     I          S
               GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                     STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                                 COPYRIGHT, 1991-2002

                        VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                             ALL RIGHTS RESERVED, WORLDWIDE

                                     VERSION 7.2

                                BUILD CODE 200212131048




     PROJECT NAME: A022
     RUN STARTED:  Dec 13, 2002 12:50
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    1
 HEAT CONDUCTION IN AN ANISOTROPIC PLATE.
 USE OF 4 CONDUCTIVE QUAD4 AND 2 QHBDY(LINE). HEAT FLUX LOADING.

                                ANALYSIS PROBLEM SUMMARY

                  NUMBER OF GRID POINTS:                      9
                  NUMBER OF CQUAD4->PSHELL ELEMENTS:          4
                  TOTAL NUMBER OF NON RIGID ELEMENTS:         4
```

```
                    NUMBER OF ELEMENT PROPERTIES:              1
                    NUMBER OF MATERIALS:                       1
                    NUMBER OF THERMAL DEGREES OF FREEDOM:      6


                                LOAD CASES SUMMARY

                   NUMBER OF HEAT TRANSFER LOAD CASES:           1
                   TOTAL NUMBER OF LOAD CASES:                   1

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    2
 HEAT CONDUCTION IN AN ANISOTROPIC PLATE.
 USE OF 4 CONDUCTIVE QUAD4 AND 2 QHBDY(LINE). HEAT FLUX LOADING.

               ********************************************
               *  D E S I G N  C Y C L E     0 (ANALYSIS)*
               ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    3
 HEAT CONDUCTION IN AN ANISOTROPIC PLATE.
 USE OF 4 CONDUCTIVE QUAD4 AND 2 QHBDY(LINE). HEAT FLUX LOADING.

                    M A S S / V O L U M E   S U M M A R Y

                    SYSTEM MASS             0.000000E+00
                    SYSTEM VOLUME           4.000000E+02
                    SYSTEM MASS/VOLUME      0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    4
 HEAT CONDUCTION IN AN ANISOTROPIC PLATE.
 USE OF 4 CONDUCTIVE QUAD4 AND 2 QHBDY(LINE). HEAT FLUX LOADING.

              H E A T   S O L U T I O N   R E S I D U A L S

 LOADCASE       10 ; RESIDUAL : -5.362542E-16 ;   HEAT ENERGY 5.183068E+04
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    5
 HEAT CONDUCTION IN AN ANISOTROPIC PLATE.
 USE OF 4 CONDUCTIVE QUAD4 AND 2 QHBDY(LINE). HEAT FLUX LOADING.
                                                           LOADCASE       10

                      G R I D   T E M P E R A T U R E S

  GRID ID          TEMP

        1      0.000000E+00
        2      0.000000E+00
        3      0.000000E+00
        4      1.617075E+01
        5      1.263648E+01
        6      9.790604E+00
        7      2.993856E+01
        8      2.583861E+01
        9      2.204558E+01
1                            ***** END OF OUTPUT *****
```

2.23 Heat Conduction in an Anisotropic Solid

Example ID:

A023

Analysis Data Used:

GRID, CHEXA, PSOLID, MAT5, MAT1(DUMMY), LOADCASE, HEAT, QHBDY, SPC, SPC1, THERMAL.

Special Features Used:

Utilization of anisotropic material MAT5 with PSOLID.

Problem Statement:

Find the temperature distribution in the anisotropic solid shown in the figure below. The solid is loaded in one face with a constant flux load of 100.0 units. The boundary at the face opposite of the loading has a constant temperature of zero degrees.

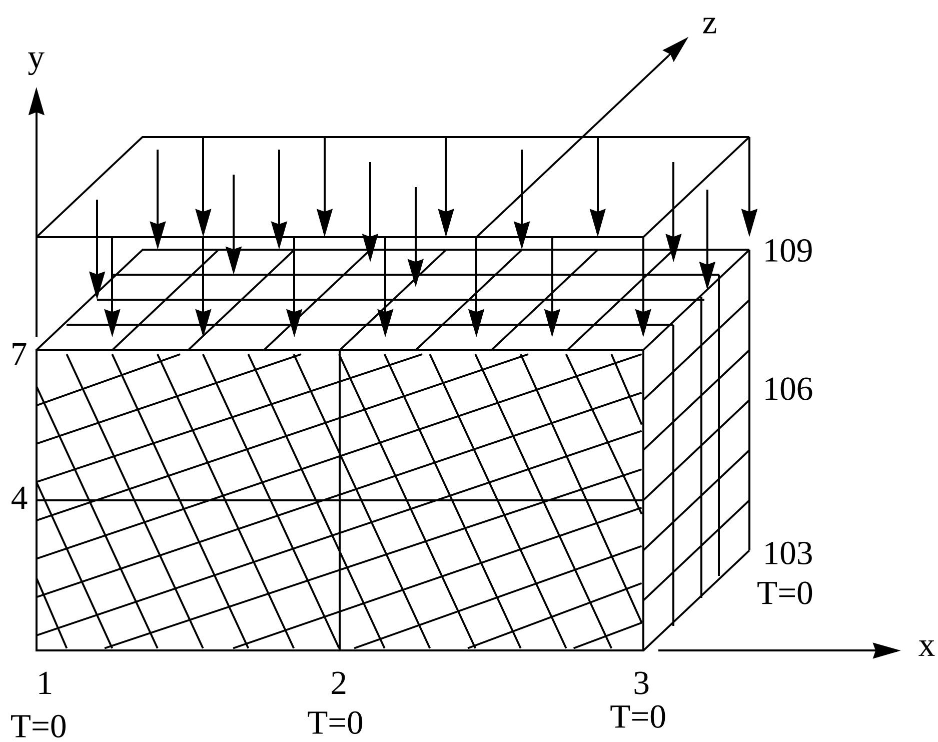


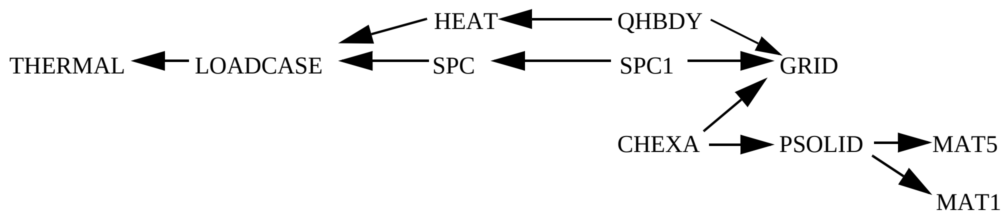
Figure 2-26

Heat Transfer Analysis Model:

1. Solid assembled with 4 conductive CHEXA elements.
2. Material:
   - KXX=65.21500
   - KXY=12.02410
   - KYY=39.78501
   - KZZ=50.00000

   This material corresponds to an orthotropic material of kxx=70, kyy=35 and kzz=50 rotated 21.7 degrees in the z-axis.
   In addition, dummy structural material MAT1 is included in the input data. Structural material data is necessary to run *GENESIS*.
3. One HEAT FLUX Load case: Q_0 = 100.0 units.

Analysis Data Relationships:



Special Modeling Techniques:

NONE.

Reference Solutions:

See problem A022, in that problem the solid is modeled as a plate. Since the heat flux gradient is zero in the z direction the plate solution can capture the 3-D temperature field. Calculated Solutions:

Grid ID	**Temperature**
1	0.000
2	0.000
3	0.000
4	16.171
5	12.636
6	9.791
7	29.939
8	25.839
9	22.046
101	0.000
102	0.000
103	0.000
104	16.171
105	12.636
106	9.791
107	29.939
108	25.839
109	22.046

Comparison Between Calculated Solution And Reference Solution:

There are no differences between the reference solutions and the calculated solution.

2.23.1 Input Data

```
ID A023
SOL COMPAT1
CEND
TITLE   =HEAT CONDUCTION IN AN ANISOTROPIC SOLID.
ECHO=NONE
LINE=64,80
LOADCASE 10
   HEAT = 1
   SPC=1
   THERMAL=ALL
BEGIN BULK
$
$     HEAT TRANSFER BOUNDARY CONDITIONS
$
SPC1    1               1       2       3
SPC1    1               101     102     103
$
$     GRID DATA
$
GRID    1               0.0     0.00    0.0
GRID    2               10.0    0.00    0.0
GRID    3               20.0    0.00    0.0
$
GRID    4               0.0     5.00    0.0
GRID    5               10.0    5.00    0.0
GRID    6               20.0    5.00    0.0
$
GRID    7               0.0     10.00   0.0
GRID    8               10.0    10.00   0.0
GRID    9               20.0    10.00   0.0
$
GRID    101             0.0     0.00    2.0
GRID    102             10.0    0.00    2.0
GRID    103             20.0    0.00    2.0
$
GRID    104             0.0     5.00    2.0
GRID    105             10.0    5.00    2.0
GRID    106             20.0    5.00    2.0
$
GRID    107             0.0     10.00   2.0
GRID    108             10.0    10.00   2.0
GRID    109             20.0    10.00   2.0
$
$     ELEMENT DEFINITIONS
$
CHEXA   1       1       1       2       5       4       101     102
+       105     104
CHEXA   2       1       2       3       6       5       102     103
+       106     105
CHEXA   3       1       4       5       8       7       104     105
+       108     107
CHEXA   4       1       5       6       9       8       105     106
```

```
+       109     108
$
$     PROPERTY DEFINITIONS
$
PSOLID  1       1
$
$     MATERIAL DEFINITIONS
$
MAT1    1       7.777           0.3
MAT5    1       65.215  12.0241 0.0     39.78501 0.0    50.0
$
$
$    HEAT FLUX DEFINITION
$
QHBDY   1       AREA4   100.0           7       8       108     107
QHBDY    1       AREA4   100.0           8       9       109     108
$
ENDDATA
```

2.23.2 Output

```
1




             GGGG     EEEEE    N   N    EEEEE     SSSSS    IIIII    SSSSS
            G         E        NN  N    E        S           I     S
            G   GG    EEEE     N N N    EEEE      SSSS       I      SSSS
            G    G    E        N  NN    E             S      I          S
             GGGG     EEEEE    N   N    EEEEE    SSSSS     IIIII   SSSSS


                 STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                              COPYRIGHT, 1991-2002

                    VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                         ALL RIGHTS RESERVED, WORLDWIDE

                                  VERSION 7.2

                            BUILD CODE 200212131048



     PROJECT NAME: A023
     RUN STARTED:  Dec 13, 2002 12:50
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    1
 HEAT CONDUCTION IN AN ANISOTROPIC SOLID.


                            ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                    18
                   NUMBER OF CHEXA ELEMENTS:                  4
                   TOTAL NUMBER OF NON RIGID ELEMENTS:        4
```

```
                      NUMBER OF ELEMENT PROPERTIES:              1
                      NUMBER OF MATERIALS:                       1
                      NUMBER OF THERMAL DEGREES OF FREEDOM:     12


                                  LOAD CASES SUMMARY

                     NUMBER OF HEAT TRANSFER LOAD CASES:           1
                     TOTAL NUMBER OF LOAD CASES:                   1

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    2
 HEAT CONDUCTION IN AN ANISOTROPIC SOLID.


                 ********************************************
                 *  D E S I G N  C Y C L E      0 (ANALYSIS)*
                 ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    3
 HEAT CONDUCTION IN AN ANISOTROPIC SOLID.


                       M A S S / V O L U M E   S U M M A R Y

                       SYSTEM MASS              0.000000E+00
                       SYSTEM VOLUME            4.000000E+02
                       SYSTEM MASS/VOLUME       0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    4
 HEAT CONDUCTION IN AN ANISOTROPIC SOLID.


                H E A T   S O L U T I O N   R E S I D U A L S

 LOADCASE       10 ; RESIDUAL : -1.637177E-15 ;   HEAT ENERGY 5.183068E+04
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    5
 HEAT CONDUCTION IN AN ANISOTROPIC SOLID.

                                                         LOADCASE        10

                        G R I D   T E M P E R A T U R E S

  GRID ID          TEMP

        1      0.000000E+00
        2      0.000000E+00
        3      0.000000E+00
        4      1.617075E+01
        5      1.263648E+01
        6      9.790604E+00
        7      2.993856E+01
        8      2.583861E+01
        9      2.204558E+01
      101      0.000000E+00
      102      0.000000E+00
      103      0.000000E+00
```

```
      104      1.617075E+01
      105      1.263648E+01
      106      9.790604E+00
      107      2.993856E+01
      108      2.583861E+01
      109      2.204558E+01
1                           ***** END OF OUTPUT *****
```

2.24 Convection-Conduction Heat Transfer in the Straight Cantilever Problem

Example ID:

A024

Analysis Data Used:

GRID, CQUAD4, CHBDY (AREA4), PSHELL, PHBDY, MAT4, MAT1(DUMMY), LOADCASE, HEAT, SPCD, THERMAL, SPC and SPC1.

Special Features Used:

Utilization of ambient temperature loading and use of boundary element AREA4.

Problem Statement:

Find the temperature distribution in the straight cantilever shown in the figure bellow. The beam is subjected to an ambient temperature of 100 degrees. Consider k = 90 watts/cm-^oK for conduction and h=10 watts/cm^2-^oK for convection. The length of the beam is 6.00 cm and its cross section 0.2x0.1 cm^2. The temperature at the root is zero. Consider convection through one of the 6*0.2 faces.

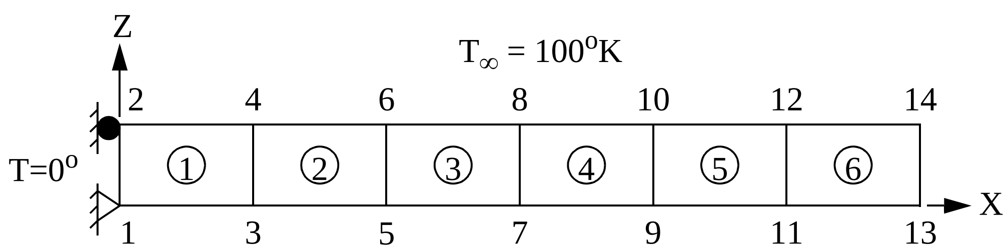


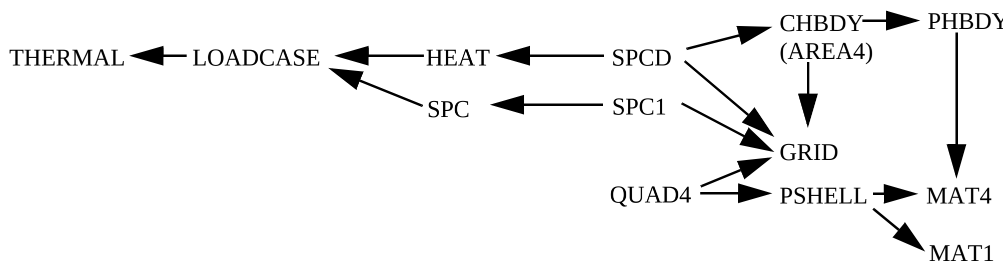
Figure 2-27

Heat Transfer Analysis Model:

1. Beam structure assembled with 6 conductive QUAD4 elements and 6 convective CHBDY (AREA4) boundary elements.
2. Section properties:
   - thickness=0.1 cm.
3. Materials:
   - k=90 Watts/cm-^{o}K (conduction).
   - h=10.0 Watts/cm^{2}-^{o}K (convection).
   In addition, dummy structural material MAT1 is included in the input data.
   Structural material data is necessary to run *GENESIS*.
4. One load case: Conduction and convection due to ambient temperature of 100.0 degrees.

The ambient temperature is specified with a SPCD data statement. In addition, it is necessary to constrain the corresponding grid (999). The grid is constrained with a SPC1 data statement.

Analysis Data Relationships:



Special Modeling Techniques:

NONE

Reference Solutions:

NONE.

Calculated Solutions:

Location	Temperature
x=0.0	0.000
x=1.0	67.04
x=2.0	89.14
x=3.0	96.42
x=4.0	98.81
x=5.0	99.57
x=6.0	99.74

2.24.1 Input Data

```
ID A024
SOL COMPAT1
CEND
TITLE= CONDUCTION-CONVECTION ANALYSIS OF THE STRAIGHT CANTILEVER BEAM
SUBTITLE= 1 HEAT TRANSFER LOAD CONDITIONS, 6 QUAD4 & 6 CHBDY (AREA4).
LINE=64,80
ECHO=NONE
$
LOADCASE 1
   HEAT=101
   SPC=101
   THERMAL=ALL
$
BEGIN BULK
$
$   HEAT TRANSFER BOUNDARY CONDITIONS
$
SPC1    101             1
SPC1    101             2
$
$     AMBIENT TEMPERATURE
$
SPC1    101             999
SPCD    101     999             100.0
GRID    999     0       0.0     0.0     3.0     0       0
$
$     GRID DATA
$
GRID    1       0       0.0     0.0     0.0     0       0
GRID    2       0       0.0     0.0     0.2     0       0
GRID    3       0       1.0     0.0     0.0     0       0
GRID    4       0       1.0     0.0     0.2     0       0
GRID    5       0       2.0     0.0     0.0     0       0
GRID    6       0       2.0     0.0     0.2     0       0
GRID    7       0       3.0     0.0     0.0     0       0
GRID    8       0       3.0     0.      0.2     0       0
GRID    9       0       4.0     0.      0.0     0       0
GRID    10      0       4.0     0.0     0.2     0       0
GRID    11      0       5.0     0.0     0.0     0       0
GRID    12      0       5.0     0.0     0.2     0       0
GRID    13      0       6.0     0.0     0.0     0       0
GRID    14      0       6.0     0.0     0.2     0       0
$
$   ELEMENT DEFINITIONS
$
CQUAD4  1       22      1       3       4       2
CQUAD4  2       22      3       5       6       4
CQUAD4  3       22      5       7       8       6
CQUAD4  4       22      7       9       10      8
CQUAD4  5       22      9       11      12      10
CQUAD4  6       22      11      13      14      12
$
```

```
CHBDY   101     109     AREA4   1       3       4       2
+       999     999     999     999     1.0     0.0     0.0
CHBDY   102     109     AREA4   3       5       6       4
+       999     999     999     999     1.0     0.0     0.0
CHBDY   103     109     AREA4   5       7       8       6
+       999     999     999     999     1.0     0.0     0.0
CHBDY   104     109     AREA4   7       9       10      8
+       999     999     999     999     1.0     0.0     0.0
CHBDY   105     109     AREA4   9       11      12      10
+       999     999     999     999     1.0     0.0     0.0
CHBDY   106     109     AREA4   11      13      14      12
+       999     999     999     999     1.0     0.0     0.0
$
$   PROPERTY DEFINITIONS
$
PSHELL   22      33      0.1     33
PHBDY   109     109
$
$   MATERIAL DATA
$
MAT1    33      1.0+7           0.30
MAT4    33      90.0
MAT4    109     10.0
$
ENDDATA
```

2.24.2 Output

```
1

                 GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
                G        E       NN  N   E       S          I     S
                G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
                G    G   E       N  NN   E            S     I          S
                 GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS

                     STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE

                                  COPYRIGHT, 1991-2002

                        VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                             ALL RIGHTS RESERVED, WORLDWIDE

                                      VERSION 7.2

                                 BUILD CODE 200212131048

     PROJECT NAME: A024
     RUN STARTED:  Dec 13, 2002 12:50
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000

     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    1
 CONDUCTION-CONVECTION ANALYSIS OF THE STRAIGHT CANTILEVER BEAM
 1 HEAT TRANSFER LOAD CONDITIONS, 6 QUAD4 & 6 CHBDY (AREA4).

                             ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                    15
                   NUMBER OF CQUAD4->PSHELL ELEMENTS:         6
                   NUMBER OF CHBDY ELEMENTS:                  6
```

```
                         TOTAL NUMBER OF NON RIGID ELEMENTS:        12
                         NUMBER OF ELEMENT PROPERTIES:               2
                         NUMBER OF MATERIALS:                        1
                         NUMBER OF THERMAL DEGREES OF FREEDOM:      13



                                   LOAD CASES SUMMARY

                        NUMBER OF HEAT TRANSFER LOAD CASES:            1
                        TOTAL NUMBER OF LOAD CASES:                    1

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    2
 CONDUCTION-CONVECTION ANALYSIS OF THE STRAIGHT CANTILEVER BEAM
 1 HEAT TRANSFER LOAD CONDITIONS, 6 QUAD4 & 6 CHBDY (AREA4).

             ********************************************
             *  D E S I G N  C Y C L E     0 (ANALYSIS)*
             ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    3
 CONDUCTION-CONVECTION ANALYSIS OF THE STRAIGHT CANTILEVER BEAM
 1 HEAT TRANSFER LOAD CONDITIONS, 6 QUAD4 & 6 CHBDY (AREA4).

                    M A S S / V O L U M E   S U M M A R Y

                    SYSTEM MASS              0.000000E+00
                    SYSTEM VOLUME            1.200000E-01
                    SYSTEM MASS/VOLUME       0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    4
 CONDUCTION-CONVECTION ANALYSIS OF THE STRAIGHT CANTILEVER BEAM
 1 HEAT TRANSFER LOAD CONDITIONS, 6 QUAD4 & 6 CHBDY (AREA4).

            H E A T   S O L U T I O N   R E S I D U A L S

 LOADCASE        1 ; RESIDUAL :  6.636613E-15 ;   HEAT ENERGY 5.008372E+04
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    5
 CONDUCTION-CONVECTION ANALYSIS OF THE STRAIGHT CANTILEVER BEAM
 1 HEAT TRANSFER LOAD CONDITIONS, 6 QUAD4 & 6 CHBDY (AREA4).
                                                          LOADCASE        1

                      G R I D   T E M P E R A T U R E S

  GRID ID          TEMP

       1      0.000000E+00
       2      0.000000E+00
       3      6.704024E+01
       4      6.704024E+01
       5      8.913534E+01
       6      8.913534E+01
       7      9.641499E+01
       8      9.641499E+01
       9      9.880599E+01
      10      9.880599E+01
      11      9.956880E+01
```

```
      12      9.956880E+01
      13      9.974361E+01
      14      9.974361E+01
     999      1.000000E+02
1                            ***** END OF OUTPUT *****
```

2.25 Dynamic Response of the Cantilevered Beam

Example ID:

A025

Analysis Data Used:

GRID, CBAR, PBAR, MAT1, LOADCASE, METHOD, DLOAD, FREQ, MODES, DISP, EIGR, RLOAD1, DAREA, DELAY, TABLED1

Special Feature Used:

Frequency response analysis using direct dynamic analysis and modal dynamic analysis.

Problem Statement:

Find the nodal displacements of the cantilever beam shown in the figure below. The beam is loaded with a tip point load of 100.0 N and it is applied at three different frequencies. The first frequency is close to zero to simulate a static loading (f=1.0e-8 hz), the second frequency is f=8.8 hz and the third is f=57.1 hz. The last two frequencies are very close to the first and second natural modes to simulate loadings close to resonance. Use direct dynamic analysis and modal analysis. For modal analysis consider the first three modes. Do not consider damping.

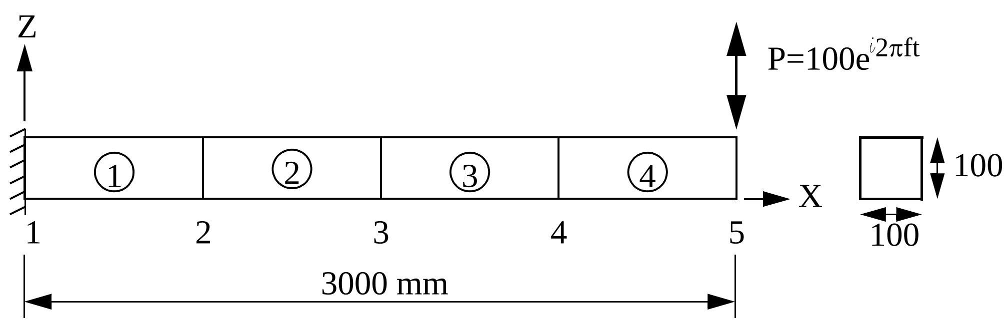
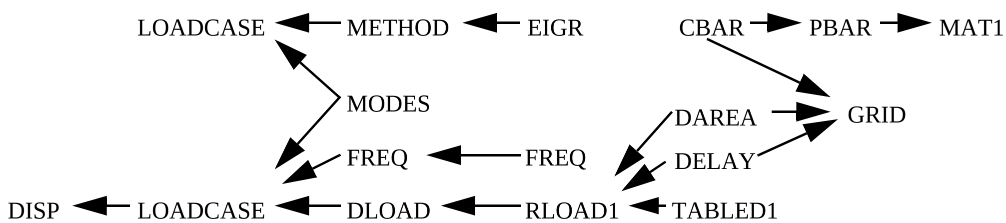


Figure 2-28

Structural Analysis Model:

1. Four BAR elements.
2. The section properties are: area=10000 mm^2. I=8.3+6 mm^4
3. Material: E=2.07E+5 MPa. density=8.0-9 N-sec^2/mm^4
4. One frequency load case, necessary for modal dynamic analysis.
5. One direct dynamic response load case. P=100 N
6. One modal dynamic response load case. P=100 N
7. Excitation frequencies for the problem are: f1=1.0e-8 hz, f2=8.8 hz and f3=57.1 hz.

Analysis Data Relationships:



Special Modeling Techniques:

NONE.

Reference Solutions:

None for the displacements. Their values can be verified by comparing load cases two and three which are obtained using different methodologies.
Note that the theoretical solutions for the natural frequencies and the static solution at the tip are:

$$f1 = 0.5596\sqrt{EI/\rho AL^4} = 9.13Hz$$

$$f2 = 3.5069\sqrt{EI/\rho AL^4} = 57.21Hz$$

$$Y = PL^3/3EI = 0.52176mm$$

where E is the young’s modulus, A the cross section area, I the inertia, ρ the mass density and L the length.

Calculated Solutions:

Grid	Direct Dynamic Response (mm)	Modal Dynamic Response (mm)
	f = 1.0e-8 hz	
1	0.0000	0.0000
2	0.0448	0.0448
3	0.1631	0.1631
4	0.3302	0.3302
5	0.5218	0.5218
	f = 8.80 hz	
1	0.0000	0.0000
2	0.6930	0.6930
3	2.4254	2.4254
4	4.7134	4.7134
5	7.1863	7.1863
	f = 57.1 hz	
1	0.0000	0.0000
2	-1.5875	-1.5875
3	-2.7210	-2.7210
4	-0.5268	-0.5268
5	3.7934	3.7934

The solutions for the natural frequencies are:

f1 = 9.13 hz
f2 = 57.20 hz

Comparison Between Calculated Solutions And Reference Solutions:

The two approaches, direct and modal analysis, give the same results for the two load cases.
The differences between analytical solutions and calculated solutions for natural frequencies and static tip displacement are:

f1: 0%
f2: 0.05%
y : 0%

2.25.1 Input Data

```
ID A025
SOL COMPAT1
CEND
TITLE=DYNAMIC RESPONSE OF THE CANTILEVER BEAM
LINE=64,80
ECHO=NONE
$
DYNOUTPUT = REAL
$
LOADCASE 1
LABEL = NATURAL FREQUENCIES (TO BE USED IN LOADCASE 3)
METHOD=4
$
LOADCASE 2
LABEL = SOLUTION USING:  DIRECT DYNAMIC RESPONSE
FREQ = 32
DLOAD = 23
DISP=ALL
$
LOADCASE 3
LABEL = SOLUTION USING:  MODAL DYNAMIC RESPONSE
FREQ = 32
DLOAD = 23
MODES=1
DISP=ALL
$
BEGIN BULK
$
$    FREQUENCIES (FIRST FREQ. IS CLOSE STATIC SOLUTION, NEXT 2 ARE
$    CLOSE TO THE FIRST 2 NATURAL FREQUENCIES I.E. CLOSE TO RESONANCE)
$
FREQ    32      1.0E-8  8.8     57.1
$
$   GRID DATA (ONLY DISPLACEMENTS IN Z AND ROTATIONS IN Y ARE REQUESTED)
$
GRID    1               0.00    0.      0.0             123456
GRID    2               750.0   0.      0.0             1246
GRID    3               1500.0  0.      0.0             1246
GRID    4               2250.0  0.      0.0             1246
GRID    5               3000.0  0.      0.0             1246
$
$   ELEMENT DEFINITIONS
$
CBAR    1       1       1       2       0.      1.0     0.
CBAR    2       1       2       3       0.      1.0     0.
CBAR    3       1       3       4       0.      1.0     0.
CBAR    4       1       4       5       0.      1.0     0.
$
$   PROPERTY DEFINITIONS
$
PBAR    1       1       1.0+4   8.333+6 8.333+6 0.0
$
```

```
$   MATERIAL DATA
$
MAT1    1       2.07+5          0.3     8.0-9
$
$   EIGENVALUES DATA
$
EIGR    4       SUB                             3       MAX
$
$   LOAD DEFINITION
$
RLOAD1  23      1       2               4
$
DAREA   1       5       3       100.0
DELAY   2       5       3       60.0
$
$    C(W) = 1.0 = CONSTANT (SAME LOAD FOR EACH EXITING FREQUENCY)
$
TABLED1 4
+       1.0     1.0     2.0     1.0
$
ENDDATA
```

2.25.2 Output

```
1








           GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
          G        E       NN  N   E       S          I     S
          G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
          G    G   E       N  NN   E            S     I          S
           GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE



                             COPYRIGHT, 1991-2002

                   VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                        ALL RIGHTS RESERVED, WORLDWIDE

                                 VERSION 7.2

                           BUILD CODE 200212131048




     PROJECT NAME: A025
     RUN STARTED:  Dec 13, 2002 12:50
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    1
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM


                            ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                      5
                   NUMBER OF CBAR ELEMENTS:                    4
                   TOTAL NUMBER OF NON RIGID ELEMENTS:         4
```

```
                    NUMBER OF ELEMENT PROPERTIES:              1
                    NUMBER OF MATERIALS:                       1
                    NUMBER OF DEGREES OF FREEDOM:              8


                              LOAD CASES SUMMARY

                   NUMBER OF USER FREQUENCY LOAD CASES:          1
                   NUMBER OF DIRECT DYNAMIC LOAD CASES:          1
                   NUMBER OF MODAL  DYNAMIC LOAD CASES:          1
                   TOTAL NUMBER OF LOAD CASES:                   3

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    2
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM


               ********************************************
               *  D E S I G N  C Y C L E     0 (ANALYSIS)*
               ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    3
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM


                    M A S S / V O L U M E   S U M M A R Y

                    SYSTEM MASS              2.400000E-01
                    SYSTEM VOLUME            3.000000E+07
                    SYSTEM MASS/VOLUME       8.000000E-09
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    4
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM

 NATURAL FREQUENCIES (TO BE USED IN LOADCASE 3)              LOADCASE        1

                           E I G E N V A L U E S

                                                          GENERALIZED   GENERALIZED
   MODE        CYCLES      EIGENVALUE     RADIANS             MASS       STIFFNESS

       1  9.128302E+00  3.289575E+03  5.735481E+01  6.001558E-02  1.974257E+02
       2  5.719718E+01  1.291543E+05  3.593805E+02  5.994695E-02  7.742408E+03
       3  1.608664E+02  1.021622E+06  1.010753E+03  5.897694E-02  6.025216E+04
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    5
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM

 SOLUTION USING:  DIRECT DYNAMIC RESPONSE                    LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  1.0000E-08)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                               (REAL/IMAGINARY)

       1  REAL   0.000000E+00       0.000000E+00       0.000000E+00
```

```
          REAL   0.000000E+00      0.000000E+00      0.000000E+00
          IMAG   0.000000E+00      0.000000E+00      0.000000E+00
          IMAG   0.000000E+00      0.000000E+00      0.000000E+00

       2  REAL   0.000000E+00      0.000000E+00      4.483875E-02
          REAL   0.000000E+00     -1.141350E-04      0.000000E+00
          IMAG   0.000000E+00      0.000000E+00      1.690381E-07
          IMAG   0.000000E+00     -4.302788E-10      0.000000E+00

       3  REAL   0.000000E+00      0.000000E+00      1.630500E-01
          REAL   0.000000E+00     -1.956600E-04      0.000000E+00
          IMAG   0.000000E+00      0.000000E+00      6.146840E-07
          IMAG   0.000000E+00     -7.376208E-10      0.000000E+00

       4  REAL   0.000000E+00      0.000000E+00      3.301763E-01
          REAL   0.000000E+00     -2.445750E-04      0.000000E+00
          IMAG   0.000000E+00      0.000000E+00      1.244735E-06
          IMAG   0.000000E+00     -9.220260E-10      0.000000E+00

       5  REAL   0.000000E+00      0.000000E+00      5.217600E-01
          REAL   0.000000E+00     -2.608800E-04      0.000000E+00
          IMAG   0.000000E+00      0.000000E+00      1.966989E-06
          IMAG   0.000000E+00     -9.834944E-10      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    6
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM

 SOLUTION USING:  DIRECT DYNAMIC RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  8.8000E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                   (REAL/IMAGINARY)

       1  REAL   0.000000E+00      0.000000E+00      0.000000E+00
          REAL   0.000000E+00      0.000000E+00      0.000000E+00
          IMAG   0.000000E+00      0.000000E+00      0.000000E+00
          IMAG   0.000000E+00      0.000000E+00      0.000000E+00

       2  REAL   0.000000E+00      0.000000E+00      6.929855E-01
          REAL   0.000000E+00     -1.731171E-03      0.000000E+00
          IMAG   0.000000E+00      0.000000E+00      3.043009E-13
          IMAG   0.000000E+00     -7.601845E-16      0.000000E+00

       3  REAL   0.000000E+00      0.000000E+00      2.425352E+00
          REAL   0.000000E+00     -2.779265E-03      0.000000E+00
          IMAG   0.000000E+00      0.000000E+00      1.065010E-12
          IMAG   0.000000E+00     -1.220419E-15      0.000000E+00

       4  REAL   0.000000E+00      0.000000E+00      4.713387E+00
          REAL   0.000000E+00     -3.237488E-03      0.000000E+00
          IMAG   0.000000E+00      0.000000E+00      2.069722E-12
          IMAG   0.000000E+00     -1.421632E-15      0.000000E+00
```

```
       5  REAL   0.000000E+00      0.000000E+00      7.186289E+00
          REAL   0.000000E+00     -3.319345E-03      0.000000E+00
          IMAG   0.000000E+00      0.000000E+00      3.155613E-12
          IMAG   0.000000E+00     -1.457577E-15      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    7
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM

 SOLUTION USING:  DIRECT DYNAMIC RESPONSE                       LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  5.7100E+01)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                               (REAL/IMAGINARY)

       1  REAL   0.000000E+00      0.000000E+00      0.000000E+00
          REAL   0.000000E+00      0.000000E+00      0.000000E+00
          IMAG   0.000000E+00      0.000000E+00      0.000000E+00
          IMAG   0.000000E+00      0.000000E+00      0.000000E+00

       2  REAL   0.000000E+00      0.000000E+00     -1.587532E+00
          REAL   0.000000E+00      2.902462E-03      0.000000E+00
          IMAG   0.000000E+00      0.000000E+00     -4.050359E-13
          IMAG   0.000000E+00      7.405213E-16      0.000000E+00

       3  REAL   0.000000E+00      0.000000E+00     -2.720996E+00
          REAL   0.000000E+00     -5.631984E-04      0.000000E+00
          IMAG   0.000000E+00      0.000000E+00     -6.942228E-13
          IMAG   0.000000E+00     -1.436919E-16      0.000000E+00

       4  REAL   0.000000E+00      0.000000E+00     -5.267900E-01
          REAL   0.000000E+00     -4.930351E-03      0.000000E+00
          IMAG   0.000000E+00      0.000000E+00     -1.344028E-13
          IMAG   0.000000E+00     -1.257908E-15      0.000000E+00

       5  REAL   0.000000E+00      0.000000E+00      3.793373E+00
          REAL   0.000000E+00     -6.071034E-03      0.000000E+00
          IMAG   0.000000E+00      0.000000E+00      9.678243E-13
          IMAG   0.000000E+00     -1.548937E-15      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    8
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM

 SOLUTION USING:  MODAL DYNAMIC RESPONSE                        LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  1.0000E-08)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                               (REAL/IMAGINARY)
```

```
        1  REAL   0.000000E+00      0.000000E+00      0.000000E+00
           REAL   0.000000E+00      0.000000E+00      0.000000E+00
           IMAG   0.000000E+00      0.000000E+00      0.000000E+00
           IMAG   0.000000E+00      0.000000E+00      0.000000E+00

        2  REAL   0.000000E+00      0.000000E+00      4.483875E-02
           REAL   0.000000E+00     -1.141350E-04      0.000000E+00
           IMAG   0.000000E+00      0.000000E+00      1.690381E-07
           IMAG   0.000000E+00     -4.302788E-10      0.000000E+00

        3  REAL   0.000000E+00      0.000000E+00      1.630500E-01
           REAL   0.000000E+00     -1.956600E-04      0.000000E+00
           IMAG   0.000000E+00      0.000000E+00      6.146840E-07
           IMAG   0.000000E+00     -7.376208E-10      0.000000E+00

        4  REAL   0.000000E+00      0.000000E+00      3.301763E-01
           REAL   0.000000E+00     -2.445750E-04      0.000000E+00
           IMAG   0.000000E+00      0.000000E+00      1.244735E-06
           IMAG   0.000000E+00     -9.220260E-10      0.000000E+00

        5  REAL   0.000000E+00      0.000000E+00      5.217600E-01
           REAL   0.000000E+00     -2.608800E-04      0.000000E+00
           IMAG   0.000000E+00      0.000000E+00      1.966989E-06
           IMAG   0.000000E+00     -9.834944E-10      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    9
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM

 SOLUTION USING:  MODAL DYNAMIC RESPONSE                    LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  8.8000E+00)

  GRID ID                T1                 T2                 T3
                         R1                 R2                 R3

                                      (REAL/IMAGINARY)

        1  REAL   0.000000E+00      0.000000E+00      0.000000E+00
           REAL   0.000000E+00      0.000000E+00      0.000000E+00
           IMAG   0.000000E+00      0.000000E+00      0.000000E+00
           IMAG   0.000000E+00      0.000000E+00      0.000000E+00

        2  REAL   0.000000E+00      0.000000E+00      6.929856E-01
           REAL   0.000000E+00     -1.731171E-03      0.000000E+00
           IMAG   0.000000E+00      0.000000E+00      3.043009E-13
           IMAG   0.000000E+00     -7.601844E-16      0.000000E+00

        3  REAL   0.000000E+00      0.000000E+00      2.425352E+00
           REAL   0.000000E+00     -2.779265E-03      0.000000E+00
           IMAG   0.000000E+00      0.000000E+00      1.065010E-12
           IMAG   0.000000E+00     -1.220419E-15      0.000000E+00

        4  REAL   0.000000E+00      0.000000E+00      4.713387E+00
           REAL   0.000000E+00     -3.237488E-03      0.000000E+00
           IMAG   0.000000E+00      0.000000E+00      2.069722E-12
```

```
           IMAG   0.000000E+00     -1.421632E-15      0.000000E+00

        5  REAL   0.000000E+00      0.000000E+00      7.186289E+00
           REAL   0.000000E+00     -3.319345E-03      0.000000E+00
           IMAG   0.000000E+00      0.000000E+00      3.155613E-12
           IMAG   0.000000E+00     -1.457577E-15      0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   10
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM

 SOLUTION USING:  MODAL DYNAMIC RESPONSE                      LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  5.7100E+01)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                    (REAL/IMAGINARY)

        1  REAL   0.000000E+00      0.000000E+00      0.000000E+00
           REAL   0.000000E+00      0.000000E+00      0.000000E+00
           IMAG   0.000000E+00      0.000000E+00      0.000000E+00
           IMAG   0.000000E+00      0.000000E+00      0.000000E+00

        2  REAL   0.000000E+00      0.000000E+00     -1.587528E+00
           REAL   0.000000E+00      2.902470E-03      0.000000E+00
           IMAG   0.000000E+00      0.000000E+00     -4.050349E-13
           IMAG   0.000000E+00      7.405232E-16      0.000000E+00

        3  REAL   0.000000E+00      0.000000E+00     -2.721000E+00
           REAL   0.000000E+00     -5.632021E-04      0.000000E+00
           IMAG   0.000000E+00      0.000000E+00     -6.942238E-13
           IMAG   0.000000E+00     -1.436929E-16      0.000000E+00

        4  REAL   0.000000E+00      0.000000E+00     -5.267867E-01
           REAL   0.000000E+00     -4.930345E-03      0.000000E+00
           IMAG   0.000000E+00      0.000000E+00     -1.344020E-13
           IMAG   0.000000E+00     -1.257906E-15      0.000000E+00

        5  REAL   0.000000E+00      0.000000E+00      3.793373E+00
           REAL   0.000000E+00     -6.071053E-03      0.000000E+00
           IMAG   0.000000E+00      0.000000E+00      9.678243E-13
           IMAG   0.000000E+00     -1.548941E-15      0.000000E+00

1                             ***** END OF OUTPUT *****
```

2.26 Dynamic Response of the Cantilevered Beam With Element Structural Damping

Example ID:

A026

Analysis Data Used:

GRID, CBAR, PBAR, MAT1, LOADCASE, METHOD, DLOAD, FREQ, MODES, DISP, EIGR, RLOAD1, DAREA, DELAY, TABLED1, FREQ

Special Feature Used:

Element structural damping (ge values in MAT1 data).

Problem Statement:

Find the magnitude of the tip displacement of the cantilever beam shown in the figure below. The beam is loaded with a tip point load of 100.0 N which is applied at 6 different frequencies. The frequencies cover a range that includes the first natural frequency of the beam. Use both direct dynamic analysis and modal analysis. For the modal analysis consider the first three modes. Consider also, that each beam element has a structural damping (ge) equal to 5%.

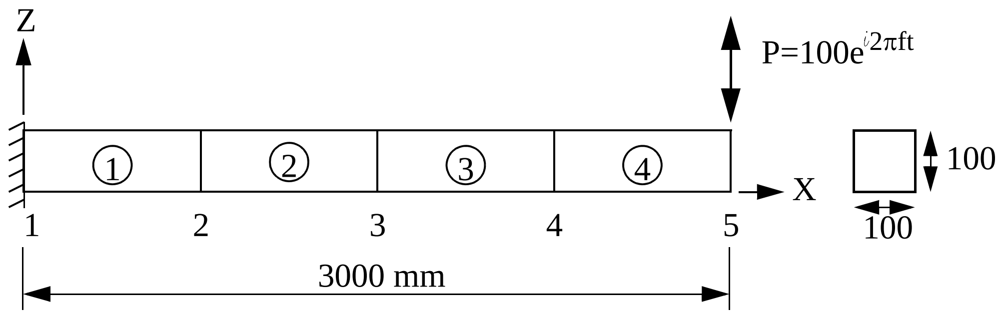


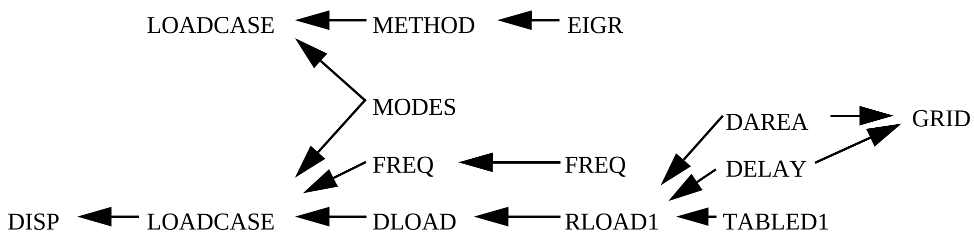
Figure 2-29

Structural Analysis Model:

1. Four CBAR elements.
2. The section properties are: Area=10000 mm^2. I=8.3+6 mm^4
3. Material: E=2.07E+5 MPa. density=8.0-9 N-sec^2/mm^4, ge = 0.05
4. One frequency load case, necessary for modal dynamic analysis.
5. One direct dynamic response load case. P=100 N
6. One modal dynamic response load case. P=100 N
7. Excitation frequencies for the problem are: f1=8.6 hz, f2=8.8 hz, f3=9.0 hz, f4=9.1283 hz, f5=9.2 hz, f6=9.4 hz.
8. The magnitude of the displacements are selected by using DYNOUTPUT=POLAR in the solution control.

NOTE: Because the damping is uniform, the same results can be obtained by using the command: PARAM,G,0.05. In this case the thee coefficient in MAT1 must be blank.

Analysis Data Relationships:



Special Modeling Techniques:

NONE.

Reference Solutions:

None for the displacements. Their values can be verified comparing load cases two and three which are obtained using the two different methodologies.

Calculated Solutions:

f (Hz)	Direct Dynamic Response (mm)	Modal Dynamic Response (mm)
8.6	4.1319	4.1319
8.8	5.8660	5.8660
9.0	8.8536	8.8536
9.1283	10.1312	10.1312*
9.2	9.6573	9.6573
9.4	6.4475	6.4475

* close to the natural frequency.

Comparison Between Calculated Solutions and Reference Solutions:

Both methodologies give same results.

2.26.1 Input Data

```
ID A026
SOL COMPAT1
CEND
TITLE=DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH ELEMENT STRUCTURAL DAMPING
SUBTITLE=FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCY
LINE=64,80
ECHO=NONE
$
DYNOUTPUT = POLAR
SET 5 = 5
$
LOADCASE 1
LABEL = NATURAL FREQUENCIES (TO BE USED IN LOADCASE 3)
METHOD=4
$
LOADCASE 2
LABEL = SOLUTION USING:  DIRECT DYNAMIC RESPONSE
DLOAD = 23
FREQ = 32
DISP=5
$
LOADCASE 3
LABEL = SOLUTION USING:  MODAL DYNAMIC RESPONSE
DLOAD = 23
FREQ = 32
MODES=1
DISP=5
$
BEGIN BULK
$
$    FREQUENCIES (FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCY)
$
FREQ    32      8.6     8.8     9.0     9.1283  9.2     9.4
$
$   GRID DATA (ONLY DISPLACEMENTS IN Z AND ROTATIONS IN Y ARE REQUESTED)
$
GRID    1               0.00    0.      0.0             123456
GRID    2               750.0   0.      0.0             1246
GRID    3               1500.0  0.      0.0             1246
GRID    4               2250.0  0.      0.0             1246
GRID    5               3000.0  0.      0.0             1246
$
$   ELEMENT DEFINITIONS
$
CBAR    1       1       1       2       0.      1.0     0.
CBAR    2       1       2       3       0.      1.0     0.
CBAR    3       1       3       4       0.      1.0     0.
CBAR    4       1       4       5       0.      1.0     0.
$
$   PROPERTY DEFINITIONS
$
PBAR    1       1       1.0+4   8.333+6 8.333+6 0.0
```

```
$
$   MATERIAL DATA
$
MAT1    1       2.07+5          0.3     8.0-9                   0.05
$
$   EIGENVALUES DATA
$
EIGR    4       SUB                             3       MAX
$
$   LOAD DEFINITION
$
RLOAD1  23      1       2               4
$
DAREA   1       5       3       100.0
DELAY   2       5       3       60.0
$
$    C(W) = 1.0 = CONSTANT (SAME LOAD FOR EACH EXITING FREQUENCY)
$
TABLED1 4
+       1.0     1.0     2.0     1.0
$
ENDDATA
```

2.26.2 Output

```
1








              GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
             G        E       NN  N   E       S          I     S
             G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
             G    G   E       N  NN   E            S     I          S
              GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                  STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE



                               COPYRIGHT, 1991-2002

                     VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                          ALL RIGHTS RESERVED, WORLDWIDE

                                   VERSION 7.2

                              BUILD CODE 200212131048




     PROJECT NAME: A026
     RUN STARTED:  Dec 13, 2002 12:50
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    1
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH ELEMENT STRUCTURAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCY

                              ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                        5
                   NUMBER OF CBAR ELEMENTS:                      4
                   TOTAL NUMBER OF NON RIGID ELEMENTS:           4
```

```
              NUMBER OF ELEMENT PROPERTIES:              1
              NUMBER OF MATERIALS:                       1
              NUMBER OF DEGREES OF FREEDOM:              8


                            LOAD CASES SUMMARY

             NUMBER OF USER FREQUENCY LOAD CASES:           1
             NUMBER OF DIRECT DYNAMIC LOAD CASES:           1
             NUMBER OF MODAL  DYNAMIC LOAD CASES:           1
             TOTAL NUMBER OF LOAD CASES:                    3

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    2
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH ELEMENT STRUCTURAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCY

              ********************************************
              *  D E S I G N  C Y C L E      0 (ANALYSIS)*
              ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    3
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH ELEMENT STRUCTURAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCY

                   M A S S / V O L U M E   S U M M A R Y

                   SYSTEM MASS              2.400000E-01
                   SYSTEM VOLUME            3.000000E+07
                   SYSTEM MASS/VOLUME       8.000000E-09
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    4
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH ELEMENT STRUCTURAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCY
 NATURAL FREQUENCIES (TO BE USED IN LOADCASE 3)              LOADCASE        1

                          E I G E N V A L U E S

                                                            GENERALIZED   GENERALIZED
   MODE        CYCLES       EIGENVALUE      RADIANS            MASS        STIFFNESS

       1  9.128302E+00  3.289575E+03  5.735481E+01  6.001558E-02  1.974257E+02
       2  5.719718E+01  1.291543E+05  3.593805E+02  5.994695E-02  7.742408E+03
       3  1.608664E+02  1.021622E+06  1.010753E+03  5.897694E-02  6.025216E+04
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    5
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH ELEMENT STRUCTURAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCY
 SOLUTION USING:  DIRECT DYNAMIC RESPONSE                    LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  8.6000E+00)

  GRID ID              T1                  T2                  T3
                       R1                  R2                  R3

                                    (MAGNITUDE/PHASE)

       5  MAGN   0.000000E+00       0.000000E+00       4.131863E+00
```

```
          MAGN   0.000000E+00      1.916311E-03      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.360961E+02
          PHASE  0.000000E+00      1.563295E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    6
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH ELEMENT STRUCTURAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCY
 SOLUTION USING:  DIRECT DYNAMIC RESPONSE                     LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  8.8000E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                    (MAGNITUDE/PHASE)

       5  MAGN   0.000000E+00      0.000000E+00      5.865974E+00
          MAGN   0.000000E+00      2.710126E-03      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.247887E+02
          PHASE  0.000000E+00      1.450351E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    7
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH ELEMENT STRUCTURAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCY
 SOLUTION USING:  DIRECT DYNAMIC RESPONSE                     LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.0000E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                    (MAGNITUDE/PHASE)

       5  MAGN   0.000000E+00      0.000000E+00      8.853634E+00
          MAGN   0.000000E+00      4.074254E-03      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      2.992584E+02
          PHASE  0.000000E+00      1.195181E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    8
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH ELEMENT STRUCTURAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCY
 SOLUTION USING:  DIRECT DYNAMIC RESPONSE                     LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.1283E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                    (MAGNITUDE/PHASE)

       5  MAGN   0.000000E+00      0.000000E+00      1.013120E+01
          MAGN   0.000000E+00      4.650014E-03      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      1.613684E+02
          PHASE  0.000000E+00      3.416371E+02      0.000000E+00
```

```
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    9
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH ELEMENT STRUCTURAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCY
 SOLUTION USING:  DIRECT DYNAMIC RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.2000E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                   (MAGNITUDE/PHASE)

        5  MAGN   0.000000E+00      0.000000E+00      9.657305E+00
           MAGN   0.000000E+00      4.425950E-03      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      2.525835E+02
           PHASE  0.000000E+00      7.285720E+01      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   10
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH ELEMENT STRUCTURAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCY
 SOLUTION USING:  DIRECT DYNAMIC RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.4000E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                   (MAGNITUDE/PHASE)

        5  MAGN   0.000000E+00      0.000000E+00      6.447469E+00
           MAGN   0.000000E+00      2.942451E-03      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      2.197053E+02
           PHASE  0.000000E+00      3.999351E+01      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   11
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH ELEMENT STRUCTURAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCY
 SOLUTION USING:  MODAL DYNAMIC RESPONSE                    LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  8.6000E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                   (MAGNITUDE/PHASE)

        5  MAGN   0.000000E+00      0.000000E+00      4.131863E+00
           MAGN   0.000000E+00      1.916311E-03      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.360961E+02
           PHASE  0.000000E+00      1.563295E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   12
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH ELEMENT STRUCTURAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCY
 SOLUTION USING:  MODAL DYNAMIC RESPONSE                    LOADCASE        3
```

```
 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  8.8000E+00)

  GRID ID                T1                  T2                  T3
                         R1                  R2                  R3

                                   (MAGNITUDE/PHASE)

        5  MAGN   0.000000E+00      0.000000E+00      5.865974E+00
           MAGN   0.000000E+00      2.710126E-03      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.247887E+02
           PHASE  0.000000E+00      1.450351E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   13
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH ELEMENT STRUCTURAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCY
 SOLUTION USING:  MODAL DYNAMIC RESPONSE                        LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.0000E+00)

  GRID ID                T1                  T2                  T3
                         R1                  R2                  R3

                                   (MAGNITUDE/PHASE)

        5  MAGN   0.000000E+00      0.000000E+00      8.853634E+00
           MAGN   0.000000E+00      4.074255E-03      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      2.992584E+02
           PHASE  0.000000E+00      1.195182E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   14
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH ELEMENT STRUCTURAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCY
 SOLUTION USING:  MODAL DYNAMIC RESPONSE                        LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.1283E+00)

  GRID ID                T1                  T2                  T3
                         R1                  R2                  R3

                                   (MAGNITUDE/PHASE)

        5  MAGN   0.000000E+00      0.000000E+00      1.013120E+01
           MAGN   0.000000E+00      4.650014E-03      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      1.613684E+02
           PHASE  0.000000E+00      3.416371E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   15
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH ELEMENT STRUCTURAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCY
 SOLUTION USING:  MODAL DYNAMIC RESPONSE                        LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.2000E+00)

  GRID ID                T1                  T2                  T3
```

```
                      R1                  R2                  R3

                                     (MAGNITUDE/PHASE)

        5  MAGN   0.000000E+00      0.000000E+00      9.657305E+00
           MAGN   0.000000E+00      4.425950E-03      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      2.525835E+02
           PHASE  0.000000E+00      7.285721E+01      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   16
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH ELEMENT STRUCTURAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCY
 SOLUTION USING:  MODAL DYNAMIC RESPONSE                        LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.4000E+00)

  GRID ID             T1                  T2                  T3
                      R1                  R2                  R3

                                     (MAGNITUDE/PHASE)

        5  MAGN   0.000000E+00      0.000000E+00      6.447469E+00
           MAGN   0.000000E+00      2.942451E-03      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      2.197053E+02
           PHASE  0.000000E+00      3.999352E+01      0.000000E+00

1                             ***** END OF OUTPUT *****
```

2.27 Dynamic Response of the Cantilevered Beam With and Without Modal Damping

Example ID:

A027

Analysis data used:

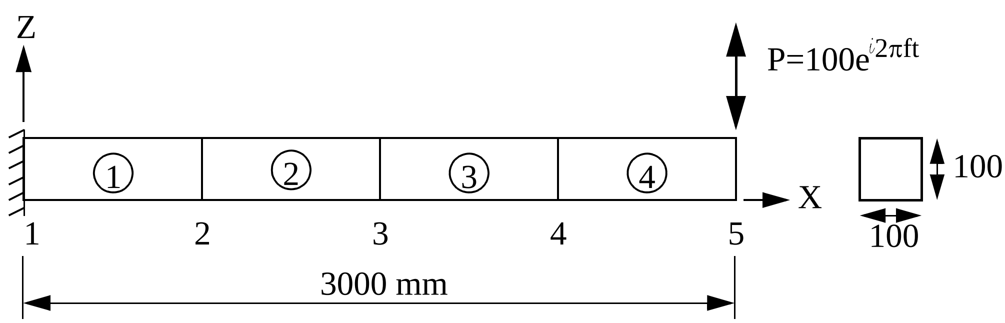
GRID, CBAR, PBAR, MAT1, LOADCASE, METHOD, DLOAD, FREQ, MODES, SDAMPING, DISP, EIGR, RLOAD1, DAREA, DELAY, TABLED1, TABDMP1

Special feature used:

Modal structural damping.

Problem statement:

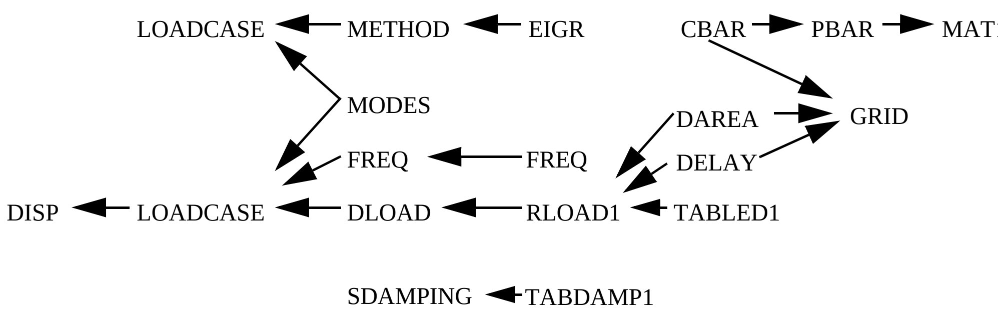
Find the magnitude of the tip displacement of the cantilever beam shown in the figure below. The beam is loaded with a tip point load of 100.0 N which is applied at 6 different frequencies. The frequencies cover a range that includes the first natural frequency of the beam. Use modal analysis with modal damping and use modal analysis without any kind of damping. Consider the first three modes in the two modal analyses.



Structural Analysis Model:

1. Four CBAR elements.
2. The section properties are: Area=10000 mm^2. I=8.3+6 mm^4
3. Material: E=2.07E+5 MPa. density=8.0-9 N-sec^2/mm^4.
4. One frequency load case, necessary for modal dynamic analysis.
5. One modal dynamic response load case. P=100 N with modal damping.
6. One modal dynamic response load case. P=100 N
7. Excitation frequencies for the problem are: f1=8.6 hz, f2=8.8 hz, f3=9.0 hz, f4=9.1283 hz, f5=9.2 hz, f6=9.4 hz.
8. The magnitude of the displacements are selected by using DYNOUTPUT=POLAR in the solution control. Modal structural damping is selected with parameter KDAMP = -1.
9. Damping is ge(f) = constant = 0.05

Analysis Data Relationships:



Special Modeling Techniques:

NONE.

Reference Solutions:

None. However, the damped solution can be compared with the modal damped solution of example A026. Because the damping is uniform in both examples the solution should be very close. The undamped solution can be verified at the frequency f=9.1283. The displacements there should be extremely large because that frequency is very close to the first natural frequency (9.128302).

Calculated Solutions:

Magnitude of Tip Displacement Using Modal Analysis		
Hz	**Modal Damping (mm)**	**Undamped (mm)**
8.6	4.1319	4.5219
8.8	5.8660	7.1863
9.0	8.8536	18.1618
9.1283	10.1312	1,080,290.0000*
9.2	9.6573	32.1024
9.4	6.4474	8.3685

* Resonance

Comparison Between Calculated Solutions and Reference Solutions:

The modal damped solution is very close to the damped solution in example A026 (differences are less than 0.01%). The undamped solution captures the resonance condition.

2.27.1 Input Data

```
ID A027
SOL COMPAT1
CEND
TITLE=DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH AND WITHOUT MODAL DAMPING
SUBTITLE=FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCIE.
LINE=64,80
ECHO=NONE
$
DYNOUTPUT = POLAR
SET 5 = 5
$
LOADCASE 1
LABEL = NATURAL FREQUENCIES (TO BE USED IN LOADCASES 2 & 3)
METHOD=4
$
LOADCASE 2
LABEL = LOADCASE USING:  MODAL DYNAMIC RESPONSE WITH MODAL DAMPING
DLOAD = 23
FREQ = 32
MODES=1
SDAMPING=1
DISP=5
$
LOADCASE 3
LABEL = LOADCASE USING:  MODAL DYNAMIC RESPONSE WITH OUT DAMPING
DLOAD = 23
FREQ = 32
MODES=1
DISP=5
$
BEGIN BULK
$
PARAM   KDAMP   -1
$
$    MODAL DAMPING
$
$    G(W) = 0.05 = CONSTANT (SAME DAMPING FOR EACH EXITING FREQUENCY)
$
TABDMP1 1       G
+       1.0     0.05    2.0     0.05
$
$    FREQUENCIES (FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCIES
$                 I.E. CLOSE TO FIRST RESONANCE MODE.)
$
FREQ    32      8.6     8.8     9.0     9.1283  9.2     9.4
$
$   GRID DATA (ONLY DISPLACEMENT IN Z AND ROTATIONS IN Y ARE REQUESTED)
$
GRID    1               0.00    0.      0.0             123456
GRID    2               750.0   0.      0.0             1246
GRID    3               1500.0  0.      0.0             1246
GRID    4               2250.0  0.      0.0             1246
```

```
GRID    5               3000.0  0.      0.0             1246
$
$   ELEMENT DEFINITIONS
$
CBAR    1       1       1       2       0.      1.0     0.
CBAR    2       1       2       3       0.      1.0     0.
CBAR    3       1       3       4       0.      1.0     0.
CBAR    4       1       4       5       0.      1.0     0.
$
$   PROPERTY DEFINITIONS
$
PBAR    1       1       1.0+4   8.333+6 8.333+6 0.0
$
$   MATERIAL DATA
$
MAT1    1       2.07+5          0.3     8.0-9
$
$   EIGENVALUES DATA
$
EIGR    4       SUB                             3       MAX
$
$   LOAD DEFINITION
$
RLOAD1  23      1       2               4
$
DAREA   1       5       3       100.0
DELAY   2       5       3       60.0
$
$    C(W) = 1.0 = CONSTANT (SAME VALUE FOR EACH EXITING FREQUENCY)
$
TABLED1 4
+       1.0     1.0     2.0     1.0
$
ENDDATA
```

2.27.2 Output

```
1
                GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
               G        E       NN  N   E       S          I     S
               G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
               G    G   E       N  NN   E            S     I          S
                GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                     STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                                  COPYRIGHT, 1991-2002

                        VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                             ALL RIGHTS RESERVED, WORLDWIDE

                                      VERSION 7.2

                                BUILD CODE 200212131048



     PROJECT NAME: A027
     RUN STARTED:  Dec 13, 2002 12:50
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    1
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH AND WITHOUT MODAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCIE.

                             ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                      5
                   NUMBER OF CBAR ELEMENTS:                    4
                   TOTAL NUMBER OF NON RIGID ELEMENTS:         4
```

```
                   NUMBER OF ELEMENT PROPERTIES:              1
                   NUMBER OF MATERIALS:                       1
                   NUMBER OF DEGREES OF FREEDOM:              8


                            LOAD CASES SUMMARY

                  NUMBER OF USER FREQUENCY LOAD CASES:          1
                  NUMBER OF MODAL  DYNAMIC LOAD CASES:          2
                  TOTAL NUMBER OF LOAD CASES:                   3

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    2
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH AND WITHOUT MODAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCIE.

                ********************************************
                *  D E S I G N  C Y C L E     0 (ANALYSIS)*
                ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    3
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH AND WITHOUT MODAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCIE.

                    M A S S / V O L U M E   S U M M A R Y

                    SYSTEM MASS              2.400000E-01
                    SYSTEM VOLUME            3.000000E+07
                    SYSTEM MASS/VOLUME       8.000000E-09
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    4
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH AND WITHOUT MODAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCIE.
 NATURAL FREQUENCIES (TO BE USED IN LOADCASES 2 & 3)         LOADCASE         1

                           E I G E N V A L U E S

                                                        GENERALIZED   GENERALIZED
   MODE        CYCLES      EIGENVALUE     RADIANS          MASS        STIFFNESS

       1  9.128302E+00  3.289575E+03  5.735481E+01  6.001558E-02  1.974257E+02
       2  5.719718E+01  1.291543E+05  3.593805E+02  5.994695E-02  7.742408E+03
       3  1.608664E+02  1.021622E+06  1.010753E+03  5.897694E-02  6.025216E+04
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    5
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH AND WITHOUT MODAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCIE.
 LOADCASE USING:  MODAL DYNAMIC RESPONSE WITH MODAL DAMPING   LOADCASE         2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  8.6000E+00)

  GRID ID               T1                  T2                  T3
                        R1                  R2                  R3

                                  (MAGNITUDE/PHASE)

       5  MAGN   0.000000E+00       0.000000E+00       4.131851E+00
          MAGN   0.000000E+00       1.916249E-03       0.000000E+00
```

```
          PHASE  0.000000E+00      0.000000E+00      3.360965E+02
          PHASE  0.000000E+00      1.563344E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    6
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH AND WITHOUT MODAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCIE.
 LOADCASE USING:  MODAL DYNAMIC RESPONSE WITH MODAL DAMPING   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  8.8000E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

       5  MAGN   0.000000E+00      0.000000E+00      5.865956E+00
          MAGN   0.000000E+00      2.710034E-03      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.247890E+02
          PHASE  0.000000E+00      1.450382E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    7
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH AND WITHOUT MODAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCIE.
 LOADCASE USING:  MODAL DYNAMIC RESPONSE WITH MODAL DAMPING   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.0000E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

       5  MAGN   0.000000E+00      0.000000E+00      8.853606E+00
          MAGN   0.000000E+00      4.074108E-03      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      2.992585E+02
          PHASE  0.000000E+00      1.195195E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    8
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH AND WITHOUT MODAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCIE.
 LOADCASE USING:  MODAL DYNAMIC RESPONSE WITH MODAL DAMPING   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.1283E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

       5  MAGN   0.000000E+00      0.000000E+00      1.013117E+01
          MAGN   0.000000E+00      4.649840E-03      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      1.613684E+02
          PHASE  0.000000E+00      3.416372E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    9
```

```
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH AND WITHOUT MODAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCIE.
 LOADCASE USING:  MODAL DYNAMIC RESPONSE WITH MODAL DAMPING   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.2000E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                   (MAGNITUDE/PHASE)

        5  MAGN   0.000000E+00      0.000000E+00      9.657273E+00
           MAGN   0.000000E+00      4.425781E-03      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      2.525834E+02
           PHASE  0.000000E+00      7.285665E+01      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   10
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH AND WITHOUT MODAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCIE.
 LOADCASE USING:  MODAL DYNAMIC RESPONSE WITH MODAL DAMPING   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.4000E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                   (MAGNITUDE/PHASE)

        5  MAGN   0.000000E+00      0.000000E+00      6.447446E+00
           MAGN   0.000000E+00      2.942332E-03      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      2.197051E+02
           PHASE  0.000000E+00      3.999103E+01      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   11
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH AND WITHOUT MODAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCIE.
 LOADCASE USING:  MODAL DYNAMIC RESPONSE WITH OUT DAMPING     LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  8.6000E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                   (MAGNITUDE/PHASE)

        5  MAGN   0.000000E+00      0.000000E+00      4.521913E+00
           MAGN   0.000000E+00      2.096748E-03      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.600000E+02
           PHASE  0.000000E+00      1.800000E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   12
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH AND WITHOUT MODAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCIE.
 LOADCASE USING:  MODAL DYNAMIC RESPONSE WITH OUT DAMPING     LOADCASE        3
```

```
 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  8.8000E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                     (MAGNITUDE/PHASE)

        5  MAGN   0.000000E+00      0.000000E+00      7.186289E+00
           MAGN   0.000000E+00      3.319345E-03      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      2.515948E-11
           PHASE  0.000000E+00      1.800000E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   13
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH AND WITHOUT MODAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCIE.
 LOADCASE USING:  MODAL DYNAMIC RESPONSE WITH OUT DAMPING    LOADCASE         3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.0000E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                     (MAGNITUDE/PHASE)

        5  MAGN   0.000000E+00      0.000000E+00      1.816175E+01
           MAGN   0.000000E+00      8.355583E-03      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.600000E+02
           PHASE  0.000000E+00      1.800000E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   14
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH AND WITHOUT MODAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCIE.
 LOADCASE USING:  MODAL DYNAMIC RESPONSE WITH OUT DAMPING    LOADCASE         3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.1283E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                     (MAGNITUDE/PHASE)

        5  MAGN   0.000000E+00      0.000000E+00      1.080290E+06
           MAGN   0.000000E+00      4.957038E+02      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      2.512800E+02
           PHASE  0.000000E+00      7.128000E+01      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   15
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH AND WITHOUT MODAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCIE.
 LOADCASE USING:  MODAL DYNAMIC RESPONSE WITH OUT DAMPING    LOADCASE         3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.2000E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3
```

```
                                   (MAGNITUDE/PHASE)

         5  MAGN   0.000000E+00      0.000000E+00      3.210236E+01
            MAGN   0.000000E+00      1.470868E-02      0.000000E+00
            PHASE  0.000000E+00      0.000000E+00      1.800000E+02
            PHASE  0.000000E+00      3.600000E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   16
 DYNAMIC RESPONSE OF THE CANTILEVER BEAM WITH AND WITHOUT MODAL DAMPING
 FREQUENCIES ARE CLOSE TO THE FIRST NATURAL FREQUENCIE.
 LOADCASE USING:  MODAL DYNAMIC RESPONSE WITH OUT DAMPING    LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.4000E+00)

  GRID ID              T1                  T2                  T3
                       R1                  R2                  R3

                                   (MAGNITUDE/PHASE)

         5  MAGN   0.000000E+00      0.000000E+00      8.368456E+00
            MAGN   0.000000E+00      3.818078E-03      0.000000E+00
            PHASE  0.000000E+00      0.000000E+00      1.800000E+02
            PHASE  0.000000E+00      6.741409E-12      0.000000E+00

1                             ***** END OF OUTPUT *****
```

2.28 Dynamic Response of a CELAS1/CDAMP1/CMASS1 Structure

Example ID:

A028

Analysis Data Used:

SPOINT, CELAS1, CDAMP1, CMASS1, PELAS, PDAMP, PMASS, LOADCASE, FREQ, SPC, DLOAD, DISP, VELO, ACCE, FORCE, STRESS, FREQ, RLOAD3, SPC1

Special Features Used:

Utilization of scalar point (SPOINT) and the scalar elements CDAMP1 and CMASS1.

Problem Statement:

Find the displacement, velocity and acceleration at the free degree of freedom of the scalar point 2 shown in the figure below. Obtain the elastic stress and force of the elastic element and the force acting in the damper. Verify that the forces of the structure are in dynamic equilibrium.

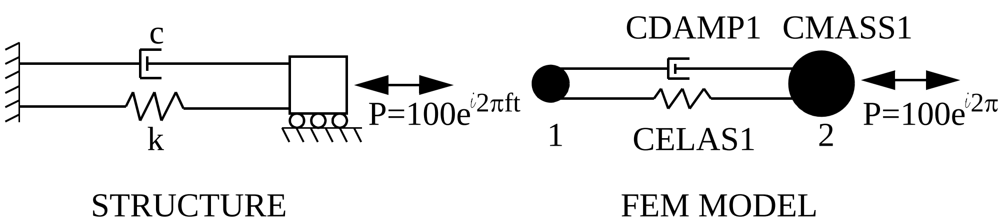
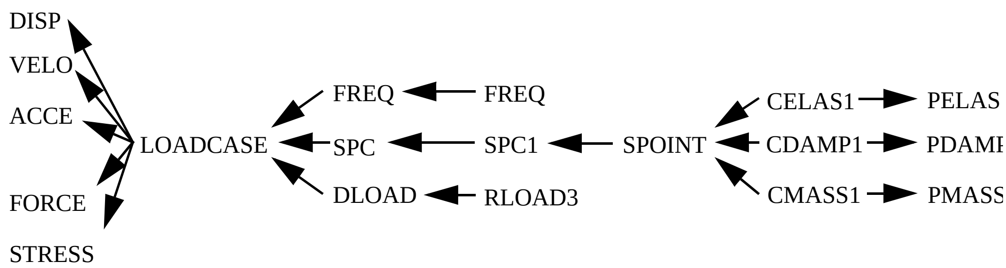


Figure 2-30

Structural Analysis Model:

1. One degree of freedom structure assembled with one CELAS1 element one CDAMP1 element and one CMASS1 element. Elements are connected using two scalar points (SPOINT).
2. Properties of CELAS1: k=10, S=0.1
3. Properties of CDAMP1: c=2.5
4. Properties of CMASS1: m=2.5
5. One Load case: P=100.0, applied at a frequency f=0.159155 hz.

Analysis Data Relationships:



Special Modeling Techniques:

NONE

Reference Solutions:

The analytical solution for this problem is:

$$u2 = \frac{P}{k - ((2\pi f)^2 m + (2\pi f)ci)} = 12 - 4i$$

$$v2 = (2\pi f)ui = 4 + 12i$$

$$a2 = (2\pi f)vi = -12 + 4i$$

Force elas1 = k(u1-u2) = -120 + 40i
Stress elas1 = S**x**Force elas1 = -12 + 4i
Force damp1 = c(v1-v2) = -10.0 - 30i
Inertial Force = m (a1-a2) = 30 - 10i
where: P is the applied load, k is the elas1 stiffness, m is the mass, c the viscous coefficient, i is the imaginary number (square root of -1) and pi is 3.141592.

Calculated solution:

u2 = 12 - 4i
v2 = 4 + 12i
a2 = -12 + 4i
Force elas1 = -120 + 40i
Stress elas1 = -12 + 4i
Force damp1 = -10.0 - 30i
Inertial Force = m (a1-a2) = 30 - 10i (*)
Note: Inertial forces are not calculated in the program. a1=0.

Comparison Between Calculated Solution And Reference Solution

There are no differences between the analytical solution and calculated solution.

2.28.1 Input Data

```
ID A028
SOL COMPAT1
CEND
$
TITLE=DYNAMIC RESPONSE OF THE ELAS1/DAMP1/MASS1 STRUCTURE
LINE=64,80
ECHO=NONE
$
LOADCASE 1
LABEL = DIRECT DYNAMIC RESPONSE.
FREQ = 100
SPC=1
DLOAD = 200
DISP=ALL
VELO=ALL
ACCE=ALL
FORCE=ALL
STRESS=ALL
$
BEGIN BULK
$
$    FREQUENCIES
$
FREQ    100     0.159155
$
$   BOUNDARY CONDITION
$
SPC1    1               1
$
$   SPOINT DATA
$
SPOINT  1       2
$
$   ELEMENT DEFINITIONS
$
CELAS1  1       1       1               2
CDAMP1  2       2       1               2
CMASS1  3       3       2
$
$
$   PROPERTY DEFINITIONS
$
PELAS   1       10.0            0.1
PDAMP   2       2.5
PMASS   3       2.5
$
$   LOAD DEFINITION
$
RLOAD3  200     2               100.0
$
ENDDATA
```

2.28.2 Output

```
1









                 GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
                G        E       NN  N   E       S          I     S
                G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
                G    G   E       N  NN   E            S     I          S
                 GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                     STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE



                                  COPYRIGHT, 1991-2002

                        VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                             ALL RIGHTS RESERVED, WORLDWIDE

                                      VERSION 7.2

                                 BUILD CODE 200212131048




     PROJECT NAME: A028
     RUN STARTED:  Dec 13, 2002 12:50
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    1
 DYNAMIC RESPONSE OF THE ELAS1/DAMP1/MASS1 STRUCTURE


                                 ANALYSIS PROBLEM SUMMARY

                   NUMBER OF SPOINTS:                          2
                   NUMBER OF CELAS1/2 ELEMENTS:                1
                   NUMBER OF CDAMP1/2 ELEMENTS:                1
```

```
                    NUMBER OF CMASS1/2 ELEMENTS:                1
                    TOTAL NUMBER OF NON RIGID ELEMENTS:         3
                    NUMBER OF ELEMENT PROPERTIES:               3
                    NUMBER OF DEGREES OF FREEDOM:               1


                                LOAD CASES SUMMARY

                   NUMBER OF DIRECT DYNAMIC LOAD CASES:           1
                   TOTAL NUMBER OF LOAD CASES:                    1

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    2
 DYNAMIC RESPONSE OF THE ELAS1/DAMP1/MASS1 STRUCTURE


                ********************************************
                *  D E S I G N  C Y C L E     0 (ANALYSIS)*
                ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    3
 DYNAMIC RESPONSE OF THE ELAS1/DAMP1/MASS1 STRUCTURE


                    M A S S / V O L U M E   S U M M A R Y

                    SYSTEM MASS              2.500000E+00
                    SYSTEM VOLUME            0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    4
 DYNAMIC RESPONSE OF THE ELAS1/DAMP1/MASS1 STRUCTURE

 DIRECT DYNAMIC RESPONSE.                                    LOADCASE        1

 S P O I N T  D Y N A M I C   D I S P L A C E M E N T S (FREQUENCY = 1.5915E-01)

 SPOINT ID          REAL           IMAGINARY

       1      0.000000E+00      0.000000E+00
       2      1.200000E+01     -4.000003E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    5
 DYNAMIC RESPONSE OF THE ELAS1/DAMP1/MASS1 STRUCTURE

 DIRECT DYNAMIC RESPONSE.                                    LOADCASE        1

 S P O I N T  D Y N A M I C   V E L O C I T I E S (FREQUENCY =  1.5915E-01)

 SPOINT ID          REAL           IMAGINARY

       1      0.000000E+00      0.000000E+00
       2      4.000004E+00      1.200001E+01
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    6
 DYNAMIC RESPONSE OF THE ELAS1/DAMP1/MASS1 STRUCTURE

 DIRECT DYNAMIC RESPONSE.                                    LOADCASE        1

 S P O I N T  D Y N A M I C   A C C E L E R A T I O N S (FREQUENCY = 1.5915E-01)
```

```
 SPOINT ID          REAL           IMAGINARY

       1      0.000000E+00      0.000000E+00
       2     -1.200001E+01      4.000006E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    7
 DYNAMIC RESPONSE OF THE ELAS1/DAMP1/MASS1 STRUCTURE

 DIRECT DYNAMIC RESPONSE.                                    LOADCASE        1

  F O R C E S   I N   E L A S   E L E M E N T S   (FREQUENCY =  1.5915E-01)

 ELAS1 ID            REAL FORCE              IMAG FORCE

       1          -1.200000E+02           4.000003E+01
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    8
 DYNAMIC RESPONSE OF THE ELAS1/DAMP1/MASS1 STRUCTURE

 DIRECT DYNAMIC RESPONSE.                                    LOADCASE        1

  F O R C E S   I N   D A M P   E L E M E N T S   (FREQUENCY =  1.5915E-01)

 DAMP1 ID            REAL FORCE              IMAG FORCE

       2          -1.000001E+01          -3.000001E+01
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    9
 DYNAMIC RESPONSE OF THE ELAS1/DAMP1/MASS1 STRUCTURE

 DIRECT DYNAMIC RESPONSE.                                    LOADCASE        1

  S T R E S S E S   I N   E L A S   E L E M E N T S   (FREQUENCY =  1.5915E-01)

 ELAS1 ID               STRESS                   STRESS

       1      REAL  -1.200000E+01      IMAG   4.000003E+00
1                            ***** END OF OUTPUT *****
```

2.29 Three Rod Truss - Analysis Using Multidisciplinary Load Cases

Example ID:

A029

Analysis data used:

GRID, GRDSET, CROD, PROD, MAT1, MAT4, LOADCASE, HEAT, TEMP, LOAD, METHOD, FREQ, DLOAD, MODES, SDAMPING, SPC, QHBDY, SPCD, SPC1, FORCE, EIGR, FREQ, RLOAD1, TABLED1, TABDMP1, THERMAL, DISP, STRESS

Special Feature Used:

Multiple load case types

Problem Statement:

The three rod truss of **Figure 2-31** is subjected to five different loadcases. The first load case corresponds to a heat transfer analysis. The second to a static analysis where the results of the heat transfer analysis are used to create thermal loads. The third load case corresponds to a frequency calculation analysis. This load case is used to calculate the first two natural frequencies and also is used for the fifth load case. The forth load case corresponds to a direct dynamic response analysis in which a point load is applied at a frequency of 20 hz. The last loadcase is a modal dynamic response analysis. In this load case another point load is applied also at a frequency of 20 hz. Considering the geometry described for example A001 and modal damping of 5% for the fifth load case find:

1. For the heat transfer loadcase, the temperature at grid 4.
2. For the static load case, the displacements u4 and v4 at grid 4 and the stresses at the three rods.
3. For the normal mode analysis, the first natural frequency. Do not consider an extra mass element as it is in the A009 example.
4. For the direct frequency response analysis, find the magnitudes of the dynamic displacements u4 and v4 of grid 4.

5. For the modal frequency response analysis find the magnitudes of the dynamic displacements u4 and v4 of grid 4.

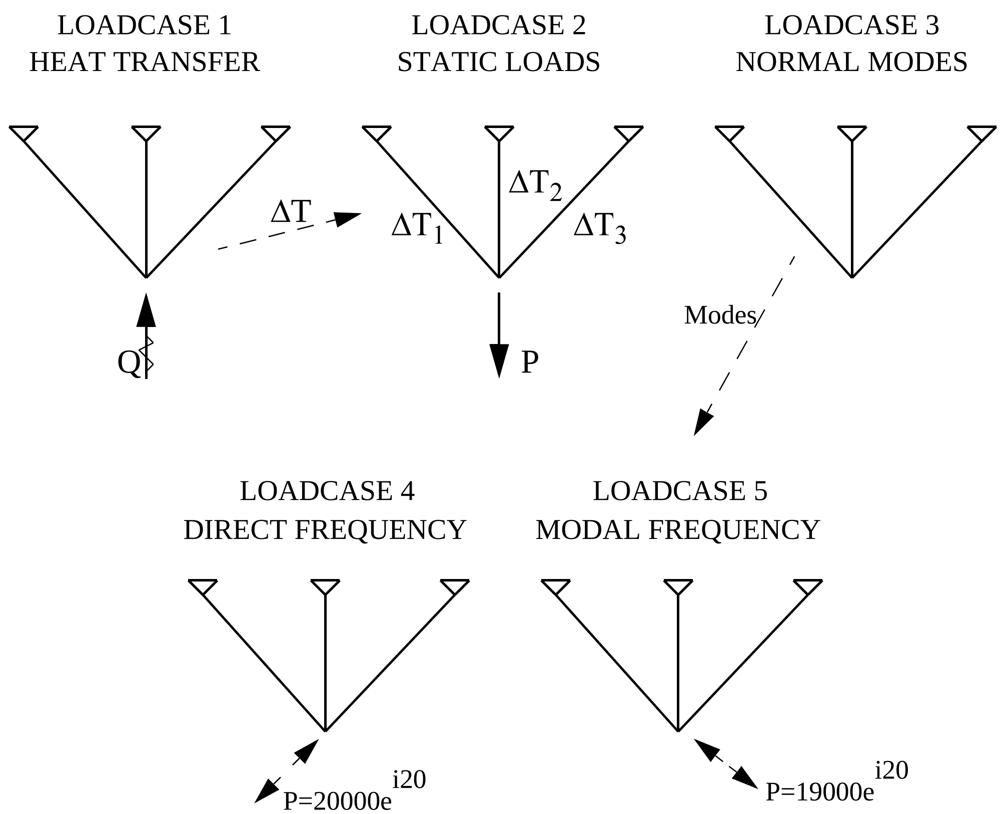


Figure 2-31

Structural Analysis Model:

1. Three CROD elements.
2. Section properties: A1=A3=1.0, A2=2.0
3. Material: E=1.0+7 psi, Conductivity = 70.0
4. Five load cases

   Conduction heat transfer due to a heat flux of Q_0 = 100.0 at grid 4.

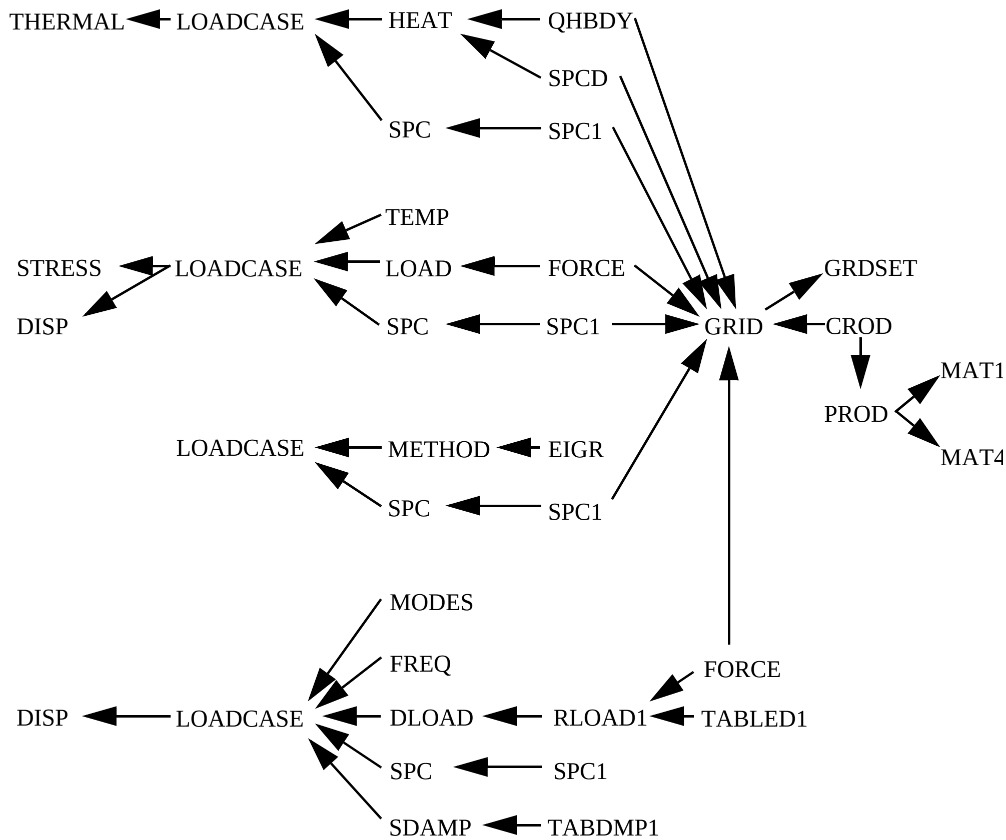
   Static analysis: P2=20000 and TEMP due to heat conduction.

   Natural vibrations. Distributed mass: m=0.1.

   Direct dynamic response P4=20000, f=20 hz.

   Modal dynamic response P5=19000, f=20 hz, modal damping ge=5%.

Analysis Data Relationships:



Special Modeling Techniques:

NONE

Reference Solutions:

NONE

Calculated Solutions:

Heat transfer Analysis:
T4 = 29.18
Static analysis:
U4 = 0.0
V4 = -0.0073
SXX_1 = 3,691.361
SXX_2 = 7,389.814
SXX_3 = 3,691.361
Normal modes analysis:
f1 = 105.5
Direct dynamic response (undamped solutions):
U4 = 0.002347
V4 = 0.004475
Modal dynamic response (damped solutions):
U4 = 0.02230
V4 = 0.00425

2.29.1 Input Data

```
ID A029
SOL COMPAT1
CEND
TITLE = THREE ROD TRUSS - MULTIDICIPLINARY ANALYSIS
ECHO=NONE
LINE = 64,80
DYNOUTPUT = POLAR
LOADCASE 1
LABEL = HEAT TRANSFER LOACASE
SPC=50
HEAT=50
THERMAL=ALL
LOADCASE 2
LABEL = STATIC LOADCASE: USES TEMPERATURE LOADING GENERATED BY HEAT TRANSFER
SPC=100
TEMP=1
LOAD=100
DISP = ALL
STRESS = ALL
LOADCASE 3
LABEL = NATURAL FREQUENCY LOACASE
SPC=100
METHOD=300
LOADCASE 4
LABEL = FREQUENCY RESPONSE LOADCASE USING DIRECT DYNAMIC ANALYSIS
SPC=100
FREQ=200
DLOAD=400
DISP = ALL
LOADCASE 5
LABEL = FREQUENCY RESPONSE LOADCASE USING MODAL DYNAMIC ANALYSIS AND MODAL
DAMPING
FREQ=200
DLOAD=500
MODES=3
SDAMPING=500
DISP = ALL
BEGIN BULK
$
$---- FREQUENCY DEFINITION
$
FREQ    200     20.0
$
$---- ANALYSIS DATA
$
$ GRID DATA
GRID    1               -10.    0.0     0.0
GRID    2               0.0     0.0     0.0
GRID    3               10.0    0.0     0.0
GRID    4               0.0     -10.0   0.0
$ STRUCTURAL BOUNDARY CONDITION DATA
GRDSET                                                  3456
SPC1    100     123456  1       2       3
```

```
SPC1    100     3456    4
$ THERMAL BOUNDARY CONDITION DATA
SPC1    50              1       2       3
SPCD    50      1               25.0
SPCD    50      2               25.0
SPCD    50      3               25.0
$ ELEMENT DATA
CROD    1       11      1       4
CROD    2       12      2       4
CROD    3       13      3       4
$ PROPERTY AND MATERIAL DATA
PROD    11      1       1.0
PROD    12      1       2.0
PROD    13      1       1.0
MAT1    1       1.0E+7          0.33    0.1     0.1E-6  20.0
MAT4    1       70.0
$ HEAT TRANSFER LOAD
QHBDY   50      POINT   100.0   1.0     4
$ EIGENVALUE METHOD
EIGR    300     SUB                             2       MASS
$ STATIC LOAD
FORCE   100     4               20000.  0.0     -1.0
$ DYNAMIC LOAD
TABLED1 45
+       1.0     1.0     100.0   1.0
RLOAD1  400                             45              444
FORCE   444     4               20000.  -0.8    -0.6
RLOAD1  500                             45              555
FORCE   555     4               19000.  0.8     -0.6
$ MODAL DAMPING
TABDMP1 500     G
+       1.0     0.05    100.0   0.05
ENDDATA
```

2.29.2 Output

```
1









            GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
           G        E       NN  N   E       S          I     S
           G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
           G    G   E       N  NN   E            S     I          S
            GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                 STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE



                              COPYRIGHT, 1991-2002

                    VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                         ALL RIGHTS RESERVED, WORLDWIDE

                                  VERSION 7.2

                            BUILD CODE 200212131048




     PROJECT NAME: A029
     RUN STARTED:  Dec 13, 2002 12:50
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    1
 THREE ROD TRUSS - MULTIDICIPLINARY ANALYSIS


                            ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                      4
                   NUMBER OF CROD ELEMENTS:                    3
                   TOTAL NUMBER OF NON RIGID ELEMENTS:         3
```

```
                   NUMBER OF ELEMENT PROPERTIES:             3
                   NUMBER OF MATERIALS:                      1
                   NUMBER OF DEGREES OF FREEDOM:             2
                   NUMBER OF THERMAL DEGREES OF FREEDOM:     4


                         LOAD CASES SUMMARY

                  NUMBER OF STATIC LOAD CASES:                  1
                  NUMBER OF USER FREQUENCY LOAD CASES:          1
                  NUMBER OF HEAT TRANSFER LOAD CASES:           1
                  NUMBER OF DIRECT DYNAMIC LOAD CASES:          1
                  NUMBER OF MODAL  DYNAMIC LOAD CASES:          1
                  TOTAL NUMBER OF LOAD CASES:                   5
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    2
 THREE ROD TRUSS - MULTIDICIPLINARY ANALYSIS


               ********************************************
               *  D E S I G N  C Y C L E      0 (ANALYSIS)*
               ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    3
 THREE ROD TRUSS - MULTIDICIPLINARY ANALYSIS


                    M A S S / V O L U M E   S U M M A R Y

                    SYSTEM MASS             4.828427E+00
                    SYSTEM VOLUME           4.828427E+01
                    SYSTEM MASS/VOLUME      1.000000E-01
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    4
 THREE ROD TRUSS - MULTIDICIPLINARY ANALYSIS


              H E A T   S O L U T I O N   R E S I D U A L S

 LOADCASE        1 ; RESIDUAL : -1.630235E-14 ;   HEAT ENERGY 2.092094E+02
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    5
 THREE ROD TRUSS - MULTIDICIPLINARY ANALYSIS

 HEAT TRANSFER LOACASE                                    LOADCASE         1

                     G R I D   T E M P E R A T U R E S

  GRID ID          TEMP

        1      2.500000E+01
        2      2.500000E+01
        3      2.500000E+01
        4      2.918419E+01
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    6
 THREE ROD TRUSS - MULTIDICIPLINARY ANALYSIS
```

```
                   S O L U T I O N   R E S I D U A L S

 LOADCASE        2 ; RESIDUAL :  0.000000E+00 ; STRAIN ENERGY :  7.405861E+01
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    7
 THREE ROD TRUSS - MULTIDICIPLINARY ANALYSIS


                     O L O A D   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      2  0.0000E+00 -2.0000E+04  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    8
 THREE ROD TRUSS - MULTIDICIPLINARY ANALYSIS


                   S P C F O R C E   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      2  0.0000E+00  2.0000E+04  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    9
 THREE ROD TRUSS - MULTIDICIPLINARY ANALYSIS


               M A X I M U M   A P P L I E D   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1           T2           T3

       2        4     2.0024E+04  0.0000E+00 -2.0024E+04  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   10
 THREE ROD TRUSS - MULTIDICIPLINARY ANALYSIS


                   M A X I M U M   S P C   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1           T2           T3

       2        2     1.4780E+04  0.0000E+00  1.4780E+04  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   11
 THREE ROD TRUSS - MULTIDICIPLINARY ANALYSIS


                  M A X I M U M   D I S P L A C E M E N T

 LOADCASE GRID ID      MAGNITUDE      T1           T2           T3

       2        4     7.3969E-03  0.0000E+00 -7.3969E-03  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   12
 THREE ROD TRUSS - MULTIDICIPLINARY ANALYSIS

 STATIC LOADCASE: USES TEMPERATURE LOADING GENERATED BY HEAT  LOADCASE        2

                      G R I D   D I S P L A C E M E N T S
```

```
  GRID ID           T1                  T2                  T3
                    R1                  R2                  R3

        1      0.000000E+00      0.000000E+00      0.000000E+00
               0.000000E+00      0.000000E+00      0.000000E+00

        2      0.000000E+00      0.000000E+00      0.000000E+00
               0.000000E+00      0.000000E+00      0.000000E+00

        3      0.000000E+00      0.000000E+00      0.000000E+00
               0.000000E+00      0.000000E+00      0.000000E+00

        4      0.000000E+00     -7.396906E-03      0.000000E+00
               0.000000E+00      0.000000E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   13
 THREE ROD TRUSS - MULTIDICIPLINARY ANALYSIS

 STATIC LOADCASE: USES TEMPERATURE LOADING GENERATED BY HEAT  LOADCASE        2

             S T R E S S E S   I N   R O D   E L E M E N T S

   ROD ID          STRESS-A            STRESS-B

        1        3.691361E+03        3.691361E+03
        2        7.389814E+03        7.389814E+03
        3        3.691361E+03        3.691361E+03
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   14
 THREE ROD TRUSS - MULTIDICIPLINARY ANALYSIS

 NATURAL FREQUENCY LOACASE                                    LOADCASE        3

                           E I G E N V A L U E S

                                                             GENERALIZED   GENERALIZED
   MODE       CYCLES      EIGENVALUE     RADIANS           MASS        STIFFNESS

        1  1.054922E+02  4.393398E+05  6.628271E+02  1.000000E+00  4.393398E+05
        2  2.064099E+02  1.681981E+06  1.296912E+03  1.000000E+00  1.681981E+06
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   15
 THREE ROD TRUSS - MULTIDICIPLINARY ANALYSIS

 FREQUENCY RESPONSE LOADCASE USING DIRECT DYNAMIC ANALYSIS    LOADCASE        4

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  2.0000E+01)

  GRID ID              T1                  T2                  T3
                       R1                  R2                  R3

                              (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00
```

```
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        2  MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        3  MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        4  MAGN   2.347105E-02      4.474789E-03      0.000000E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  1.800000E+02      1.800000E+02      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   16
 THREE ROD TRUSS - MULTIDICIPLINARY ANALYSIS

 FREQUENCY RESPONSE LOADCASE USING MODAL DYNAMIC ANALYSIS AND LOADCASE        5

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  2.0000E+01)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                  (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        2  MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        3  MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        4  MAGN   2.229642E-02      4.250998E-03      0.000000E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  3.594366E+02      1.797198E+02      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

1                            ***** END OF OUTPUT *****
```

2.30 Thin Axisymmetric Annulus

Example ID:

A030

Analysis Data:

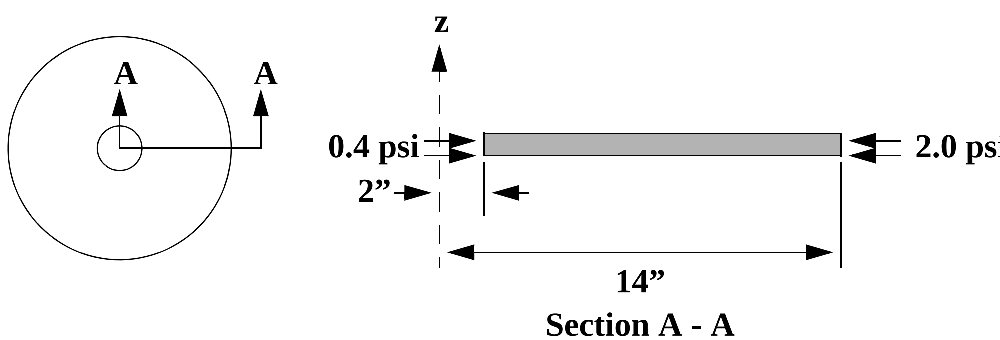
GRDSET, GRID, CTRIAX6, PAXIS, PLOADX1, RFORCE, LOADCASE, LOAD, GRDSET, SPC, SPC1, MAT1

Special Features Used:

None

Problem Statement:

Find the circumferential stresses at the inner and outer surfaces of a thin axisymmetric annulus for separate loading conditions of centrifugal loading and combined inner and outer pressure.



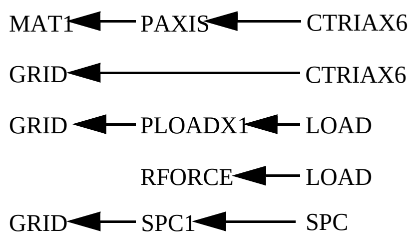
Structural Analysis Model:

1. Axisymmetric model composed of 24 CTRIAX6 elements.
2. Inner radius (a) = 2.0 Outer radius (b) = 14.0
3. Material: E=10.0E+6, ν = 0.3, ρ = 0.1
4. Two load cases:

   ω = 0.2 revolutions per unit time

   ρ_i = 0.4; ρ_o = 2.0

Analysis Data Relationships:



Special Modeling Techniques:

None.

Reference Solutions:

For centrifugal loading, the analytical solution is:

1. At inner surface (r = a): $\sigma_{\theta\theta} = \frac{3+\upsilon}{4}\rho\omega^2 b^2\left[1 + \frac{1-\upsilon}{3+\upsilon}\left(\frac{a}{b}\right)^2\right]$ = 25.6096 psi
2. At outer surface (r = b): $\sigma_{\theta\theta} = \frac{3+\upsilon}{4}\rho\omega^2 b^2\left[\left(\frac{a}{b}\right)^2 + \frac{1-\upsilon}{3+\upsilon}\right]$ = 5.9376 psi

For pressure loading, the analytical solution is:

1. At inner surface (r = a): $\sigma_{\theta\theta} = \frac{p_i(a^2+b^2) - 2p_o b^2}{b^2 - a^2}$ = -3.6667 psi
2. At outer surface (r = b): $\sigma_{\theta\theta} = \frac{2p_i a^2 - p_o(a^2+b^2)}{b^2 - a^2}$ = -2.0667

where: p_i = inner surface pressurem, p_o = outer surface pressure.

Calculated Solutions:

For the centrifugal loading loadcase:

1. At r = a: $\sigma_{\theta\theta}$ = 24.26129
2. At r = b: $\sigma_{\theta\theta}$ = 5.953738

For the pressure loadcase:

1. At r = a: $\sigma_{\theta\theta}$ = = -3.486024
2. At r = b: $\sigma_{\theta\theta}$ = = -2.066367

Comparison Between Calculated Solutions and Reference Solutions:

The differences between the analytical solutions and the *GENESIS* solutions are:
For the centrifugal loading loadcase:

1. At r = a: -5.3%
2. At r = b: 0.3%

For the pressure loadcase:

1. At r = a: -4.9%
2. At r = b: -0.01%

The error at the inner surface (r=a) is due to the high stress gradient at this point.

2.30.1 Input Data

```
ID A030
SOL COMPAT1
CEND

TITLE=Analysis of a thin axisymmetric annulus
ECHO=NONE
LINE=*,80

LOADCASE 30
    LABEL = Centrifugal loading
    CENT=300
    SPC =200
    OLOAD = ALL
    DISPLACEMENT=ALL
    STRESS = ALL
    STRAIN = ALL
    GSTRESS = ALL

LOADCASE 60
    LABEL = Inner and outer pressure loading
    LOAD=600
    SPC =200
    OLOAD = ALL
    DISPLACEMENT=ALL
    STRESS = ALL
    STRAIN = ALL
    GSTRESS = ALL

BEGIN BULK
$                               Analysis Data
$
$   STRUCTURAL LOAD DATA
$
$------12------23------34------45------56------67------78------89------9
RFORCE  300                     0.2     0.0     0.0     1.0
$
PLOADX1 600     306     2.0     2.0     113     313
PLOADX1 600     307     2.0     2.0     313     513
PLOADX1 600     102     0.4     0.4     101     301
PLOADX1 600     103     0.4     0.4     301     501
$
$   GRID DATA
$
$------12------23------34------45------56------67------78------89------9
GRDSET                                                  2456
GRID    101             2.0     0.0     3.0
GRID    102             3.0     0.0     3.0
GRID    103             4.0     0.0     3.0
GRID    104             5.0     0.0     3.0
GRID    105             6.0     0.0     3.0
GRID    106             7.0     0.0     3.0
GRID    107             8.0     0.0     3.0
```

```
GRID    108             9.0     0.0     3.0
GRID    109             10.0    0.0     3.0
GRID    110             11.0    0.0     3.0
GRID    111             12.0    0.0     3.0
GRID    112             13.0    0.0     3.0
GRID    113             14.0    0.0     3.0

GRID    201             2.0     0.0     3.25
GRID    202             3.0     0.0     3.25
GRID    203             4.0     0.0     3.25
GRID    204             5.0     0.0     3.25
GRID    205             6.0     0.0     3.25
GRID    206             7.0     0.0     3.25
GRID    207             8.0     0.0     3.25
GRID    208             9.0     0.0     3.25
GRID    209             10.0    0.0     3.25
GRID    210             11.0    0.0     3.25
GRID    211             12.0    0.0     3.25
GRID    212             13.0    0.0     3.25
GRID    213             14.0    0.0     3.25

GRID    301             2.0     0.0     3.5
GRID    302             3.0     0.0     3.5
GRID    303             4.0     0.0     3.5
GRID    304             5.0     0.0     3.5
GRID    305             6.0     0.0     3.5
GRID    306             7.0     0.0     3.5
GRID    307             8.0     0.0     3.5
GRID    308             9.0     0.0     3.5
GRID    309             10.0    0.0     3.5
GRID    310             11.0    0.0     3.5
GRID    311             12.0    0.0     3.5
GRID    312             13.0    0.0     3.5
GRID    313             14.0    0.0     3.5

GRID    401             2.0     0.0     3.75
GRID    402             3.0     0.0     3.75
GRID    403             4.0     0.0     3.75
GRID    404             5.0     0.0     3.75
GRID    405             6.0     0.0     3.75
GRID    406             7.0     0.0     3.75
GRID    407             8.0     0.0     3.75
GRID    408             9.0     0.0     3.75
GRID    409             10.0    0.0     3.75
GRID    410             11.0    0.0     3.75
GRID    411             12.0    0.0     3.75
GRID    412             13.0    0.0     3.75
GRID    413             14.0    0.0     3.75

GRID    501             2.0     0.0     4.0
GRID    502             3.0     0.0     4.0
GRID    503             4.0     0.0     4.0
GRID    504             5.0     0.0     4.0
GRID    505             6.0     0.0     4.0
GRID    506             7.0     0.0     4.0
```

```
GRID    507             8.0     0.0     4.0
GRID    508             9.0     0.0     4.0
GRID    509             10.0    0.0     4.0
GRID    510             11.0    0.0     4.0
GRID    511             12.0    0.0     4.0
GRID    512             13.0    0.0     4.0
GRID    513             14.0    0.0     4.0
$
$   BOUNDARY CONDITIONS
$
SPC1    200     23456   301
$
$   ELEMENT DATA
$
$------12------23------34------45------56------67------78------89------9
CTRIAX6 101     101     101     102     103     203     303     202
CTRIAX6 102     101     101     202     303     302     301     201
CTRIAX6 103     101     301     302     303     402     501     401
CTRIAX6 104     101     501     402     303     403     503     502

CTRIAX6 105     101     103     104     105     204     303     203
CTRIAX6 106     101     105     205     305     304     303     204
CTRIAX6 107     101     303     304     305     405     505     404
CTRIAX6 108     101     303     404     505     504     503     403

CTRIAX6 201     101     105     106     107     207     307     206
CTRIAX6 202     101     105     206     307     306     305     205
CTRIAX6 203     101     305     306     307     406     505     405
CTRIAX6 204     101     505     406     307     407     507     506

CTRIAX6 205     101     107     108     109     208     307     207
CTRIAX6 206     101     109     209     309     308     307     208
CTRIAX6 207     101     307     308     309     409     509     408
CTRIAX6 208     101     307     408     509     508     507     407

CTRIAX6 301     101     109     110     111     211     311     210
CTRIAX6 302     101     109     210     311     310     309     209
CTRIAX6 303     101     309     310     311     410     509     409
CTRIAX6 304     101     509     410     311     411     511     510

CTRIAX6 305     101     111     112     113     212     311     211
CTRIAX6 306     101     113     213     313     312     311     212
CTRIAX6 307     101     311     312     313     413     513     412
CTRIAX6 308     101     311     412     513     512     511     411
$
$   PROPERTY DATA
$
PAXIS   101     11      1.0
$
$   MATERIAL DATA
$
$------12------23------34------45------56------67------78------89------9
MAT1    11      10.0+6          0.3     0.1     0.1E-6  25.0
$
ENDDATA
```

2.30.2 Output

```
1




          GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
         G        E       NN  N   E       S          I     S
         G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
         G    G   E       N  NN   E            S     I          S
          GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                             COPYRIGHT, 1991-2002

                   VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                        ALL RIGHTS RESERVED, WORLDWIDE

                                 VERSION 7.2

                           BUILD CODE 200212131048



     PROJECT NAME: A030
     RUN STARTED:  Dec 13, 2002 12:50
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    1
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS


                           ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                      65
                   NUMBER OF TRIAX6 ELEMENTS:                  24
                   TOTAL NUMBER OF NON RIGID ELEMENTS:         24
```

```
                NUMBER OF ELEMENT PROPERTIES:              1
                NUMBER OF MATERIALS:                       1
                NUMBER OF DEGREES OF FREEDOM:            129


                            LOAD CASES SUMMARY

               NUMBER OF STATIC LOAD CASES:                  2
               TOTAL NUMBER OF LOAD CASES:                   2

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    2
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS


             ********************************************
             *  D E S I G N  C Y C L E      0 (ANALYSIS)*
             ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    3
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS


                M A S S / V O L U M E   S U M M A R Y

                SYSTEM MASS               6.031858E+01
                SYSTEM VOLUME             6.031858E+02
                SYSTEM MASS/VOLUME        1.000000E-01
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    4
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS


               S O L U T I O N   R E S I D U A L S

 LOADCASE       30 ; RESIDUAL :  1.399112E-14 ; STRAIN ENERGY :  3.540702E-03
 LOADCASE       60 ; RESIDUAL :  1.604735E-14 ; STRAIN ENERGY :  1.788327E-04
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    5
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS


                O L O A D   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

     30  9.0489E+02  0.0000E+00  0.0000E+00  0.0000E+00  3.1671E+03  0.0000E+00
     60 -1.7090E+02  0.0000E+00  0.0000E+00  0.0000E+00 -5.9816E+02  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    6
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS


               S P C F O R C E   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

     30  4.6788E-12  0.0000E+00 -3.1566E-12  0.0000E+00  3.1867E-11  0.0000E+00
     60 -2.3712E-12  0.0000E+00 -3.6669E-13  0.0000E+00  3.3130E-12  0.0000E+00
```

```
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    7
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS


               M A X I M U M   A P P L I E D   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      30      312     5.7903E+01  5.7903E+01  0.0000E+00  0.0000E+00
      60      213     5.8643E+01 -5.8643E+01  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    8
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS


                   M A X I M U M   S P C   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      30      310     1.0037E-11 -1.5667E-12  0.0000E+00 -9.9145E-12
      60      211     2.6432E-12 -2.6432E-12  0.0000E+00  7.9936E-15
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    9
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS


                  M A X I M U M   D I S P L A C E M E N T

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      30      312     8.4227E-06  8.4227E-06  0.0000E+00  2.6039E-17
      60      113     2.0542E-06 -2.0533E-06  0.0000E+00 -6.1002E-08
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   10
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 CENTRIFUGAL LOADING                                           LOADCASE       30

                          L O A D   V E C T O R

       ID            F1                  F2                  F3
                     M1                  M2                  M3

      101     -3.368583E-01      0.000000E+00      0.000000E+00
               0.000000E+00      0.000000E+00      0.000000E+00

      102      1.757788E+00      0.000000E+00      0.000000E+00
               0.000000E+00      0.000000E+00      0.000000E+00

      103     -6.124697E-02      0.000000E+00      0.000000E+00
               0.000000E+00      0.000000E+00      0.000000E+00

      104      3.815686E+00      0.000000E+00      0.000000E+00
               0.000000E+00      0.000000E+00      0.000000E+00

      105     -2.327385E-01      0.000000E+00      0.000000E+00
               0.000000E+00      0.000000E+00      0.000000E+00
```

```
    106     8.666446E+00      0.000000E+00      0.000000E+00
            0.000000E+00      0.000000E+00      0.000000E+00

    107    -6.124697E-02      0.000000E+00      0.000000E+00
            0.000000E+00      0.000000E+00      0.000000E+00

    108     1.278224E+01      0.000000E+00      0.000000E+00
            0.000000E+00      0.000000E+00      0.000000E+00

    109    -2.327385E-01      0.000000E+00      0.000000E+00
            0.000000E+00      0.000000E+00      0.000000E+00

    110     2.086684E+01      0.000000E+00      0.000000E+00
            0.000000E+00      0.000000E+00      0.000000E+00

    111    -6.124697E-02      0.000000E+00      0.000000E+00
            0.000000E+00      0.000000E+00      0.000000E+00

    112     2.704054E+01      0.000000E+00      0.000000E+00
            0.000000E+00      0.000000E+00      0.000000E+00

    113     1.427054E+00      0.000000E+00      0.000000E+00
            0.000000E+00      0.000000E+00      0.000000E+00

    201     1.004450E+00      0.000000E+00      0.000000E+00
            0.000000E+00      0.000000E+00      0.000000E+00

    202     3.074598E+00      0.000000E+00      0.000000E+00
            0.000000E+00      0.000000E+00      0.000000E+00

    203     5.389733E+00      0.000000E+00      0.000000E+00
            0.000000E+00      0.000000E+00      0.000000E+00

    204     8.366336E+00      0.000000E+00      0.000000E+00
            0.000000E+00      0.000000E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   11
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 CENTRIFUGAL LOADING                                        LOADCASE        30

                            L O A D   V E C T O R

     ID            F1                F2                F3
                   M1                M2                M3

    205     1.200441E+01      0.000000E+00      0.000000E+00
            0.000000E+00      0.000000E+00      0.000000E+00

    206     1.630394E+01      0.000000E+00      0.000000E+00
            0.000000E+00      0.000000E+00      0.000000E+00

    207     2.126495E+01      0.000000E+00      0.000000E+00
            0.000000E+00      0.000000E+00      0.000000E+00
```

```
     208      2.688742E+01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     209      3.317136E+01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     210      4.011676E+01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     211      4.772364E+01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     212      5.599198E+01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     213      3.040299E+01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     301     -2.082397E-01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     302      2.633620E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     303     -4.654769E-01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     304      9.101299E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     305     -1.224939E-01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     306      1.527499E+01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     307     -4.654769E-01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     308      2.821035E+01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   12
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 CENTRIFUGAL LOADING                                        LOADCASE        30

                           L O A D   V E C T O R

      ID             F1                F2                F3
                     M1                M2                M3

     309     -1.224939E-01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00
```

```
     310      3.849984E+01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     311     -4.654769E-01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     312      5.790288E+01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     313      9.677021E-01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     401      1.004450E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     402      3.074598E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     403      5.389733E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     404      8.366336E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     405      1.200441E+01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     406      1.630394E+01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     407      2.126495E+01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     408      2.688742E+01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     409      3.317136E+01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     410      4.011676E+01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     411      4.772364E+01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     412      5.599198E+01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   13
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 CENTRIFUGAL LOADING                                          LOADCASE       30

                           L O A D   V E C T O R
```

ID	F1 M1	F2 M2	F3 M3
413	3.040299E+01 0.000000E+00	0.000000E+00 0.000000E+00	0.000000E+00 0.000000E+00
501	-3.368583E-01 0.000000E+00	0.000000E+00 0.000000E+00	0.000000E+00 0.000000E+00
502	1.757788E+00 0.000000E+00	0.000000E+00 0.000000E+00	0.000000E+00 0.000000E+00
503	-6.124697E-02 0.000000E+00	0.000000E+00 0.000000E+00	0.000000E+00 0.000000E+00
504	3.815686E+00 0.000000E+00	0.000000E+00 0.000000E+00	0.000000E+00 0.000000E+00
505	-2.327385E-01 0.000000E+00	0.000000E+00 0.000000E+00	0.000000E+00 0.000000E+00
506	8.666446E+00 0.000000E+00	0.000000E+00 0.000000E+00	0.000000E+00 0.000000E+00
507	-6.124697E-02 0.000000E+00	0.000000E+00 0.000000E+00	0.000000E+00 0.000000E+00
508	1.278224E+01 0.000000E+00	0.000000E+00 0.000000E+00	0.000000E+00 0.000000E+00
509	-2.327385E-01 0.000000E+00	0.000000E+00 0.000000E+00	0.000000E+00 0.000000E+00
510	2.086684E+01 0.000000E+00	0.000000E+00 0.000000E+00	0.000000E+00 0.000000E+00
511	-6.124697E-02 0.000000E+00	0.000000E+00 0.000000E+00	0.000000E+00 0.000000E+00
512	2.704054E+01 0.000000E+00	0.000000E+00 0.000000E+00	0.000000E+00 0.000000E+00
513	1.427054E+00 0.000000E+00	0.000000E+00 0.000000E+00	0.000000E+00 0.000000E+00

```
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   14
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 INNER AND OUTER PRESSURE LOADING                            LOADCASE        60

                          L O A D   V E C T O R

        ID              F1                 F2                 F3
                        M1                 M2                 M3
```

```
     101      4.188790E-01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     113     -1.466077E+01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     201      1.675516E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     213     -5.864306E+01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     301      8.377580E-01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     313     -2.932153E+01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     401      1.675516E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     413     -5.864306E+01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     501      4.188790E-01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

     513     -1.466077E+01      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   15
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 CENTRIFUGAL LOADING                                         LOADCASE       30

                    G R I D   D I S P L A C E M E N T S

  GRID ID             T1                  T2                  T3
                      R1                  R2                  R3

     101      5.103899E-06      0.000000E+00      3.956459E-07
              0.000000E+00      0.000000E+00      0.000000E+00

     102      4.903241E-06      0.000000E+00      3.725951E-07
              0.000000E+00      0.000000E+00      0.000000E+00

     103      5.185217E-06      0.000000E+00      3.717595E-07
              0.000000E+00      0.000000E+00      0.000000E+00

     104      5.658290E-06      0.000000E+00      3.512351E-07
              0.000000E+00      0.000000E+00      0.000000E+00

     105      6.186207E-06      0.000000E+00      3.366666E-07
              0.000000E+00      0.000000E+00      0.000000E+00
```

```
     106      6.712006E-06      0.000000E+00      3.148896E-07
              0.000000E+00      0.000000E+00      0.000000E+00

     107      7.200679E-06      0.000000E+00      2.933777E-07
              0.000000E+00      0.000000E+00      0.000000E+00

     108      7.630017E-06      0.000000E+00      2.657057E-07
              0.000000E+00      0.000000E+00      0.000000E+00

     109      7.981138E-06      0.000000E+00      2.375532E-07
              0.000000E+00      0.000000E+00      0.000000E+00

     110      8.238201E-06      0.000000E+00      2.041323E-07
              0.000000E+00      0.000000E+00      0.000000E+00

     111      8.385785E-06      0.000000E+00      1.699485E-07
              0.000000E+00      0.000000E+00      0.000000E+00

     112      8.412127E-06      0.000000E+00      1.302380E-07
              0.000000E+00      0.000000E+00      0.000000E+00

     113      8.305752E-06      0.000000E+00      8.979336E-08
              0.000000E+00      0.000000E+00      0.000000E+00

     201      5.125909E-06      0.000000E+00      1.975667E-07
              0.000000E+00      0.000000E+00      0.000000E+00

     202      4.898145E-06      0.000000E+00      1.863327E-07
              0.000000E+00      0.000000E+00      0.000000E+00

     203      5.189862E-06      0.000000E+00      1.862237E-07
              0.000000E+00      0.000000E+00      0.000000E+00

     204      5.662790E-06      0.000000E+00      1.754314E-07
              0.000000E+00      0.000000E+00      0.000000E+00

     205      6.189201E-06      0.000000E+00      1.682508E-07
              0.000000E+00      0.000000E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   16
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 CENTRIFUGAL LOADING                                         LOADCASE       30

                      G R I D   D I S P L A C E M E N T S

  GRID ID             T1                 T2                 T3
                      R1                 R2                 R3

     206      6.715479E-06      0.000000E+00      1.575187E-07
              0.000000E+00      0.000000E+00      0.000000E+00

     207      7.205325E-06      0.000000E+00      1.467803E-07
              0.000000E+00      0.000000E+00      0.000000E+00
```

208	7.635640E-06	0.000000E+00	1.329131E-07
	0.000000E+00	0.000000E+00	0.000000E+00
209	7.986976E-06	0.000000E+00	1.187532E-07
	0.000000E+00	0.000000E+00	0.000000E+00
210	8.244171E-06	0.000000E+00	1.021088E-07
	0.000000E+00	0.000000E+00	0.000000E+00
211	8.392740E-06	0.000000E+00	8.505267E-08
	0.000000E+00	0.000000E+00	0.000000E+00
212	8.419898E-06	0.000000E+00	6.512112E-08
	0.000000E+00	0.000000E+00	0.000000E+00
213	8.312647E-06	0.000000E+00	4.489989E-08
	0.000000E+00	0.000000E+00	0.000000E+00
301	5.137338E-06	0.000000E+00	0.000000E+00
	0.000000E+00	0.000000E+00	0.000000E+00
302	4.893787E-06	0.000000E+00	1.348741E-18
	0.000000E+00	0.000000E+00	0.000000E+00
303	5.195306E-06	0.000000E+00	2.762346E-18
	0.000000E+00	0.000000E+00	0.000000E+00
304	5.665125E-06	0.000000E+00	4.374391E-18
	0.000000E+00	0.000000E+00	0.000000E+00
305	6.190040E-06	0.000000E+00	6.257340E-18
	0.000000E+00	0.000000E+00	0.000000E+00
306	6.716238E-06	0.000000E+00	8.427085E-18
	0.000000E+00	0.000000E+00	0.000000E+00
307	7.206867E-06	0.000000E+00	1.091795E-17
	0.000000E+00	0.000000E+00	0.000000E+00
308	7.637802E-06	0.000000E+00	1.368473E-17
	0.000000E+00	0.000000E+00	0.000000E+00
309	7.988914E-06	0.000000E+00	1.666887E-17
	0.000000E+00	0.000000E+00	0.000000E+00
310	8.245911E-06	0.000000E+00	1.978005E-17
	0.000000E+00	0.000000E+00	0.000000E+00

```
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   17
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 CENTRIFUGAL LOADING                                      LOADCASE        30

                    G R I D   D I S P L A C E M E N T S
```

GRID ID	T1 R1	T2 R2	T3 R3
311	8.395039E-06	0.000000E+00	2.295020E-17
	0.000000E+00	0.000000E+00	0.000000E+00
312	8.422692E-06	0.000000E+00	2.603941E-17
	0.000000E+00	0.000000E+00	0.000000E+00
313	8.314920E-06	0.000000E+00	2.896641E-17
	0.000000E+00	0.000000E+00	0.000000E+00
401	5.125909E-06	0.000000E+00	-1.975667E-07
	0.000000E+00	0.000000E+00	0.000000E+00
402	4.898145E-06	0.000000E+00	-1.863327E-07
	0.000000E+00	0.000000E+00	0.000000E+00
403	5.189862E-06	0.000000E+00	-1.862237E-07
	0.000000E+00	0.000000E+00	0.000000E+00
404	5.662790E-06	0.000000E+00	-1.754314E-07
	0.000000E+00	0.000000E+00	0.000000E+00
405	6.189201E-06	0.000000E+00	-1.682508E-07
	0.000000E+00	0.000000E+00	0.000000E+00
406	6.715479E-06	0.000000E+00	-1.575187E-07
	0.000000E+00	0.000000E+00	0.000000E+00
407	7.205325E-06	0.000000E+00	-1.467803E-07
	0.000000E+00	0.000000E+00	0.000000E+00
408	7.635640E-06	0.000000E+00	-1.329131E-07
	0.000000E+00	0.000000E+00	0.000000E+00
409	7.986976E-06	0.000000E+00	-1.187532E-07
	0.000000E+00	0.000000E+00	0.000000E+00
410	8.244171E-06	0.000000E+00	-1.021088E-07
	0.000000E+00	0.000000E+00	0.000000E+00
411	8.392740E-06	0.000000E+00	-8.505267E-08
	0.000000E+00	0.000000E+00	0.000000E+00
412	8.419898E-06	0.000000E+00	-6.512112E-08
	0.000000E+00	0.000000E+00	0.000000E+00
413	8.312647E-06	0.000000E+00	-4.489989E-08
	0.000000E+00	0.000000E+00	0.000000E+00
501	5.103899E-06	0.000000E+00	-3.956459E-07
	0.000000E+00	0.000000E+00	0.000000E+00
502	4.903241E-06	0.000000E+00	-3.725951E-07

```
                0.000000E+00      0.000000E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   18
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 CENTRIFUGAL LOADING                                            LOADCASE       30

                           G R I D   D I S P L A C E M E N T S

  GRID ID           T1                 T2                 T3
                    R1                 R2                 R3

      503       5.185217E-06      0.000000E+00     -3.717595E-07
                0.000000E+00      0.000000E+00      0.000000E+00

      504       5.658290E-06      0.000000E+00     -3.512351E-07
                0.000000E+00      0.000000E+00      0.000000E+00

      505       6.186207E-06      0.000000E+00     -3.366666E-07
                0.000000E+00      0.000000E+00      0.000000E+00

      506       6.712006E-06      0.000000E+00     -3.148896E-07
                0.000000E+00      0.000000E+00      0.000000E+00

      507       7.200679E-06      0.000000E+00     -2.933777E-07
                0.000000E+00      0.000000E+00      0.000000E+00

      508       7.630017E-06      0.000000E+00     -2.657057E-07
                0.000000E+00      0.000000E+00      0.000000E+00

      509       7.981138E-06      0.000000E+00     -2.375532E-07
                0.000000E+00      0.000000E+00      0.000000E+00

      510       8.238201E-06      0.000000E+00     -2.041323E-07
                0.000000E+00      0.000000E+00      0.000000E+00

      511       8.385785E-06      0.000000E+00     -1.699485E-07
                0.000000E+00      0.000000E+00      0.000000E+00

      512       8.412127E-06      0.000000E+00     -1.302380E-07
                0.000000E+00      0.000000E+00      0.000000E+00

      513       8.305752E-06      0.000000E+00     -8.979336E-08
                0.000000E+00      0.000000E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   19
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 INNER AND OUTER PRESSURE LOADING                               LOADCASE       60

                           G R I D   D I S P L A C E M E N T S

  GRID ID           T1                 T2                 T3
                    R1                 R2                 R3
```

```
101     -7.065214E-07     0.000000E+00     -6.226232E-08
         0.000000E+00     0.000000E+00      0.000000E+00

102     -7.106714E-07     0.000000E+00     -6.048677E-08
         0.000000E+00     0.000000E+00      0.000000E+00

103     -7.810126E-07     0.000000E+00     -6.160999E-08
         0.000000E+00     0.000000E+00      0.000000E+00

104     -8.813021E-07     0.000000E+00     -6.090128E-08
         0.000000E+00     0.000000E+00      0.000000E+00

105     -9.954867E-07     0.000000E+00     -6.108051E-08
         0.000000E+00     0.000000E+00      0.000000E+00

106     -1.117588E-06     0.000000E+00     -6.098522E-08
         0.000000E+00     0.000000E+00      0.000000E+00

107     -1.244721E-06     0.000000E+00     -6.102965E-08
         0.000000E+00     0.000000E+00      0.000000E+00

108     -1.375270E-06     0.000000E+00     -6.099210E-08
         0.000000E+00     0.000000E+00      0.000000E+00

109     -1.508184E-06     0.000000E+00     -6.100628E-08
         0.000000E+00     0.000000E+00      0.000000E+00

110     -1.642801E-06     0.000000E+00     -6.099661E-08
         0.000000E+00     0.000000E+00      0.000000E+00

111     -1.778697E-06     0.000000E+00     -6.100439E-08
         0.000000E+00     0.000000E+00      0.000000E+00

112     -1.915589E-06     0.000000E+00     -6.099759E-08
         0.000000E+00     0.000000E+00      0.000000E+00

113     -2.053264E-06     0.000000E+00     -6.100215E-08
         0.000000E+00     0.000000E+00      0.000000E+00

201     -7.090013E-07     0.000000E+00     -3.109508E-08
         0.000000E+00     0.000000E+00      0.000000E+00

202     -7.098267E-07     0.000000E+00     -3.025120E-08
         0.000000E+00     0.000000E+00      0.000000E+00

203     -7.813261E-07     0.000000E+00     -3.083959E-08
         0.000000E+00     0.000000E+00      0.000000E+00

204     -8.814682E-07     0.000000E+00     -3.041591E-08
         0.000000E+00     0.000000E+00      0.000000E+00

205     -9.954037E-07     0.000000E+00     -3.053178E-08
         0.000000E+00     0.000000E+00      0.000000E+00

1GENESIS   VERSION  7.2                    DATE 12-13-2002  TIME 12:50  PAGE   20
```

ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

INNER AND OUTER PRESSURE LOADING LOADCASE 60

G R I D   D I S P L A C E M E N T S

GRID ID	T1 R1	T2 R2	T3 R3
206	-1.117560E-06	0.000000E+00	-3.049841E-08
	0.000000E+00	0.000000E+00	0.000000E+00
207	-1.244729E-06	0.000000E+00	-3.051621E-08
	0.000000E+00	0.000000E+00	0.000000E+00
208	-1.375282E-06	0.000000E+00	-3.049503E-08
	0.000000E+00	0.000000E+00	0.000000E+00
209	-1.508179E-06	0.000000E+00	-3.050234E-08
	0.000000E+00	0.000000E+00	0.000000E+00
210	-1.642797E-06	0.000000E+00	-3.049880E-08
	0.000000E+00	0.000000E+00	0.000000E+00
211	-1.778698E-06	0.000000E+00	-3.050243E-08
	0.000000E+00	0.000000E+00	0.000000E+00
212	-1.915591E-06	0.000000E+00	-3.049843E-08
	0.000000E+00	0.000000E+00	0.000000E+00
213	-2.053259E-06	0.000000E+00	-3.050087E-08
	0.000000E+00	0.000000E+00	0.000000E+00
301	-7.103496E-07	0.000000E+00	0.000000E+00
	0.000000E+00	0.000000E+00	0.000000E+00
302	-7.092190E-07	0.000000E+00	-6.080026E-19
	0.000000E+00	0.000000E+00	0.000000E+00
303	-7.819624E-07	0.000000E+00	-1.215105E-18
	0.000000E+00	0.000000E+00	0.000000E+00
304	-8.816004E-07	0.000000E+00	-1.858645E-18
	0.000000E+00	0.000000E+00	0.000000E+00
305	-9.953549E-07	0.000000E+00	-2.557270E-18
	0.000000E+00	0.000000E+00	0.000000E+00
306	-1.117527E-06	0.000000E+00	-3.314536E-18
	0.000000E+00	0.000000E+00	0.000000E+00
307	-1.244745E-06	0.000000E+00	-4.135129E-18
	0.000000E+00	0.000000E+00	0.000000E+00
308	-1.375293E-06	0.000000E+00	-5.009955E-18

```
              0.000000E+00      0.000000E+00      0.000000E+00

     309     -1.508176E-06      0.000000E+00     -5.926024E-18
              0.000000E+00      0.000000E+00      0.000000E+00

     310     -1.642792E-06      0.000000E+00     -6.862998E-18
              0.000000E+00      0.000000E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   21
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 INNER AND OUTER PRESSURE LOADING                            LOADCASE       60

                    G R I D   D I S P L A C E M E N T S

  GRID ID              T1                  T2                  T3
                       R1                  R2                  R3

     311     -1.778701E-06      0.000000E+00     -7.804032E-18
              0.000000E+00      0.000000E+00      0.000000E+00

     312     -1.915593E-06      0.000000E+00     -8.719172E-18
              0.000000E+00      0.000000E+00      0.000000E+00

     313     -2.053255E-06      0.000000E+00     -9.591801E-18
              0.000000E+00      0.000000E+00      0.000000E+00

     401     -7.090013E-07      0.000000E+00      3.109508E-08
              0.000000E+00      0.000000E+00      0.000000E+00

     402     -7.098267E-07      0.000000E+00      3.025120E-08
              0.000000E+00      0.000000E+00      0.000000E+00

     403     -7.813261E-07      0.000000E+00      3.083959E-08
              0.000000E+00      0.000000E+00      0.000000E+00

     404     -8.814682E-07      0.000000E+00      3.041591E-08
              0.000000E+00      0.000000E+00      0.000000E+00

     405     -9.954037E-07      0.000000E+00      3.053178E-08
              0.000000E+00      0.000000E+00      0.000000E+00

     406     -1.117560E-06      0.000000E+00      3.049841E-08
              0.000000E+00      0.000000E+00      0.000000E+00

     407     -1.244729E-06      0.000000E+00      3.051621E-08
              0.000000E+00      0.000000E+00      0.000000E+00

     408     -1.375282E-06      0.000000E+00      3.049503E-08
              0.000000E+00      0.000000E+00      0.000000E+00

     409     -1.508179E-06      0.000000E+00      3.050234E-08
              0.000000E+00      0.000000E+00      0.000000E+00

     410     -1.642797E-06      0.000000E+00      3.049880E-08
```

```
                0.000000E+00      0.000000E+00      0.000000E+00

      411      -1.778698E-06      0.000000E+00      3.050243E-08
                0.000000E+00      0.000000E+00      0.000000E+00

      412      -1.915591E-06      0.000000E+00      3.049843E-08
                0.000000E+00      0.000000E+00      0.000000E+00

      413      -2.053259E-06      0.000000E+00      3.050087E-08
                0.000000E+00      0.000000E+00      0.000000E+00

      501      -7.065214E-07      0.000000E+00      6.226232E-08
                0.000000E+00      0.000000E+00      0.000000E+00

      502      -7.106714E-07      0.000000E+00      6.048677E-08
                0.000000E+00      0.000000E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   22
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 INNER AND OUTER PRESSURE LOADING                            LOADCASE        60

                      G R I D   D I S P L A C E M E N T S

  GRID ID              T1                T2                T3
                       R1                R2                R3

      503      -7.810126E-07      0.000000E+00      6.160999E-08
                0.000000E+00      0.000000E+00      0.000000E+00

      504      -8.813021E-07      0.000000E+00      6.090128E-08
                0.000000E+00      0.000000E+00      0.000000E+00

      505      -9.954867E-07      0.000000E+00      6.108051E-08
                0.000000E+00      0.000000E+00      0.000000E+00

      506      -1.117588E-06      0.000000E+00      6.098522E-08
                0.000000E+00      0.000000E+00      0.000000E+00

      507      -1.244721E-06      0.000000E+00      6.102965E-08
                0.000000E+00      0.000000E+00      0.000000E+00

      508      -1.375270E-06      0.000000E+00      6.099210E-08
                0.000000E+00      0.000000E+00      0.000000E+00

      509      -1.508184E-06      0.000000E+00      6.100628E-08
                0.000000E+00      0.000000E+00      0.000000E+00

      510      -1.642801E-06      0.000000E+00      6.099661E-08
                0.000000E+00      0.000000E+00      0.000000E+00

      511      -1.778697E-06      0.000000E+00      6.100439E-08
                0.000000E+00      0.000000E+00      0.000000E+00

      512      -1.915589E-06      0.000000E+00      6.099759E-08
```

```
               0.000000E+00      0.000000E+00      0.000000E+00

      513     -2.053264E-06      0.000000E+00      6.100215E-08
               0.000000E+00      0.000000E+00      0.000000E+00
```



```
 CENTRIFUGAL LOADING                                          LOADCASE        30

              S T R E S S E S   I N   T R I A X 6   E L E M E N T S

 TRIAX6 ID       NORMAL            SHEAR            PRINCIPAL
                 VON MISES         OCTAHEDRAL       MAX SHEAR          PRESSURE

      101  X  7.333945E+00  XY  0.000000E+00  1  1.750564E+01
           Y  1.750564E+01  YZ  0.000000E+00  2  7.334185E+00
           Z  6.478222E-03  ZX -4.199049E-02  3  6.237600E-03
              1.522147E+01      7.175469E+00     8.749699E+00    -8.282019E+00

      102  X  4.771605E+00  XY  0.000000E+00  1  2.063059E+01
           Y  2.063059E+01  YZ  0.000000E+00  2  4.771636E+00
           Z  1.414895E-02  ZX  1.223711E-02  3  1.411747E-02
              1.869732E+01      8.814002E+00     1.030824E+01    -8.472116E+00

      103  X  4.771605E+00  XY  0.000000E+00  1  2.063059E+01
           Y  2.063059E+01  YZ  0.000000E+00  2  4.771636E+00
           Z  1.414895E-02  ZX -1.223711E-02  3  1.411747E-02
              1.869732E+01      8.814002E+00     1.030824E+01    -8.472116E+00

      104  X  7.333945E+00  XY  0.000000E+00  1  1.750564E+01
           Y  1.750564E+01  YZ  0.000000E+00  2  7.334185E+00
           Z  6.478222E-03  ZX  4.199049E-02  3  6.237600E-03
              1.522147E+01      7.175469E+00     8.749699E+00    -8.282019E+00

      105  X  9.197781E+00  XY  0.000000E+00  1  1.461221E+01
           Y  1.461221E+01  YZ  0.000000E+00  2  9.197833E+00
           Z -2.350039E-02  ZX  2.185451E-02  3 -2.355219E-02
              1.281707E+01      6.042027E+00     7.317879E+00    -7.928829E+00

      106  X  9.306973E+00  XY  0.000000E+00  1  1.379188E+01
           Y  1.379188E+01  YZ  0.000000E+00  2  9.306998E+00
           Z  7.042980E-03  ZX  1.536937E-02  3  7.017581E-03
              1.217839E+01      5.740947E+00     6.892432E+00    -7.701966E+00

      107  X  9.306973E+00  XY  0.000000E+00  1  1.379188E+01
           Y  1.379188E+01  YZ  0.000000E+00  2  9.306998E+00
           Z  7.042980E-03  ZX -1.536937E-02  3  7.017581E-03
              1.217839E+01      5.740947E+00     6.892432E+00    -7.701966E+00

      108  X  9.197781E+00  XY  0.000000E+00  1  1.461221E+01
           Y  1.461221E+01  YZ  0.000000E+00  2  9.197833E+00
           Z -2.350039E-02  ZX -2.185451E-02  3 -2.355219E-02
              1.281707E+01      6.042027E+00     7.317879E+00    -7.928829E+00
```

```
     201  X  8.544251E+00  XY  0.000000E+00  1  1.196043E+01
          Y  1.196043E+01  YZ  0.000000E+00  2  8.544253E+00
          Z -1.004880E-03  ZX -3.794252E-03  3 -1.006565E-03
             1.067164E+01      5.030657E+00     5.980717E+00    -6.834558E+00

     202  X  8.958858E+00  XY  0.000000E+00  1  1.252003E+01
          Y  1.252003E+01  YZ  0.000000E+00  2  8.958869E+00
          Z -1.278222E-03  ZX -9.901391E-03  3 -1.289163E-03
             1.117474E+01      5.267823E+00     6.260657E+00    -7.159202E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   24
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 CENTRIFUGAL LOADING                                           LOADCASE       30

             S T R E S S E S   I N   T R I A X 6   E L E M E N T S

 TRIAX6 ID       NORMAL            SHEAR            PRINCIPAL
                 VON MISES         OCTAHEDRAL       MAX SHEAR         PRESSURE

     203  X  8.958858E+00  XY  0.000000E+00  1  1.252003E+01
          Y  1.252003E+01  YZ  0.000000E+00  2  8.958869E+00
          Z -1.278222E-03  ZX  9.901391E-03  3 -1.289163E-03
             1.117474E+01      5.267823E+00     6.260657E+00    -7.159202E+00

     204  X  8.544251E+00  XY  0.000000E+00  1  1.196043E+01
          Y  1.196043E+01  YZ  0.000000E+00  2  8.544253E+00
          Z -1.004880E-03  ZX  3.794252E-03  3 -1.006565E-03
             1.067164E+01      5.030657E+00     5.980717E+00    -6.834558E+00

     205  X  7.435289E+00  XY  0.000000E+00  1  1.088634E+01
          Y  1.088634E+01  YZ  0.000000E+00  2  7.435290E+00
          Z -4.989227E-04  ZX  2.197288E-03  3 -4.995720E-04
             9.636493E+00      4.542687E+00     5.443420E+00    -6.107044E+00

     206  X  6.748748E+00  XY  0.000000E+00  1  1.034390E+01
          Y  1.034390E+01  YZ  0.000000E+00  2  6.748753E+00
          Z -2.436511E-04  ZX  5.799399E-03  3 -2.486345E-04
             9.096031E+00      4.287910E+00     5.172075E+00    -5.697469E+00

     207  X  6.748748E+00  XY  0.000000E+00  1  1.034390E+01
          Y  1.034390E+01  YZ  0.000000E+00  2  6.748753E+00
          Z -2.436511E-04  ZX -5.799399E-03  3 -2.486345E-04
             9.096031E+00      4.287910E+00     5.172075E+00    -5.697469E+00

     208  X  7.435289E+00  XY  0.000000E+00  1  1.088634E+01
          Y  1.088634E+01  YZ  0.000000E+00  2  7.435290E+00
          Z -4.989227E-04  ZX -2.197288E-03  3 -4.995720E-04
             9.636493E+00      4.542687E+00     5.443420E+00    -6.107044E+00

     301  X  4.244436E+00  XY  0.000000E+00  1  8.599099E+00
          Y  8.599099E+00  YZ  0.000000E+00  2  4.244437E+00
          Z -5.568710E-04  ZX -2.111130E-03  3 -5.579209E-04
             7.447724E+00      3.510891E+00     4.299829E+00    -4.280993E+00
```

```
     302  X  5.153632E+00  XY  0.000000E+00  1  9.205834E+00
          Y  9.205834E+00  YZ  0.000000E+00  2  5.153637E+00
          Z  1.250512E-03  ZX -4.885708E-03  3  1.245879E-03
             7.990365E+00      3.766694E+00     4.602294E+00    -4.786906E+00

     303  X  5.153632E+00  XY  0.000000E+00  1  9.205834E+00
          Y  9.205834E+00  YZ  0.000000E+00  2  5.153637E+00
          Z  1.250512E-03  ZX  4.885708E-03  3  1.245879E-03
             7.990365E+00      3.766694E+00     4.602294E+00    -4.786906E+00

     304  X  4.244436E+00  XY  0.000000E+00  1  8.599099E+00
          Y  8.599099E+00  YZ  0.000000E+00  2  4.244437E+00
          Z -5.568710E-04  ZX  2.111130E-03  3 -5.579209E-04
             7.447724E+00      3.510891E+00     4.299829E+00    -4.280993E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   25
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 CENTRIFUGAL LOADING                                           LOADCASE       30

             S T R E S S E S   I N   T R I A X 6   E L E M E N T S

 TRIAX6 ID      NORMAL            SHEAR            PRINCIPAL
                VON MISES         OCTAHEDRAL       MAX SHEAR         PRESSURE

     305  X  2.243721E+00  XY  0.000000E+00  1  7.320398E+00
          Y  7.320398E+00  YZ  0.000000E+00  2  2.243722E+00
          Z -2.053575E-04  ZX  9.419530E-04  3 -2.057529E-04
             6.496117E+00      3.062299E+00     3.660302E+00    -3.187971E+00

     306  X  1.143814E+00  XY  0.000000E+00  1  6.640925E+00
          Y  6.640925E+00  YZ  0.000000E+00  2  1.143814E+00
          Z  2.360518E-04  ZX  3.130736E-04  3  2.359661E-04
             6.149176E+00      2.898749E+00     3.320344E+00    -2.594992E+00

     307  X  1.143814E+00  XY  0.000000E+00  1  6.640925E+00
          Y  6.640925E+00  YZ  0.000000E+00  2  1.143814E+00
          Z  2.360518E-04  ZX -3.130736E-04  3  2.359661E-04
             6.149176E+00      2.898749E+00     3.320344E+00    -2.594992E+00

     308  X  2.243721E+00  XY  0.000000E+00  1  7.320398E+00
          Y  7.320398E+00  YZ  0.000000E+00  2  2.243722E+00
          Z -2.053575E-04  ZX -9.419530E-04  3 -2.057529E-04
             6.496117E+00      3.062299E+00     3.660302E+00    -3.187971E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   26
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 INNER AND OUTER PRESSURE LOADING                              LOADCASE       60

             S T R E S S E S   I N   T R I A X 6   E L E M E N T S

 TRIAX6 ID      NORMAL            SHEAR            PRINCIPAL
                VON MISES         OCTAHEDRAL       MAX SHEAR         PRESSURE
```

```
     101  X -1.399436E+00  XY  0.000000E+00  1 -1.085723E-03
          Y -2.660964E+00  YZ  0.000000E+00  2 -1.399455E+00
          Z -1.104606E-03  ZX  5.138596E-03  3 -2.660964E+00
             2.304538E+00      1.086370E+00     1.329939E+00     1.353835E+00

     102  X -1.037631E+00  XY  0.000000E+00  1 -1.753855E-03
          Y -3.040824E+00  YZ  0.000000E+00  2 -1.037633E+00
          Z -1.755801E-03  ZX -1.419788E-03  3 -3.040824E+00
             2.675983E+00      1.261470E+00     1.519535E+00     1.360070E+00

     103  X -1.037631E+00  XY  0.000000E+00  1 -1.753855E-03
          Y -3.040824E+00  YZ  0.000000E+00  2 -1.037633E+00
          Z -1.755801E-03  ZX  1.419788E-03  3 -3.040824E+00
             2.675983E+00      1.261470E+00     1.519535E+00     1.360070E+00

     104  X -1.399436E+00  XY  0.000000E+00  1 -1.085723E-03
          Y -2.660964E+00  YZ  0.000000E+00  2 -1.399455E+00
          Z -1.104606E-03  ZX -5.138596E-03  3 -2.660964E+00
             2.304538E+00      1.086370E+00     1.329939E+00     1.353835E+00

     105  X -1.726600E+00  XY  0.000000E+00  1  3.209522E-03
          Y -2.341637E+00  YZ  0.000000E+00  2 -1.726604E+00
          Z  3.205267E-03  ZX -2.713032E-03  3 -2.341637E+00
             2.105805E+00      9.926859E-01     1.172423E+00     1.355011E+00

     106  X -1.796111E+00  XY  0.000000E+00  1 -1.096134E-03
          Y -2.268527E+00  YZ  0.000000E+00  2 -1.796112E+00
          Z -1.097098E-03  ZX -1.315353E-03  3 -2.268527E+00
             2.072016E+00      9.767576E-01     1.133715E+00     1.355245E+00

     107  X -1.796111E+00  XY  0.000000E+00  1 -1.096134E-03
          Y -2.268527E+00  YZ  0.000000E+00  2 -1.796112E+00
          Z -1.097098E-03  ZX  1.315353E-03  3 -2.268527E+00
             2.072016E+00      9.767576E-01     1.133715E+00     1.355245E+00

     108  X -1.726600E+00  XY  0.000000E+00  1  3.209522E-03
          Y -2.341637E+00  YZ  0.000000E+00  2 -1.726604E+00
          Z  3.205267E-03  ZX  2.713032E-03  3 -2.341637E+00
             2.105805E+00      9.926859E-01     1.172423E+00     1.355011E+00

     201  X -1.910056E+00  XY  0.000000E+00  1 -3.408511E-05
          Y -2.156211E+00  YZ  0.000000E+00  2 -1.910056E+00
          Z -3.410794E-05  ZX  2.088492E-04  3 -2.156211E+00
             2.044245E+00      9.636664E-01     1.078089E+00     1.355434E+00

     202  X -1.884584E+00  XY  0.000000E+00  1  4.307163E-04
          Y -2.182296E+00  YZ  0.000000E+00  2 -1.884584E+00
          Z  4.304135E-04  ZX  7.555241E-04  3 -2.182296E+00
             2.050147E+00      9.664487E-01     1.091363E+00     1.355483E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   27
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 INNER AND OUTER PRESSURE LOADING                              LOADCASE       60
```

```
            S T R E S S E S   I N   T R I A X 6   E L E M E N T S

TRIAX6 ID      NORMAL           SHEAR            PRINCIPAL
               VON MISES        OCTAHEDRAL       MAX SHEAR           PRESSURE

     203  X -1.884584E+00  XY  0.000000E+00  1  4.307163E-04
          Y -2.182296E+00  YZ  0.000000E+00  2 -1.884584E+00
          Z  4.304135E-04  ZX -7.555241E-04  3 -2.182296E+00
             2.050147E+00      9.664487E-01     1.091363E+00     1.355483E+00

     204  X -1.910056E+00  XY  0.000000E+00  1 -3.408511E-05
          Y -2.156211E+00  YZ  0.000000E+00  2 -1.910056E+00
          Z -3.410794E-05  ZX -2.088492E-04  3 -2.156211E+00
             2.044245E+00      9.636664E-01     1.078089E+00     1.355434E+00

     205  X -1.945715E+00  XY  0.000000E+00  1  1.155307E-04
          Y -2.120964E+00  YZ  0.000000E+00  2 -1.945715E+00
          Z  1.155241E-04  ZX -1.135104E-04  3 -2.120964E+00
             2.039111E+00      9.612463E-01     1.060540E+00     1.355521E+00

     206  X -1.957697E+00  XY  0.000000E+00  1 -5.143151E-05
          Y -2.108838E+00  YZ  0.000000E+00  2 -1.957697E+00
          Z -5.143746E-05  ZX -1.078948E-04  3 -2.108838E+00
             2.037425E+00      9.604515E-01     1.054393E+00     1.355529E+00

     207  X -1.957697E+00  XY  0.000000E+00  1 -5.143151E-05
          Y -2.108838E+00  YZ  0.000000E+00  2 -1.957697E+00
          Z -5.143746E-05  ZX  1.078948E-04  3 -2.108838E+00
             2.037425E+00      9.604515E-01     1.054393E+00     1.355529E+00

     208  X -1.945715E+00  XY  0.000000E+00  1  1.155307E-04
          Y -2.120964E+00  YZ  0.000000E+00  2 -1.945715E+00
          Z  1.155241E-04  ZX  1.135104E-04  3 -2.120964E+00
             2.039111E+00      9.612463E-01     1.060540E+00     1.355521E+00

     301  X -1.982186E+00  XY  0.000000E+00  1 -4.144417E-06
          Y -2.084397E+00  YZ  0.000000E+00  2 -1.982186E+00
          Z -4.144895E-06  ZX  3.080522E-05  3 -2.084397E+00
             2.035213E+00      9.594086E-01     1.042196E+00     1.355529E+00

     302  X -1.975628E+00  XY  0.000000E+00  1  1.701804E-05
          Y -2.091016E+00  YZ  0.000000E+00  2 -1.975628E+00
          Z  1.701467E-05  ZX  8.153424E-05  3 -2.091016E+00
             2.035793E+00      9.596818E-01     1.045516E+00     1.355542E+00

     303  X -1.975628E+00  XY  0.000000E+00  1  1.701804E-05
          Y -2.091016E+00  YZ  0.000000E+00  2 -1.975628E+00
          Z  1.701467E-05  ZX -8.153424E-05  3 -2.091016E+00
             2.035793E+00      9.596818E-01     1.045516E+00     1.355542E+00

     304  X -1.982186E+00  XY  0.000000E+00  1 -4.144417E-06
          Y -2.084397E+00  YZ  0.000000E+00  2 -1.982186E+00
          Z -4.144895E-06  ZX -3.080522E-05  3 -2.084397E+00
             2.035213E+00      9.594086E-01     1.042196E+00     1.355529E+00
```

```
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   28
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 INNER AND OUTER PRESSURE LOADING                            LOADCASE        60

            S T R E S S E S   I N   T R I A X 6   E L E M E N T S

 TRIAX6 ID       NORMAL            SHEAR            PRINCIPAL
                 VON MISES         OCTAHEDRAL       MAX SHEAR         PRESSURE

      305  X -1.992472E+00  XY  0.000000E+00  1  1.667326E-05
           Y -2.074162E+00  YZ  0.000000E+00  2 -1.992472E+00
           Z  1.667308E-05  ZX -1.910872E-05  3 -2.074162E+00
              2.034564E+00      9.591026E-01     1.037089E+00     1.355539E+00

      306  X -1.996426E+00  XY  0.000000E+00  1 -4.616309E-06
           Y -2.070164E+00  YZ  0.000000E+00  2 -1.996426E+00
           Z -4.616320E-06  ZX -4.723096E-06  3 -2.070164E+00
              2.034293E+00      9.589750E-01     1.035080E+00     1.355532E+00

      307  X -1.996426E+00  XY  0.000000E+00  1 -4.616309E-06
           Y -2.070164E+00  YZ  0.000000E+00  2 -1.996426E+00
           Z -4.616320E-06  ZX  4.723096E-06  3 -2.070164E+00
              2.034293E+00      9.589750E-01     1.035080E+00     1.355532E+00

      308  X -1.992472E+00  XY  0.000000E+00  1  1.667326E-05
           Y -2.074162E+00  YZ  0.000000E+00  2 -1.992472E+00
           Z  1.667308E-05  ZX  1.910872E-05  3 -2.074162E+00
              2.034564E+00      9.591026E-01     1.037089E+00     1.355539E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   29
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 CENTRIFUGAL LOADING                                         LOADCASE        30

                     G R I D   S T R E S S E S

  GRID ID        NORMAL            SHEAR            PRINCIPAL
                 VON MISES         OCTAHEDRAL       MAX SHEAR         PRESSURE

      101  X  2.326530E+00  XY  0.000000E+00  1  2.322940E+01
           Y  2.322940E+01  YZ  0.000000E+00  2  2.326639E+00
           Z -3.283341E-02  ZX -1.609089E-02  3 -3.294314E-02
              2.217690E+01      1.045429E+01     1.163117E+01    -8.507698E+00

      102  X  5.985299E+00  XY  0.000000E+00  1  1.864372E+01
           Y  1.864372E+01  YZ  0.000000E+00  2  5.988120E+00
           Z -4.803320E-02  ZX -1.304885E-01  3 -5.085408E-02
              1.652454E+01      7.789742E+00     9.347288E+00    -8.193663E+00

      103  X  9.446508E+00  XY  0.000000E+00  1  1.531771E+01
           Y  1.531771E+01  YZ  0.000000E+00  2  9.446676E+00
           Z  2.159359E-02  ZX  3.986093E-02  3  2.142501E-02
              1.336564E+01      6.300622E+00     7.648141E+00    -8.261936E+00
```

```
     104  X  9.259262E+00  XY  0.000000E+00  1  1.417051E+01
          Y  1.417051E+01  YZ  0.000000E+00  2  9.259264E+00
          Z  1.053968E-02  ZX -4.406535E-03  3  1.053758E-02
             1.245319E+01      5.870491E+00     7.079984E+00    -7.813436E+00

     105  X  9.403076E+00  XY  0.000000E+00  1  1.300226E+01
          Y  1.300226E+01  YZ  0.000000E+00  2  9.403079E+00
          Z  1.383007E-02  ZX -5.309717E-03  3  1.382707E-02
             1.161490E+01      5.475315E+00     6.494218E+00    -7.473056E+00

     106  X  8.739018E+00  XY  0.000000E+00  1  1.222436E+01
          Y  1.222436E+01  YZ  0.000000E+00  2  8.739022E+00
          Z -2.164244E-03  ZX -5.940809E-03  3 -2.168282E-03
             1.090972E+01      5.142892E+00     6.113265E+00    -6.987072E+00

     107  X  8.120595E+00  XY  0.000000E+00  1  1.142315E+01
          Y  1.142315E+01  YZ  0.000000E+00  2  8.120595E+00
          Z  2.884593E-03  ZX  1.479288E-03  3  2.884323E-03
             1.017906E+01      4.798455E+00     5.710133E+00    -6.515543E+00

     108  X  7.084049E+00  XY  0.000000E+00  1  1.060667E+01
          Y  1.060667E+01  YZ  0.000000E+00  2  7.084050E+00
          Z -8.322505E-04  ZX  3.026620E-03  3 -8.335435E-04
             9.357443E+00      4.411141E+00     5.303750E+00    -5.896628E+00

     109  X  6.055790E+00  XY  0.000000E+00  1  9.796524E+00
          Y  9.796524E+00  YZ  0.000000E+00  2  6.055790E+00
          Z -4.682539E-04  ZX  1.069687E-03  3 -4.684428E-04
             8.563072E+00      4.036671E+00     4.898496E+00    -5.283948E+00

     110  X  4.691642E+00  XY  0.000000E+00  1  8.896163E+00
          Y  8.896163E+00  YZ  0.000000E+00  2  4.691643E+00
          Z -1.462503E-03  ZX -2.351016E-03  3 -1.463681E-03
             7.709442E+00      3.634266E+00     4.448813E+00    -4.528781E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   30
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 CENTRIFUGAL LOADING                                             LOADCASE       30

                      G R I D   S T R E S S E S

  GRID ID        NORMAL             SHEAR             PRINCIPAL
                 VON MISES          OCTAHEDRAL        MAX SHEAR         PRESSURE

     111  X  3.325677E+00  XY  0.000000E+00  1  7.990892E+00
          Y  7.990892E+00  YZ  0.000000E+00  2  3.325677E+00
          Z  2.276608E-03  ZX  6.874443E-04  3  2.276466E-03
             6.950799E+00      3.276638E+00     3.994308E+00    -3.772949E+00

     112  X  1.692751E+00  XY  0.000000E+00  1  6.976991E+00
          Y  6.976991E+00  YZ  0.000000E+00  2  1.692752E+00
          Z -6.168913E-04  ZX  1.220377E-03  3 -6.177708E-04
             6.303876E+00      2.971676E+00     3.488804E+00    -2.889708E+00
```

```
     113  X  5.095573E-02  XY  0.000000E+00  1  5.956761E+00
          Y  5.956761E+00  YZ  0.000000E+00  2  5.099847E-02
          Z -6.827165E-04  ZX -1.486146E-03  3 -7.254521E-04
             5.931794E+00      2.796274E+00     2.978743E+00    -2.002345E+00

     201  X  2.301235E+00  XY  0.000000E+00  1  2.428462E+01
          Y  2.428462E+01  YZ  0.000000E+00  2  2.321514E+00
          Z  6.283901E-02  ZX  2.140199E-01  3  4.255964E-02
             2.318673E+01      1.093033E+01     1.212103E+01    -8.882898E+00

     202  X  6.099160E+00  XY  0.000000E+00  1  1.875270E+01
          Y  1.875270E+01  YZ  0.000000E+00  2  6.100011E+00
          Z -8.349235E-03  ZX -7.212615E-02  3 -9.200885E-03
             1.657441E+01      7.813250E+00     9.380950E+00    -8.281170E+00

     203  X  9.499767E+00  XY  0.000000E+00  1  1.534012E+01
          Y  1.534012E+01  YZ  0.000000E+00  2  9.500318E+00
          Z  1.677693E-02  ZX  7.227601E-02  3  1.622610E-02
             1.339539E+01      6.314648E+00     7.661947E+00    -8.285555E+00

     204  X  9.242598E+00  XY  0.000000E+00  1  1.416581E+01
          Y  1.416581E+01  YZ  0.000000E+00  2  9.242731E+00
          Z -1.070969E-02  ZX  3.510880E-02  3 -1.084290E-02
             1.246681E+01      5.876911E+00     7.088325E+00    -7.799232E+00

     205  X  9.414941E+00  XY  0.000000E+00  1  1.307048E+01
          Y  1.307048E+01  YZ  0.000000E+00  2  9.414944E+00
          Z  1.229448E-02  ZX -4.965946E-03  3  1.229186E-02
             1.166810E+01      5.500394E+00     6.529093E+00    -7.499238E+00

     206  X  8.752293E+00  XY  0.000000E+00  1  1.223195E+01
          Y  1.223195E+01  YZ  0.000000E+00  2  8.752311E+00
          Z -5.997827E-03  ZX -1.263272E-02  3 -6.016048E-03
             1.092209E+01      5.148722E+00     6.118983E+00    -6.992749E+00

     207  X  8.133419E+00  XY  0.000000E+00  1  1.143114E+01
          Y  1.143114E+01  YZ  0.000000E+00  2  8.133419E+00
          Z  1.812691E-03  ZX  9.990156E-04  3  1.812569E-03
             1.018890E+01      4.803094E+00     5.714663E+00    -6.522123E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   31
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 CENTRIFUGAL LOADING                                              LOADCASE       30

                     G R I D   S T R E S S E S

  GRID ID        NORMAL             SHEAR             PRINCIPAL
                 VON MISES          OCTAHEDRAL        MAX SHEAR          PRESSURE

     208  X  7.095377E+00  XY  0.000000E+00  1  1.061397E+01
          Y  1.061397E+01  YZ  0.000000E+00  2  7.095388E+00
          Z -3.608767E-03  ZX  8.580428E-03  3 -3.619138E-03
             9.367750E+00      4.416000E+00     5.308794E+00    -5.901913E+00
```

```
     209  X  6.056095E+00  XY  0.000000E+00  1  9.804091E+00
          Y  9.804091E+00  YZ  0.000000E+00  2  6.056095E+00
          Z  6.990796E-03  ZX  5.749489E-04  3  6.990742E-03
             8.562193E+00      4.036257E+00     4.898550E+00    -5.289059E+00

     210  X  4.703051E+00  XY  0.000000E+00  1  8.903431E+00
          Y  8.903431E+00  YZ  0.000000E+00  2  4.703064E+00
          Z -2.739606E-03  ZX -7.673606E-03  3 -2.752119E-03
             7.717120E+00      3.637885E+00     4.453091E+00    -4.534581E+00

     211  X  3.336760E+00  XY  0.000000E+00  1  7.998492E+00
          Y  7.998492E+00  YZ  0.000000E+00  2  3.336760E+00
          Z  1.606330E-03  ZX  3.215829E-05  3  1.606329E-03
             6.957197E+00      3.279654E+00     3.998443E+00    -3.778953E+00

     212  X  1.701471E+00  XY  0.000000E+00  1  6.984394E+00
          Y  6.984394E+00  YZ  0.000000E+00  2  1.701477E+00
          Z -5.061432E-04  ZX  3.215185E-03  3 -5.122170E-04
             6.308521E+00      2.973865E+00     3.492453E+00    -2.895120E+00

     213  X  3.656624E-02  XY  0.000000E+00  1  5.952966E+00
          Y  5.952966E+00  YZ  0.000000E+00  2  3.798870E-02
          Z  9.925027E-04  ZX -7.254353E-03  3 -4.299578E-04
             5.934280E+00      2.797446E+00     2.976698E+00    -1.996842E+00

     301  X  2.124507E+00  XY  0.000000E+00  1  2.426129E+01
          Y  2.426129E+01  YZ  0.000000E+00  2  2.124507E+00
          Z  2.331878E-02  ZX -2.345624E-13  3  2.331878E-02
             2.325867E+01      1.096424E+01     1.211899E+01    -8.803039E+00

     302  X  5.918426E+00  XY  0.000000E+00  1  1.879192E+01
          Y  1.879192E+01  YZ  0.000000E+00  2  5.918426E+00
          Z -2.995620E-02  ZX -4.896084E-14  3 -2.995620E-02
             1.666393E+01      7.855450E+00     9.410936E+00    -8.226795E+00

     303  X  9.454527E+00  XY  0.000000E+00  1  1.483073E+01
          Y  1.483073E+01  YZ  0.000000E+00  2  9.454527E+00
          Z -1.949495E-02  ZX -2.902539E-14  3 -1.949495E-02
             1.302286E+01      6.139036E+00     7.425113E+00    -8.088588E+00

     304  X  9.223033E+00  XY  0.000000E+00  1  1.416277E+01
          Y  1.416277E+01  YZ  0.000000E+00  2  9.223033E+00
          Z  1.784934E-03  ZX -3.599725E-14  3  1.784934E-03
             1.244921E+01      5.868615E+00     7.080491E+00    -7.795862E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   32
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 CENTRIFUGAL LOADING                                             LOADCASE       30

                      G R I D   S T R E S S E S

  GRID ID        NORMAL             SHEAR             PRINCIPAL
                 VON MISES          OCTAHEDRAL        MAX SHEAR         PRESSURE
```

```
  305  X  9.409884E+00  XY  0.000000E+00  1  1.307381E+01
       Y  1.307381E+01  YZ  0.000000E+00  2  9.409884E+00
       Z  1.837404E-02  ZX -5.058031E-14  3  1.837404E-02
          1.166339E+01      5.498173E+00      6.527716E+00    -7.500688E+00

  306  X  8.755714E+00  XY  0.000000E+00  1  1.223794E+01
       Y  1.223794E+01  YZ  0.000000E+00  2  8.755714E+00
       Z  6.472778E-04  ZX -2.858824E-15  3  6.472778E-04
          1.092082E+01      5.148123E+00      6.118648E+00    -6.998102E+00

  307  X  8.141138E+00  XY  0.000000E+00  1  1.142196E+01
       Y  1.142196E+01  YZ  0.000000E+00  2  8.141138E+00
       Z -6.044442E-03  ZX  4.264812E-14  3 -6.044442E-03
          1.019165E+01      4.804391E+00      5.714001E+00    -6.519017E+00

  308  X  7.095101E+00  XY  0.000000E+00  1  1.061790E+01
       Y  1.061790E+01  YZ  0.000000E+00  2  7.095101E+00
       Z -1.686871E-03  ZX  4.785777E-14  3 -1.686871E-03
          9.368836E+00      4.416512E+00      5.309794E+00    -5.903772E+00

  309  X  6.056219E+00  XY  0.000000E+00  1  9.808332E+00
       Y  9.808332E+00  YZ  0.000000E+00  2  6.056219E+00
       Z  1.017564E-02  ZX  1.758905E-13  3  1.017564E-02
          8.562618E+00      4.036457E+00      4.899078E+00    -5.291576E+00

  310  X  4.702499E+00  XY  0.000000E+00  1  8.906852E+00
       Y  8.906852E+00  YZ  0.000000E+00  2  4.702499E+00
       Z -6.087948E-04  ZX  7.912117E-14  3 -6.087948E-04
          7.718117E+00      3.638355E+00      4.453730E+00    -4.536247E+00

  311  X  3.350677E+00  XY  0.000000E+00  1  8.007695E+00
       Y  8.007695E+00  YZ  0.000000E+00  2  3.350677E+00
       Z -2.975630E-03  ZX  1.281948E-13  3 -2.975630E-03
          6.967986E+00      3.284740E+00      4.005335E+00    -3.785132E+00

  312  X  1.694696E+00  XY  0.000000E+00  1  6.985289E+00
       Y  6.985289E+00  YZ  0.000000E+00  2  1.694696E+00
       Z -9.771231E-04  ZX  1.218210E-15  3 -9.771231E-04
          6.311640E+00      2.975336E+00      3.493133E+00    -2.893003E+00

  313  X  3.108285E-02  XY  0.000000E+00  1  5.953738E+00
       Y  5.953738E+00  YZ  0.000000E+00  2  3.108285E-02
       Z -6.773962E-04  ZX -1.519702E-13  3 -6.773962E-04
          5.938599E+00      2.799482E+00      2.977208E+00    -1.994714E+00

  401  X  2.301235E+00  XY  0.000000E+00  1  2.428462E+01
       Y  2.428462E+01  YZ  0.000000E+00  2  2.321514E+00
       Z  6.283901E-02  ZX -2.140199E-01  3  4.255964E-02
          2.318673E+01      1.093033E+01      1.212103E+01    -8.882898E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   33
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 CENTRIFUGAL LOADING                                            LOADCASE        30
```

```
                 G R I D   S T R E S S E S

GRID ID       NORMAL             SHEAR             PRINCIPAL
              VON MISES          OCTAHEDRAL        MAX SHEAR          PRESSURE

    402  X  6.099160E+00  XY  0.000000E+00  1  1.875270E+01
         Y  1.875270E+01  YZ  0.000000E+00  2  6.100011E+00
         Z -8.349235E-03  ZX  7.212615E-02  3 -9.200885E-03
            1.657441E+01      7.813250E+00     9.380950E+00    -8.281170E+00

    403  X  9.499767E+00  XY  0.000000E+00  1  1.534012E+01
         Y  1.534012E+01  YZ  0.000000E+00  2  9.500318E+00
         Z  1.677693E-02  ZX -7.227601E-02  3  1.622610E-02
            1.339539E+01      6.314648E+00     7.661947E+00    -8.285555E+00

    404  X  9.242598E+00  XY  0.000000E+00  1  1.416581E+01
         Y  1.416581E+01  YZ  0.000000E+00  2  9.242731E+00
         Z -1.070969E-02  ZX -3.510880E-02  3 -1.084290E-02
            1.246681E+01      5.876911E+00     7.088325E+00    -7.799232E+00

    405  X  9.414941E+00  XY  0.000000E+00  1  1.307048E+01
         Y  1.307048E+01  YZ  0.000000E+00  2  9.414944E+00
         Z  1.229448E-02  ZX  4.965946E-03  3  1.229186E-02
            1.166810E+01      5.500394E+00     6.529093E+00    -7.499238E+00

    406  X  8.752293E+00  XY  0.000000E+00  1  1.223195E+01
         Y  1.223195E+01  YZ  0.000000E+00  2  8.752311E+00
         Z -5.997827E-03  ZX  1.263272E-02  3 -6.016048E-03
            1.092209E+01      5.148722E+00     6.118983E+00    -6.992749E+00

    407  X  8.133419E+00  XY  0.000000E+00  1  1.143114E+01
         Y  1.143114E+01  YZ  0.000000E+00  2  8.133419E+00
         Z  1.812691E-03  ZX -9.990156E-04  3  1.812569E-03
            1.018890E+01      4.803094E+00     5.714663E+00    -6.522123E+00

    408  X  7.095377E+00  XY  0.000000E+00  1  1.061397E+01
         Y  1.061397E+01  YZ  0.000000E+00  2  7.095388E+00
         Z -3.608767E-03  ZX -8.580428E-03  3 -3.619138E-03
            9.367750E+00      4.416000E+00     5.308794E+00    -5.901913E+00

    409  X  6.056095E+00  XY  0.000000E+00  1  9.804091E+00
         Y  9.804091E+00  YZ  0.000000E+00  2  6.056095E+00
         Z  6.990796E-03  ZX -5.749489E-04  3  6.990742E-03
            8.562193E+00      4.036257E+00     4.898550E+00    -5.289059E+00

    410  X  4.703051E+00  XY  0.000000E+00  1  8.903431E+00
         Y  8.903431E+00  YZ  0.000000E+00  2  4.703064E+00
         Z -2.739606E-03  ZX  7.673606E-03  3 -2.752119E-03
            7.717120E+00      3.637885E+00     4.453091E+00    -4.534581E+00

    411  X  3.336760E+00  XY  0.000000E+00  1  7.998492E+00
         Y  7.998492E+00  YZ  0.000000E+00  2  3.336760E+00
         Z  1.606330E-03  ZX -3.215829E-05  3  1.606329E-03
            6.957197E+00      3.279654E+00     3.998443E+00    -3.778953E+00
```

```
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 CENTRIFUGAL LOADING                                                LOADCASE        30

                          G R I D   S T R E S S E S

  GRID ID        NORMAL             SHEAR              PRINCIPAL
                 VON MISES          OCTAHEDRAL         MAX SHEAR          PRESSURE

      412  X  1.701471E+00  XY  0.000000E+00  1  6.984394E+00
           Y  6.984394E+00  YZ  0.000000E+00  2  1.701477E+00
           Z -5.061432E-04  ZX -3.215185E-03  3 -5.122170E-04
              6.308521E+00      2.973865E+00     3.492453E+00    -2.895120E+00

      413  X  3.656624E-02  XY  0.000000E+00  1  5.952966E+00
           Y  5.952966E+00  YZ  0.000000E+00  2  3.798870E-02
           Z  9.925027E-04  ZX  7.254353E-03  3 -4.299578E-04
              5.934280E+00      2.797446E+00     2.976698E+00    -1.996842E+00

      501  X  2.326530E+00  XY  0.000000E+00  1  2.322940E+01
           Y  2.322940E+01  YZ  0.000000E+00  2  2.326639E+00
           Z -3.283341E-02  ZX  1.609089E-02  3 -3.294314E-02
              2.217690E+01      1.045429E+01     1.163117E+01    -8.507698E+00

      502  X  5.985299E+00  XY  0.000000E+00  1  1.864372E+01
           Y  1.864372E+01  YZ  0.000000E+00  2  5.988120E+00
           Z -4.803320E-02  ZX  1.304885E-01  3 -5.085408E-02
              1.652454E+01      7.789742E+00     9.347288E+00    -8.193663E+00

      503  X  9.446508E+00  XY  0.000000E+00  1  1.531771E+01
           Y  1.531771E+01  YZ  0.000000E+00  2  9.446676E+00
           Z  2.159359E-02  ZX -3.986093E-02  3  2.142501E-02
              1.336564E+01      6.300622E+00     7.648141E+00    -8.261936E+00

      504  X  9.259262E+00  XY  0.000000E+00  1  1.417051E+01
           Y  1.417051E+01  YZ  0.000000E+00  2  9.259264E+00
           Z  1.053968E-02  ZX  4.406535E-03  3  1.053758E-02
              1.245319E+01      5.870491E+00     7.079984E+00    -7.813436E+00

      505  X  9.403076E+00  XY  0.000000E+00  1  1.300226E+01
           Y  1.300226E+01  YZ  0.000000E+00  2  9.403079E+00
           Z  1.383007E-02  ZX  5.309717E-03  3  1.382707E-02
              1.161490E+01      5.475315E+00     6.494218E+00    -7.473056E+00

      506  X  8.739018E+00  XY  0.000000E+00  1  1.222436E+01
           Y  1.222436E+01  YZ  0.000000E+00  2  8.739022E+00
           Z -2.164244E-03  ZX  5.940809E-03  3 -2.168282E-03
              1.090972E+01      5.142892E+00     6.113265E+00    -6.987072E+00

      507  X  8.120595E+00  XY  0.000000E+00  1  1.142315E+01
           Y  1.142315E+01  YZ  0.000000E+00  2  8.120595E+00
           Z  2.884593E-03  ZX -1.479288E-03  3  2.884323E-03
              1.017906E+01      4.798455E+00     5.710133E+00    -6.515543E+00
```

```
     508  X  7.084049E+00  XY  0.000000E+00  1  1.060667E+01
          Y  1.060667E+01  YZ  0.000000E+00  2  7.084050E+00
          Z -8.322505E-04  ZX -3.026620E-03  3 -8.335435E-04
             9.357443E+00      4.411141E+00     5.303750E+00    -5.896628E+00
```

```
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   35
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 CENTRIFUGAL LOADING                                           LOADCASE       30

                      G R I D   S T R E S S E S

  GRID ID       NORMAL            SHEAR            PRINCIPAL
                VON MISES         OCTAHEDRAL       MAX SHEAR         PRESSURE

     509  X  6.055790E+00  XY  0.000000E+00  1  9.796524E+00
          Y  9.796524E+00  YZ  0.000000E+00  2  6.055790E+00
          Z -4.682539E-04  ZX -1.069687E-03  3 -4.684428E-04
             8.563072E+00      4.036671E+00     4.898496E+00    -5.283948E+00

     510  X  4.691642E+00  XY  0.000000E+00  1  8.896163E+00
          Y  8.896163E+00  YZ  0.000000E+00  2  4.691643E+00
          Z -1.462503E-03  ZX  2.351016E-03  3 -1.463681E-03
             7.709442E+00      3.634266E+00     4.448813E+00    -4.528781E+00

     511  X  3.325677E+00  XY  0.000000E+00  1  7.990892E+00
          Y  7.990892E+00  YZ  0.000000E+00  2  3.325677E+00
          Z  2.276608E-03  ZX -6.874443E-04  3  2.276466E-03
             6.950799E+00      3.276638E+00     3.994308E+00    -3.772949E+00

     512  X  1.692751E+00  XY  0.000000E+00  1  6.976991E+00
          Y  6.976991E+00  YZ  0.000000E+00  2  1.692752E+00
          Z -6.168913E-04  ZX -1.220377E-03  3 -6.177708E-04
             6.303876E+00      2.971676E+00     3.488804E+00    -2.889708E+00

     513  X  5.095573E-02  XY  0.000000E+00  1  5.956761E+00
          Y  5.956761E+00  YZ  0.000000E+00  2  5.099847E-02
          Z -6.827165E-04  ZX  1.486146E-03  3 -7.254521E-04
             5.931794E+00      2.796274E+00     2.978743E+00    -2.002345E+00
```

```
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   36
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 INNER AND OUTER PRESSURE LOADING                              LOADCASE       60

                      G R I D   S T R E S S E S

  GRID ID       NORMAL            SHEAR            PRINCIPAL
                VON MISES         OCTAHEDRAL       MAX SHEAR         PRESSURE

     101  X -6.891967E-01  XY  0.000000E+00  1  4.570140E-03
          Y -3.353569E+00  YZ  0.000000E+00  2 -6.892069E-01
          Z  4.559885E-03  ZX  2.667332E-03  3 -3.353569E+00
             3.070607E+00      1.447498E+00     1.679070E+00     1.346069E+00
```

```
     102  X -1.209616E+00  XY  0.000000E+00  1  6.380430E-03
          Y -2.796682E+00  YZ  0.000000E+00  2 -1.209846E+00
          Z  6.150145E-03  ZX  1.673395E-02  3 -2.796682E+00
             2.434585E+00      1.147675E+00     1.401531E+00     1.333383E+00

     103  X -1.705104E+00  XY  0.000000E+00  1 -2.530962E-03
          Y -2.401491E+00  YZ  0.000000E+00  2 -1.705119E+00
          Z -2.546064E-03  ZX -5.070633E-03  3 -2.401491E+00
             2.137610E+00      1.007679E+00     1.199480E+00     1.369714E+00

     104  X -1.763368E+00  XY  0.000000E+00  1 -1.520722E-03
          Y -2.301806E+00  YZ  0.000000E+00  2 -1.763369E+00
          Z -1.521230E-03  ZX  9.458069E-04  3 -2.301806E+00
             2.083907E+00      9.823631E-01     1.150143E+00     1.355565E+00

     105  X -1.864342E+00  XY  0.000000E+00  1 -1.909215E-03
          Y -2.199988E+00  YZ  0.000000E+00  2 -1.864343E+00
          Z -1.909730E-03  ZX  9.793845E-04  3 -2.199988E+00
             2.050959E+00      9.668315E-01     1.099040E+00     1.355413E+00

     106  X -1.896427E+00  XY  0.000000E+00  1  1.783106E-04
          Y -2.167703E+00  YZ  0.000000E+00  2 -1.896427E+00
          Z  1.781312E-04  ZX  5.832468E-04  3 -2.167703E+00
             2.045778E+00      9.643888E-01     1.083941E+00     1.354651E+00

     107  X -1.935147E+00  XY  0.000000E+00  1 -9.804263E-05
          Y -2.133453E+00  YZ  0.000000E+00  2 -1.935147E+00
          Z -9.805661E-05  ZX -1.644725E-04  3 -2.133453E+00
             2.041438E+00      9.623433E-01     1.066677E+00     1.356233E+00

     108  X -1.951673E+00  XY  0.000000E+00  1 -2.215872E-05
          Y -2.114491E+00  YZ  0.000000E+00  2 -1.951673E+00
          Z -2.216173E-05  ZX -7.668911E-05  3 -2.114491E+00
             2.037944E+00      9.606960E-01     1.057235E+00     1.355396E+00

     109  X -1.969398E+00  XY  0.000000E+00  1 -6.238679E-05
          Y -2.096883E+00  YZ  0.000000E+00  2 -1.969398E+00
          Z -6.238707E-05  ZX  2.331591E-05  3 -2.096883E+00
             2.036073E+00      9.598142E-01     1.048410E+00     1.355448E+00

     110  X -1.978794E+00  XY  0.000000E+00  1  2.595957E-05
          Y -2.087462E+00  YZ  0.000000E+00  2 -1.978794E+00
          Z  2.595596E-05  ZX  8.444464E-05  3 -2.087462E+00
             2.035331E+00      9.594642E-01     1.043744E+00     1.355410E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   37
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 INNER AND OUTER PRESSURE LOADING                               LOADCASE       60

                      G R I D   S T R E S S E S

  GRID ID        NORMAL             SHEAR             PRINCIPAL
                 VON MISES          OCTAHEDRAL        MAX SHEAR          PRESSURE
```

```
    111  X -1.988663E+00  XY  0.000000E+00  1 -1.498235E-05
         Y -2.078283E+00  YZ  0.000000E+00  2 -1.988663E+00
         Z -1.498255E-05  ZX -1.978378E-05  3 -2.078283E+00
            2.034939E+00      9.592795E-01     1.039134E+00     1.355654E+00

    112  X -1.994459E+00  XY  0.000000E+00  1 -2.424706E-06
         Y -2.072073E+00  YZ  0.000000E+00  2 -1.994459E+00
         Z -2.424894E-06  ZX -1.937189E-05  3 -2.072073E+00
            2.034374E+00      9.590131E-01     1.036035E+00     1.355511E+00

    113  X -2.000465E+00  XY  0.000000E+00  1 -1.917861E-05
         Y -2.066106E+00  YZ  0.000000E+00  2 -2.000465E+00
         Z -1.917864E-05  ZX  7.340983E-06  3 -2.066106E+00
            2.034060E+00      9.588653E-01     1.033043E+00     1.355530E+00

    201  X -6.881260E-01  XY  0.000000E+00  1 -7.018215E-03
         Y -3.489449E+00  YZ  0.000000E+00  2 -6.891340E-01
         Z -8.026219E-03  ZX -2.620228E-02  3 -3.489449E+00
            3.196434E+00      1.506813E+00     1.741216E+00     1.395201E+00

    202  X -1.223527E+00  XY  0.000000E+00  1  1.136728E-03
         Y -2.810060E+00  YZ  0.000000E+00  2 -1.223591E+00
         Z  1.072674E-03  ZX  8.856937E-03  3 -2.810060E+00
            2.441277E+00      1.150829E+00     1.405598E+00     1.344172E+00

    203  X -1.710587E+00  XY  0.000000E+00  1 -1.958549E-03
         Y -2.403453E+00  YZ  0.000000E+00  2 -1.710640E+00
         Z -2.011994E-03  ZX -9.556022E-03  3 -2.403453E+00
            2.140883E+00      1.009222E+00     1.200747E+00     1.372017E+00

    204  X -1.759586E+00  XY  0.000000E+00  1  9.760173E-04
         Y -2.300142E+00  YZ  0.000000E+00  2 -1.759594E+00
         Z  9.683828E-04  ZX -3.666208E-03  3 -2.300142E+00
            2.084100E+00      9.824539E-01     1.150559E+00     1.352920E+00

    205  X -1.866004E+00  XY  0.000000E+00  1 -8.127722E-04
         Y -2.208740E+00  YZ  0.000000E+00  2 -1.866004E+00
         Z -8.131639E-04  ZX  8.547957E-04  3 -2.208740E+00
            2.058076E+00      9.701862E-01     1.103964E+00     1.358519E+00

    206  X -1.896868E+00  XY  0.000000E+00  1  4.852362E-04
         Y -2.167855E+00  YZ  0.000000E+00  2 -1.896868E+00
         Z  4.849566E-04  ZX  7.282606E-04  3 -2.167855E+00
            2.046348E+00      9.646578E-01     1.084170E+00     1.354746E+00

    207  X -1.935352E+00  XY  0.000000E+00  1 -6.591495E-05
         Y -2.133511E+00  YZ  0.000000E+00  2 -1.935352E+00
         Z -6.595096E-05  ZX -2.640109E-04  3 -2.133511E+00
            2.041591E+00      9.624152E-01     1.066722E+00     1.356310E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   38
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 INNER AND OUTER PRESSURE LOADING                                LOADCASE       60
```

G R I D   S T R E S S E S

GRID ID	NORMAL VON MISES	SHEAR OCTAHEDRAL	PRINCIPAL MAX SHEAR	PRESSURE
208	X -1.951638E+00	XY 0.000000E+00	1 6.241094E-05	
	Y -2.114439E+00	YZ 0.000000E+00	2 -1.951638E+00	
	Z 6.238658E-05	ZX -2.180473E-04	3 -2.114439E+00	
	2.037984E+00	9.607148E-01	1.057251E+00	1.355338E+00
209	X -1.969580E+00	XY 0.000000E+00	1 -1.155375E-04	
	Y -2.097890E+00	YZ 0.000000E+00	2 -1.969580E+00	
	Z -1.155394E-04	ZX 6.024116E-05	3 -2.097890E+00	
	2.036653E+00	9.600875E-01	1.048887E+00	1.355862E+00
210	X -1.978866E+00	XY 0.000000E+00	1 4.659051E-05	
	Y -2.087488E+00	YZ 0.000000E+00	2 -1.978866E+00	
	Z 4.658591E-05	ZX 9.544505E-05	3 -2.087488E+00	
	2.035398E+00	9.594960E-01	1.043767E+00	1.355436E+00
211	X -1.988699E+00	XY 0.000000E+00	1 -9.860101E-06	
	Y -2.078293E+00	YZ 0.000000E+00	2 -1.988699E+00	
	Z -9.860671E-06	ZX -3.365589E-05	3 -2.078293E+00	
	2.034966E+00	9.592921E-01	1.039142E+00	1.355667E+00
212	X -1.994453E+00	XY 0.000000E+00	1 4.886525E-06	
	Y -2.072066E+00	YZ 0.000000E+00	2 -1.994453E+00	
	Z 4.885945E-06	ZX -3.400737E-05	3 -2.072066E+00	
	2.034375E+00	9.590135E-01	1.036035E+00	1.355505E+00
213	X -2.000448E+00	XY 0.000000E+00	1 -8.438761E-06	
	Y -2.066390E+00	YZ 0.000000E+00	2 -2.000448E+00	
	Z -8.440500E-06	ZX 5.897989E-05	3 -2.066390E+00	
	2.034212E+00	9.589368E-01	1.033191E+00	1.355615E+00
301	X -6.661161E-01	XY 0.000000E+00	1 -3.282193E-03	
	Y -3.486024E+00	YZ 0.000000E+00	2 -6.661161E-01	
	Z -3.282193E-03	ZX 3.440564E-14	3 -3.486024E+00	
	3.203180E+00	1.509993E+00	1.741371E+00	1.385141E+00
302	X -1.201378E+00	XY 0.000000E+00	1 3.751421E-03	
	Y -2.814799E+00	YZ 0.000000E+00	2 -1.201378E+00	
	Z 3.751421E-03	ZX -2.427919E-14	3 -2.814799E+00	
	2.449458E+00	1.154686E+00	1.409275E+00	1.337475E+00
303	X -1.702979E+00	XY 0.000000E+00	1 2.223460E-03	
	Y -2.336648E+00	YZ 0.000000E+00	2 -1.702979E+00	
	Z 2.223460E-03	ZX -2.428569E-14	3 -2.336648E+00	
	2.095182E+00	9.876781E-01	1.169436E+00	1.345801E+00
304	X -1.756845E+00	XY 0.000000E+00	1 -4.909839E-04	
	Y -2.299116E+00	YZ 0.000000E+00	2 -1.756845E+00	
	Z -4.909839E-04	ZX -1.494659E-14	3 -2.299116E+00	
	2.081167E+00	9.810717E-01	1.149313E+00	1.352151E+00

```
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 INNER AND OUTER PRESSURE LOADING                             LOADCASE       60

                     G R I D   S T R E S S E S

  GRID ID       NORMAL           SHEAR           PRINCIPAL
                VON MISES        OCTAHEDRAL      MAX SHEAR         PRESSURE

      305  X -1.865262E+00  XY  0.000000E+00  1 -1.225990E-03
           Y -2.208599E+00  YZ  0.000000E+00  2 -1.865262E+00
           Z -1.225990E-03  ZX -1.104446E-14  3 -2.208599E+00
              2.057305E+00      9.698227E-01     1.103686E+00     1.358362E+00

      306  X -1.897452E+00  XY  0.000000E+00  1 -1.087048E-04
           Y -2.168235E+00  YZ  0.000000E+00  2 -1.897452E+00
           Z -1.087048E-04  ZX -1.452020E-14  3 -2.168235E+00
              2.046217E+00      9.645958E-01     1.084063E+00     1.355265E+00

      307  X -1.934774E+00  XY  0.000000E+00  1  9.245095E-05
           Y -2.130874E+00  YZ  0.000000E+00  2 -1.934774E+00
           Z  9.245095E-05  ZX -1.921079E-14  3 -2.130874E+00
              2.039998E+00      9.616642E-01     1.065483E+00     1.355185E+00

      308  X -1.951458E+00  XY  0.000000E+00  1  2.141045E-05
           Y -2.114368E+00  YZ  0.000000E+00  2 -1.951458E+00
           Z  2.141045E-05  ZX -2.947732E-14  3 -2.114368E+00
              2.037824E+00      9.606396E-01     1.057195E+00     1.355268E+00

      309  X -1.969510E+00  XY  0.000000E+00  1 -1.546200E-04
           Y -2.097879E+00  YZ  0.000000E+00  2 -1.969510E+00
           Z -1.546200E-04  ZX -6.230420E-14  3 -2.097879E+00
              2.036576E+00      9.600512E-01     1.048862E+00     1.355848E+00

      310  X -1.978878E+00  XY  0.000000E+00  1  3.414183E-06
           Y -2.087511E+00  YZ  0.000000E+00  2 -1.978878E+00
           Z  3.414183E-06  ZX -3.685620E-14  3 -2.087511E+00
              2.035374E+00      9.594844E-01     1.043757E+00     1.355462E+00

      311  X -1.988615E+00  XY  0.000000E+00  1  2.572477E-05
           Y -2.077819E+00  YZ  0.000000E+00  2 -1.988615E+00
           Z  2.572477E-05  ZX -3.407596E-14  3 -2.077819E+00
              2.034710E+00      9.591713E-01     1.038922E+00     1.355469E+00

      312  X -1.994384E+00  XY  0.000000E+00  1  2.202793E-06
           Y -2.072040E+00  YZ  0.000000E+00  2 -1.994384E+00
           Z  2.202793E-06  ZX -2.774243E-15  3 -2.072040E+00
              2.034326E+00      9.589906E-01     1.036021E+00     1.355474E+00

      313  X -2.000386E+00  XY  0.000000E+00  1  1.373546E-06
           Y -2.066367E+00  YZ  0.000000E+00  2 -2.000386E+00
           Z  1.373546E-06  ZX  2.739240E-14  3 -2.066367E+00
              2.034180E+00      9.589218E-01     1.033184E+00     1.355584E+00
```

```
     401  X -6.881260E-01  XY  0.000000E+00  1 -7.018215E-03
          Y -3.489449E+00  YZ  0.000000E+00  2 -6.891340E-01
          Z -8.026219E-03  ZX  2.620228E-02  3 -3.489449E+00
             3.196434E+00      1.506813E+00     1.741216E+00     1.395201E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   40
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 INNER AND OUTER PRESSURE LOADING                                LOADCASE       60

                      G R I D   S T R E S S E S

  GRID ID        NORMAL            SHEAR            PRINCIPAL
                 VON MISES         OCTAHEDRAL       MAX SHEAR          PRESSURE

     402  X -1.223527E+00  XY  0.000000E+00  1  1.136728E-03
          Y -2.810060E+00  YZ  0.000000E+00  2 -1.223591E+00
          Z  1.072674E-03  ZX -8.856937E-03  3 -2.810060E+00
             2.441277E+00      1.150829E+00     1.405598E+00     1.344172E+00

     403  X -1.710587E+00  XY  0.000000E+00  1 -1.958549E-03
          Y -2.403453E+00  YZ  0.000000E+00  2 -1.710640E+00
          Z -2.011994E-03  ZX  9.556022E-03  3 -2.403453E+00
             2.140883E+00      1.009222E+00     1.200747E+00     1.372017E+00

     404  X -1.759586E+00  XY  0.000000E+00  1  9.760173E-04
          Y -2.300142E+00  YZ  0.000000E+00  2 -1.759594E+00
          Z  9.683828E-04  ZX  3.666208E-03  3 -2.300142E+00
             2.084100E+00      9.824539E-01     1.150559E+00     1.352920E+00

     405  X -1.866004E+00  XY  0.000000E+00  1 -8.127722E-04
          Y -2.208740E+00  YZ  0.000000E+00  2 -1.866004E+00
          Z -8.131639E-04  ZX -8.547957E-04  3 -2.208740E+00
             2.058076E+00      9.701862E-01     1.103964E+00     1.358519E+00

     406  X -1.896868E+00  XY  0.000000E+00  1  4.852362E-04
          Y -2.167855E+00  YZ  0.000000E+00  2 -1.896868E+00
          Z  4.849566E-04  ZX -7.282606E-04  3 -2.167855E+00
             2.046348E+00      9.646578E-01     1.084170E+00     1.354746E+00

     407  X -1.935352E+00  XY  0.000000E+00  1 -6.591495E-05
          Y -2.133511E+00  YZ  0.000000E+00  2 -1.935352E+00
          Z -6.595096E-05  ZX  2.640109E-04  3 -2.133511E+00
             2.041591E+00      9.624152E-01     1.066722E+00     1.356310E+00

     408  X -1.951638E+00  XY  0.000000E+00  1  6.241094E-05
          Y -2.114439E+00  YZ  0.000000E+00  2 -1.951638E+00
          Z  6.238658E-05  ZX  2.180473E-04  3 -2.114439E+00
             2.037984E+00      9.607148E-01     1.057251E+00     1.355338E+00

     409  X -1.969580E+00  XY  0.000000E+00  1 -1.155375E-04
          Y -2.097890E+00  YZ  0.000000E+00  2 -1.969580E+00
          Z -1.155394E-04  ZX -6.024116E-05  3 -2.097890E+00
             2.036653E+00      9.600875E-01     1.048887E+00     1.355862E+00
```

```
     410  X -1.978866E+00  XY  0.000000E+00  1  4.659051E-05
          Y -2.087488E+00  YZ  0.000000E+00  2 -1.978866E+00
          Z  4.658591E-05  ZX -9.544505E-05  3 -2.087488E+00
             2.035398E+00      9.594960E-01     1.043767E+00     1.355436E+00

     411  X -1.988699E+00  XY  0.000000E+00  1 -9.860101E-06
          Y -2.078293E+00  YZ  0.000000E+00  2 -1.988699E+00
          Z -9.860671E-06  ZX  3.365589E-05  3 -2.078293E+00
             2.034966E+00      9.592921E-01     1.039142E+00     1.355667E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   41
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 INNER AND OUTER PRESSURE LOADING                            LOADCASE       60

                      G R I D   S T R E S S E S

  GRID ID       NORMAL            SHEAR             PRINCIPAL
                VON MISES         OCTAHEDRAL        MAX SHEAR          PRESSURE

     412  X -1.994453E+00  XY  0.000000E+00  1  4.886525E-06
          Y -2.072066E+00  YZ  0.000000E+00  2 -1.994453E+00
          Z  4.885945E-06  ZX  3.400737E-05  3 -2.072066E+00
             2.034375E+00      9.590135E-01     1.036035E+00     1.355505E+00

     413  X -2.000448E+00  XY  0.000000E+00  1 -8.438761E-06
          Y -2.066390E+00  YZ  0.000000E+00  2 -2.000448E+00
          Z -8.440500E-06  ZX -5.897989E-05  3 -2.066390E+00
             2.034212E+00      9.589368E-01     1.033191E+00     1.355615E+00

     501  X -6.891967E-01  XY  0.000000E+00  1  4.570140E-03
          Y -3.353569E+00  YZ  0.000000E+00  2 -6.892069E-01
          Z  4.559885E-03  ZX -2.667332E-03  3 -3.353569E+00
             3.070607E+00      1.447498E+00     1.679070E+00     1.346069E+00

     502  X -1.209616E+00  XY  0.000000E+00  1  6.380430E-03
          Y -2.796682E+00  YZ  0.000000E+00  2 -1.209846E+00
          Z  6.150145E-03  ZX -1.673395E-02  3 -2.796682E+00
             2.434585E+00      1.147675E+00     1.401531E+00     1.333383E+00

     503  X -1.705104E+00  XY  0.000000E+00  1 -2.530962E-03
          Y -2.401491E+00  YZ  0.000000E+00  2 -1.705119E+00
          Z -2.546064E-03  ZX  5.070633E-03  3 -2.401491E+00
             2.137610E+00      1.007679E+00     1.199480E+00     1.369714E+00

     504  X -1.763368E+00  XY  0.000000E+00  1 -1.520722E-03
          Y -2.301806E+00  YZ  0.000000E+00  2 -1.763369E+00
          Z -1.521230E-03  ZX -9.458069E-04  3 -2.301806E+00
             2.083907E+00      9.823631E-01     1.150143E+00     1.355565E+00

     505  X -1.864342E+00  XY  0.000000E+00  1 -1.909215E-03
          Y -2.199988E+00  YZ  0.000000E+00  2 -1.864343E+00
          Z -1.909730E-03  ZX -9.793845E-04  3 -2.199988E+00
             2.050959E+00      9.668315E-01     1.099040E+00     1.355413E+00
```

```
     506  X -1.896427E+00  XY  0.000000E+00  1  1.783106E-04
          Y -2.167703E+00  YZ  0.000000E+00  2 -1.896427E+00
          Z  1.781312E-04  ZX -5.832468E-04  3 -2.167703E+00
             2.045778E+00      9.643888E-01     1.083941E+00     1.354651E+00

     507  X -1.935147E+00  XY  0.000000E+00  1 -9.804263E-05
          Y -2.133453E+00  YZ  0.000000E+00  2 -1.935147E+00
          Z -9.805661E-05  ZX  1.644725E-04  3 -2.133453E+00
             2.041438E+00      9.623433E-01     1.066677E+00     1.356233E+00

     508  X -1.951673E+00  XY  0.000000E+00  1 -2.215872E-05
          Y -2.114491E+00  YZ  0.000000E+00  2 -1.951673E+00
          Z -2.216173E-05  ZX  7.668911E-05  3 -2.114491E+00
             2.037944E+00      9.606960E-01     1.057235E+00     1.355396E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   42
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 INNER AND OUTER PRESSURE LOADING                            LOADCASE       60

                      G R I D   S T R E S S E S

  GRID ID       NORMAL             SHEAR            PRINCIPAL
                VON MISES          OCTAHEDRAL       MAX SHEAR          PRESSURE

     509  X -1.969398E+00  XY  0.000000E+00  1 -6.238679E-05
          Y -2.096883E+00  YZ  0.000000E+00  2 -1.969398E+00
          Z -6.238707E-05  ZX -2.331591E-05  3 -2.096883E+00
             2.036073E+00      9.598142E-01     1.048410E+00     1.355448E+00

     510  X -1.978794E+00  XY  0.000000E+00  1  2.595957E-05
          Y -2.087462E+00  YZ  0.000000E+00  2 -1.978794E+00
          Z  2.595596E-05  ZX -8.444464E-05  3 -2.087462E+00
             2.035331E+00      9.594642E-01     1.043744E+00     1.355410E+00

     511  X -1.988663E+00  XY  0.000000E+00  1 -1.498235E-05
          Y -2.078283E+00  YZ  0.000000E+00  2 -1.988663E+00
          Z -1.498255E-05  ZX  1.978378E-05  3 -2.078283E+00
             2.034939E+00      9.592795E-01     1.039134E+00     1.355654E+00

     512  X -1.994459E+00  XY  0.000000E+00  1 -2.424706E-06
          Y -2.072073E+00  YZ  0.000000E+00  2 -1.994459E+00
          Z -2.424894E-06  ZX  1.937189E-05  3 -2.072073E+00
             2.034374E+00      9.590131E-01     1.036035E+00     1.355511E+00

     513  X -2.000465E+00  XY  0.000000E+00  1 -1.917861E-05
          Y -2.066106E+00  YZ  0.000000E+00  2 -2.000465E+00
          Z -1.917864E-05  ZX -7.340983E-06  3 -2.066106E+00
             2.034060E+00      9.588653E-01     1.033043E+00     1.355530E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   43
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 CENTRIFUGAL LOADING                                         LOADCASE       30
```

```
              S T R A I N S   I N   T R I A X 6   E L E M E N T S

TRIAX6 ID      NORMAL            SHEAR            PRINCIPAL
               VON MISES         OCTAHEDRAL       MAX SHEAR          DELTA V / V

     101  X  2.080310E-07  XY  0.000000E+00  1  1.530351E-06
          Y  1.530351E-06  YZ  0.000000E+00  2  2.080623E-07
          Z -7.445396E-07  ZX -1.091753E-08  3 -7.445709E-07
             1.319194E-06      9.328109E-07     1.137461E-06     9.938423E-07

     102  X -1.421818E-07  XY  0.000000E+00  1  1.919487E-06
          Y  1.919487E-06  YZ  0.000000E+00  2 -1.421777E-07
          Z -7.606511E-07  ZX  3.181650E-09  3 -7.606551E-07
             1.620434E-06      1.145820E-06     1.340071E-06     1.016654E-06

     103  X -1.421818E-07  XY  0.000000E+00  1  1.919487E-06
          Y  1.919487E-06  YZ  0.000000E+00  2 -1.421777E-07
          Z -7.606511E-07  ZX -3.181650E-09  3 -7.606551E-07
             1.620434E-06      1.145820E-06     1.340071E-06     1.016654E-06

     104  X  2.080310E-07  XY  0.000000E+00  1  1.530351E-06
          Y  1.530351E-06  YZ  0.000000E+00  2  2.080623E-07
          Z -7.445396E-07  ZX  1.091753E-08  3 -7.445709E-07
             1.319194E-06      9.328109E-07     1.137461E-06     9.938423E-07

     105  X  4.821169E-07  XY  0.000000E+00  1  1.185992E-06
          Y  1.185992E-06  YZ  0.000000E+00  2  4.821237E-07
          Z -7.166496E-07  ZX  5.682172E-09  3 -7.166564E-07
             1.110813E-06      7.854635E-07     9.513243E-07     9.514595E-07

     106  X  5.167296E-07  XY  0.000000E+00  1  1.099768E-06
          Y  1.099768E-06  YZ  0.000000E+00  2  5.167329E-07
          Z -6.922613E-07  ZX  3.996037E-09  3 -6.922646E-07
             1.055460E-06      7.463231E-07     8.960161E-07     9.242359E-07

     107  X  5.167296E-07  XY  0.000000E+00  1  1.099768E-06
          Y  1.099768E-06  YZ  0.000000E+00  2  5.167329E-07
          Z -6.922613E-07  ZX -3.996037E-09  3 -6.922646E-07
             1.055460E-06      7.463231E-07     8.960161E-07     9.242359E-07

     108  X  4.821169E-07  XY  0.000000E+00  1  1.185992E-06
          Y  1.185992E-06  YZ  0.000000E+00  2  4.821237E-07
          Z -7.166496E-07  ZX -5.682172E-09  3 -7.166564E-07
             1.110813E-06      7.854635E-07     9.513243E-07     9.514595E-07

     201  X  4.956424E-07  XY  0.000000E+00  1  9.397454E-07
          Y  9.397454E-07  YZ  0.000000E+00  2  4.956426E-07
          Z -6.152409E-07  ZX -9.865055E-10  3 -6.152411E-07
             9.248751E-07      6.539855E-07     7.774933E-07     8.201470E-07

     202  X  5.203234E-07  XY  0.000000E+00  1  9.832752E-07
          Y  9.832752E-07  YZ  0.000000E+00  2  5.203248E-07
          Z -6.444943E-07  ZX -2.574362E-09  3 -6.444957E-07
             9.684774E-07      6.848169E-07     8.138855E-07     8.591042E-07
```

```
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 CENTRIFUGAL LOADING                                               LOADCASE       30

              S T R A I N S   I N   T R I A X 6   E L E M E N T S

 TRIAX6 ID       NORMAL             SHEAR             PRINCIPAL
                 VON MISES          OCTAHEDRAL        MAX SHEAR          DELTA V / V

      203  X  5.203234E-07  XY  0.000000E+00  1  9.832752E-07
           Y  9.832752E-07  YZ  0.000000E+00  2  5.203248E-07
           Z -6.444943E-07  ZX  2.574362E-09  3 -6.444957E-07
              9.684774E-07      6.848169E-07     8.138855E-07     8.591042E-07

      204  X  4.956424E-07  XY  0.000000E+00  1  9.397454E-07
           Y  9.397454E-07  YZ  0.000000E+00  2  4.956426E-07
           Z -6.152409E-07  ZX  9.865055E-10  3 -6.152411E-07
              9.248751E-07      6.539855E-07     7.774933E-07     8.201470E-07

      205  X  4.169536E-07  XY  0.000000E+00  1  8.655904E-07
           Y  8.655904E-07  YZ  0.000000E+00  2  4.169537E-07
           Z -5.496988E-07  ZX  5.712949E-10  3 -5.496989E-07
              8.351628E-07      5.905492E-07     7.076446E-07     7.328452E-07

      206  X  3.645651E-07  XY  0.000000E+00  1  8.319350E-07
           Y  8.319350E-07  YZ  0.000000E+00  2  3.645657E-07
           Z -5.128039E-07  ZX  1.507844E-09  3 -5.128045E-07
              7.883227E-07      5.574283E-07     6.723698E-07     6.836962E-07

      207  X  3.645651E-07  XY  0.000000E+00  1  8.319350E-07
           Y  8.319350E-07  YZ  0.000000E+00  2  3.645657E-07
           Z -5.128039E-07  ZX -1.507844E-09  3 -5.128045E-07
              7.883227E-07      5.574283E-07     6.723698E-07     6.836962E-07

      208  X  4.169536E-07  XY  0.000000E+00  1  8.655904E-07
           Y  8.655904E-07  YZ  0.000000E+00  2  4.169537E-07
           Z -5.496988E-07  ZX -5.712949E-10  3 -5.496989E-07
              8.351628E-07      5.905492E-07     7.076446E-07     7.328452E-07

      301  X  1.664873E-07  XY  0.000000E+00  1  7.325936E-07
           Y  7.325936E-07  YZ  0.000000E+00  2  1.664875E-07
           Z -3.853617E-07  ZX -5.488939E-10  3 -3.853619E-07
              6.454694E-07      4.564158E-07     5.589777E-07     5.137191E-07

      302  X  2.391507E-07  XY  0.000000E+00  1  7.659369E-07
           Y  7.659369E-07  YZ  0.000000E+00  2  2.391513E-07
           Z -4.306589E-07  ZX -1.270284E-09  3 -4.306595E-07
              6.924983E-07      4.896703E-07     5.982982E-07     5.744287E-07

      303  X  2.391507E-07  XY  0.000000E+00  1  7.659369E-07
           Y  7.659369E-07  YZ  0.000000E+00  2  2.391513E-07
           Z -4.306589E-07  ZX  1.270284E-09  3 -4.306595E-07
              6.924983E-07      4.896703E-07     5.982982E-07     5.744287E-07
```

```
     304  X  1.664873E-07  XY  0.000000E+00  1  7.325936E-07
          Y  7.325936E-07  YZ  0.000000E+00  2  1.664875E-07
          Z -3.853617E-07  ZX  5.488939E-10  3 -3.853619E-07
             6.454694E-07      4.564158E-07     5.589777E-07    5.137191E-07

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   45
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 CENTRIFUGAL LOADING                                         LOADCASE       30

              S T R A I N S   I N   T R I A X 6   E L E M E N T S

 TRIAX6 ID      NORMAL            SHEAR            PRINCIPAL
                VON MISES         OCTAHEDRAL       MAX SHEAR       DELTA V / V

     305  X  4.766362E-09  XY  0.000000E+00  1  6.647343E-07
          Y  6.647343E-07  YZ  0.000000E+00  2  4.766414E-09
          Z -2.869441E-07  ZX  2.449078E-10  3 -2.869442E-07
             5.629968E-07      3.980989E-07     4.758392E-07    3.825565E-07

     306  X -8.485340E-08  XY  0.000000E+00  1  6.297709E-07
          Y  6.297709E-07  YZ  0.000000E+00  2 -8.485339E-08
          Z -2.335186E-07  ZX  8.139913E-11  3 -2.335186E-07
             5.329286E-07      3.768374E-07     4.316448E-07    3.113990E-07

     307  X -8.485340E-08  XY  0.000000E+00  1  6.297709E-07
          Y  6.297709E-07  YZ  0.000000E+00  2 -8.485339E-08
          Z -2.335186E-07  ZX -8.139913E-11  3 -2.335186E-07
             5.329286E-07      3.768374E-07     4.316448E-07    3.113990E-07

     308  X  4.766362E-09  XY  0.000000E+00  1  6.647343E-07
          Y  6.647343E-07  YZ  0.000000E+00  2  4.766414E-09
          Z -2.869441E-07  ZX -2.449078E-10  3 -2.869442E-07
             5.629968E-07      3.980989E-07     4.758392E-07    3.825565E-07

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   46
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 INNER AND OUTER PRESSURE LOADING                            LOADCASE       60

              S T R A I N S   I N   T R I A X 6   E L E M E N T S

 TRIAX6 ID      NORMAL            SHEAR            PRINCIPAL
                VON MISES         OCTAHEDRAL       MAX SHEAR       DELTA V / V

     101  X -6.008153E-08  XY  0.000000E+00  1  1.217040E-07
          Y -2.240802E-07  YZ  0.000000E+00  2 -6.008399E-08
          Z  1.217015E-07  ZX  1.336035E-09  3 -2.240802E-07
             1.997267E-07      1.412281E-07     1.728921E-07   -1.624602E-07

     102  X -1.248568E-08  XY  0.000000E+00  1  1.221783E-07
          Y -2.729008E-07  YZ  0.000000E+00  2 -1.248594E-08
          Z  1.221781E-07  ZX -3.691448E-10  3 -2.729008E-07
             2.319185E-07      1.639912E-07     1.975396E-07   -1.632084E-07
```

```
     103  X -1.248568E-08  XY  0.000000E+00  1  1.221783E-07
          Y -2.729008E-07  YZ  0.000000E+00  2 -1.248594E-08
          Z  1.221781E-07  ZX  3.691448E-10  3 -2.729008E-07
             2.319185E-07      1.639912E-07     1.975396E-07    -1.632084E-07

     104  X -6.008153E-08  XY  0.000000E+00  1  1.217040E-07
          Y -2.240802E-07  YZ  0.000000E+00  2 -6.008399E-08
          Z  1.217015E-07  ZX -1.336035E-09  3 -2.240802E-07
             1.997267E-07      1.412281E-07     1.728921E-07    -1.624602E-07

     105  X -1.025070E-07  XY  0.000000E+00  1  1.223682E-07
          Y -1.824619E-07  YZ  0.000000E+00  2 -1.025076E-07
          Z  1.223676E-07  ZX -7.053884E-10  3 -1.824619E-07
             1.825031E-07      1.290492E-07     1.524150E-07    -1.626013E-07

     106  X -1.115224E-07  XY  0.000000E+00  1  1.218295E-07
          Y -1.729364E-07  YZ  0.000000E+00  2 -1.115225E-07
          Z  1.218294E-07  ZX -3.419918E-10  3 -1.729364E-07
             1.795747E-07      1.269785E-07     1.473830E-07    -1.626294E-07

     107  X -1.115224E-07  XY  0.000000E+00  1  1.218295E-07
          Y -1.729364E-07  YZ  0.000000E+00  2 -1.115225E-07
          Z  1.218294E-07  ZX  3.419918E-10  3 -1.729364E-07
             1.795747E-07      1.269785E-07     1.473830E-07    -1.626294E-07

     108  X -1.025070E-07  XY  0.000000E+00  1  1.223682E-07
          Y -1.824619E-07  YZ  0.000000E+00  2 -1.025076E-07
          Z  1.223676E-07  ZX  7.053884E-10  3 -1.824619E-07
             1.825031E-07      1.290492E-07     1.524150E-07    -1.626013E-07

     201  X -1.263183E-07  XY  0.000000E+00  1  1.219846E-07
          Y -1.583184E-07  YZ  0.000000E+00  2 -1.263183E-07
          Z  1.219846E-07  ZX  5.430080E-11  3 -1.583184E-07
             1.771679E-07      1.252766E-07     1.401515E-07    -1.626521E-07

     202  X -1.230024E-07  XY  0.000000E+00  1  1.220495E-07
          Y -1.617049E-07  YZ  0.000000E+00  2 -1.230025E-07
          Z  1.220494E-07  ZX  1.964363E-10  3 -1.617049E-07
             1.776794E-07      1.256383E-07     1.418772E-07    -1.626580E-07

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   47
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 INNER AND OUTER PRESSURE LOADING                                LOADCASE       60

              S T R A I N S   I N   T R I A X 6   E L E M E N T S

 TRIAX6 ID      NORMAL            SHEAR            PRINCIPAL
                VON MISES         OCTAHEDRAL       MAX SHEAR         DELTA V / V

     203  X -1.230024E-07  XY  0.000000E+00  1  1.220495E-07
          Y -1.617049E-07  YZ  0.000000E+00  2 -1.230025E-07
          Z  1.220494E-07  ZX -1.964363E-10  3 -1.617049E-07
             1.776794E-07      1.256383E-07     1.418772E-07    -1.626580E-07
```

```
     204  X -1.263183E-07  XY  0.000000E+00  1  1.219846E-07
          Y -1.583184E-07  YZ  0.000000E+00  2 -1.263183E-07
          Z  1.219846E-07  ZX -5.430080E-11  3 -1.583184E-07
             1.771679E-07      1.252766E-07     1.401515E-07    -1.626521E-07

     205  X -1.309461E-07  XY  0.000000E+00  1  1.220119E-07
          Y -1.537285E-07  YZ  0.000000E+00  2 -1.309461E-07
          Z  1.220119E-07  ZX -2.951270E-11  3 -1.537285E-07
             1.767230E-07      1.249620E-07     1.378702E-07    -1.626626E-07

     206  X -1.325031E-07  XY  0.000000E+00  1  1.219909E-07
          Y -1.521514E-07  YZ  0.000000E+00  2 -1.325031E-07
          Z  1.219909E-07  ZX -2.805264E-11  3 -1.521514E-07
             1.765769E-07      1.248587E-07     1.370711E-07    -1.626635E-07

     207  X -1.325031E-07  XY  0.000000E+00  1  1.219909E-07
          Y -1.521514E-07  YZ  0.000000E+00  2 -1.325031E-07
          Z  1.219909E-07  ZX  2.805264E-11  3 -1.521514E-07
             1.765769E-07      1.248587E-07     1.370711E-07    -1.626635E-07

     208  X -1.309461E-07  XY  0.000000E+00  1  1.220119E-07
          Y -1.537285E-07  YZ  0.000000E+00  2 -1.309461E-07
          Z  1.220119E-07  ZX  2.951270E-11  3 -1.537285E-07
             1.767230E-07      1.249620E-07     1.378702E-07    -1.626626E-07

     301  X -1.356866E-07  XY  0.000000E+00  1  1.219971E-07
          Y -1.489740E-07  YZ  0.000000E+00  2 -1.356866E-07
          Z  1.219971E-07  ZX  8.009358E-12  3 -1.489740E-07
             1.763851E-07      1.247231E-07     1.354855E-07    -1.626635E-07

     302  X -1.348328E-07  XY  0.000000E+00  1  1.220010E-07
          Y -1.498332E-07  YZ  0.000000E+00  2 -1.348328E-07
          Z  1.220010E-07  ZX  2.119890E-11  3 -1.498332E-07
             1.764354E-07      1.247586E-07     1.359171E-07    -1.626650E-07

     303  X -1.348328E-07  XY  0.000000E+00  1  1.220010E-07
          Y -1.498332E-07  YZ  0.000000E+00  2 -1.348328E-07
          Z  1.220010E-07  ZX -2.119890E-11  3 -1.498332E-07
             1.764354E-07      1.247586E-07     1.359171E-07    -1.626650E-07

     304  X -1.356866E-07  XY  0.000000E+00  1  1.219971E-07
          Y -1.489740E-07  YZ  0.000000E+00  2 -1.356866E-07
          Z  1.219971E-07  ZX -8.009358E-12  3 -1.489740E-07
             1.763851E-07      1.247231E-07     1.354855E-07    -1.626635E-07

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   48
 ANALYSIS OF A THIN AXISYMMETRIC ANNULUS

 INNER AND OUTER PRESSURE LOADING                            LOADCASE       60

              S T R A I N S   I N   T R I A X 6   E L E M E N T S

 TRIAX6 ID      NORMAL             SHEAR            PRINCIPAL
                VON MISES          OCTAHEDRAL       MAX SHEAR        DELTA V / V
```

```
305  X -1.370228E-07  XY  0.000000E+00  1  1.220007E-07
     Y -1.476425E-07  YZ  0.000000E+00  2 -1.370228E-07
     Z  1.220007E-07  ZX -4.968268E-12  3 -1.476425E-07
        1.763289E-07      1.246833E-07     1.348216E-07    -1.626647E-07

306  X -1.375375E-07  XY  0.000000E+00  1  1.219973E-07
     Y -1.471235E-07  YZ  0.000000E+00  2 -1.375375E-07
     Z  1.219973E-07  ZX -1.228005E-12  3 -1.471235E-07
        1.763054E-07      1.246668E-07     1.345604E-07    -1.626638E-07

307  X -1.375375E-07  XY  0.000000E+00  1  1.219973E-07
     Y -1.471235E-07  YZ  0.000000E+00  2 -1.375375E-07
     Z  1.219973E-07  ZX  1.228005E-12  3 -1.471235E-07
        1.763054E-07      1.246668E-07     1.345604E-07    -1.626638E-07

308  X -1.370228E-07  XY  0.000000E+00  1  1.220007E-07
     Y -1.476425E-07  YZ  0.000000E+00  2 -1.370228E-07
     Z  1.220007E-07  ZX  4.968268E-12  3 -1.476425E-07
        1.763289E-07      1.246833E-07     1.348216E-07    -1.626647E-07

1                              ***** END OF OUTPUT *****
```

2.31 Three Independent Beams

Example ID:

A031

Analysis Data:

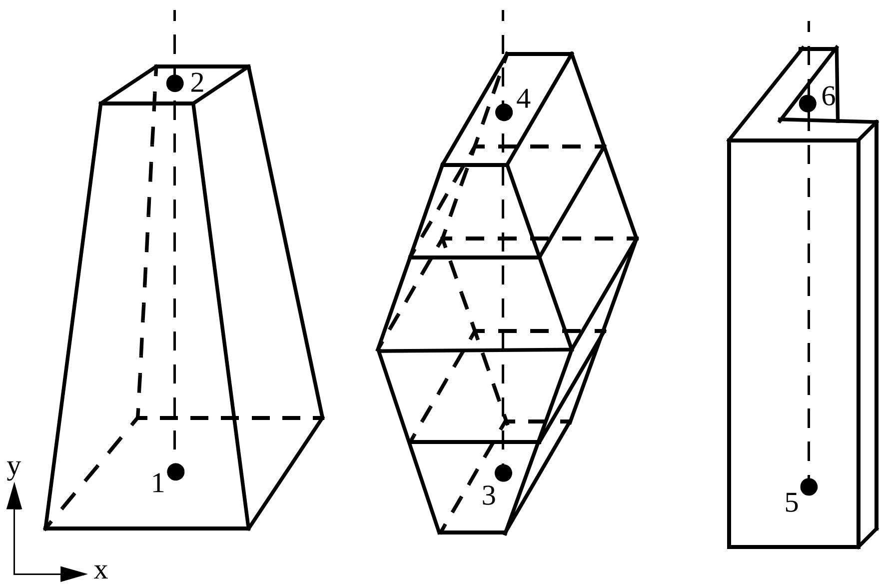
GRID, CBEAM, PBEAM, MAT1, FORCE, MOMENT, SPC1

Special Features Used:

PBEAM statement.

Problem Statement:

Find the nodal displacements of the beams shown in the figure below.



CBEAM 1 CBEAM 2 CBEAM 3

Structural Analysis Model:

1. Three CBEAM elements in the x-y plane.
2. The relevant sections properties are:

Beam 1 (tapered):

$$I_1 = I_2 = \frac{A^4}{12}$$

$$J = 0.1406A^2$$

then:

X/X_B	Area (mm2)	$I_1 = I_2$ (mm^4)	J (mm^4)
0.0 (Grid 1)	10,000	$8.333X10^6$	$1.406X10^7$
0.2	8,100	$5.467X10^6$	$9.225X10^6$
0.4	6,400	$3.413X10^6$	$5.759X10^6$
0.6	4,900	$2.000X10^6$	$3.375X10^6$
0.8	3,600	$1.080X10^6$	$1.822X10^6$
1.0 (Grid 2)	2,500	$5.208X10^5$	$8.787X10^5$

Beam 2:

$$I_1 = I_{zz} = \frac{BH^3}{12} \qquad I_2 = I_{yy} = \frac{HB^3}{12}$$

$$J = BH^3\left[0.1406 + \frac{0.1148462}{\tan(H/B - 1)}\right] \qquad B \geq H$$

$$J = HB^3\left[0.1406 + \frac{0.1148462}{\tan(H/B - 1)}\right] \qquad B < H$$

then:

X/X_B	Area (mm2)	I_1 (mm^4)	I_2 (mm^4)	J (mm^4)
0.0 (Grid 3)	600	45,000	20,000	84,200
0.25	800	$2.667X10^4$	$1.066X10^5$	68,590
0.5	500	4,166.67	$1.041X10^5$	11,9906
0.75	800	$2.667X10^4$	$1.066X10^5$	68,590
1.0 (Grid 4)	600	45,000	20,000	84,200

Beam 3 (L beam):

Area=275 mm^2, $I_1 = I_2$ = 22,200 mm^4, I_{12} = -12,784 mm^4, J = 2,291 mm^4

Material: E=7.06E4 N/mm^2, Poisson's ratio=0.33, Mass density=0.1

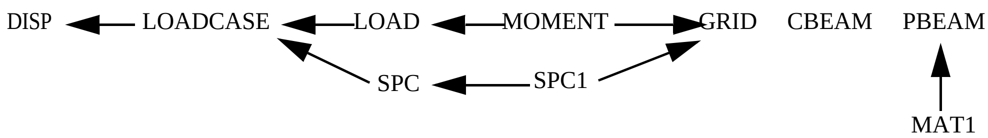
Two load cases:

Load case 1: force F=5,000 N

Load case 2: moment M=20E6 N.mm

Degrees of freedom are constrained with SPC1 data entries.

Analysis Data Relationships:



Special Modeling Techniques:

None.

Reference Solution:

None.

2.31.1 Input Data

```
ID A031
SOL COMPAT1
CEND
TITLE = BEAM WITH AND WITHOUT WARPING
ECHO=NONE
LINE=64,80
DISP = ALL
FORCE = ALL
SPC = 100
SUBCASE 1
  LABEL = FORCE
  LOAD = 110
SUBCASE 2
  LABEL = MOMENT
  LOAD = 120
$
$
BEGIN BULK
$
$ BOUNDARY CONDITIONS
$
SPC1         100  123456  1       3       5
$
$  GRID POINTS
$
GRID    1               0.0     0.0     0.0
GRID    2               0.0     1000.   0.0
GRID    3               1000.   0.0     0.0
GRID    4               1000.   1000.0  0.0
GRID    5               2000.   0.0     0.0
GRID    6               2000.   1000.0  0.0
$
$  ELEMENT DEFINITION
$
CBEAM   1       10      1       2       0.0     0.0     -1.0
CBEAM   2       20      3       4       0.0     0.0     -1.0
CBEAM   3       30      5       6       0.0     0.0     -1.0
$
$  ELEMENTS PROPERTIES
$
PBEAM   10      51      10000.0 8.333E+68.333E+6     0.01.406E+7
+       NO      0.2     8100.0  5.467E+65.467E+6     0.09.225E+6
+       NO      0.4     6400.0  3.413E+63.413E+6     0.05.759E+6
+       NO      0.6     4900.0  2.0E+6  2.0E+6       0.03.375E+6
+       NO      0.8     3600.0  1.08E+6 1.08E+6      0.01.822E+6
+       NO      1.0     2500.0  5.208E+55.208E+5     0.08.787E+5
+       0.833   0.833                   0.0             0.0     0.0
$
$
PBEAM   20      51      600.0   20000.0 45000.0      0.084200.0
+       NO      0.25    800.0   1.066E+526666.66     0.068590.0
+       NO      0.50    500.0   1.041E+54166.666     0.011990.0
```

```
+       NO      0.75    800.0   1.066E+526666.66     0.068590.0
+       NO      1.0     600.0   20000.0 45000.0      0.084200.0
+       0.833   0.833                   0.0
$
$
PBEAM   30      51      275.    22200.0 22200.0 -12784.02291.0
+       NO      1.0     275.    22200.0 22200.0 -12784.02291.0
+       0.4641  0.4641                  0.0
+       0.0     0.0     0.0     0.0     6.8181  6.8181  6.8181  6.8181
$
$
$
$  MATERIAL, LOADS, BC  DEFINITIONS
$
MAT1    51      7.06E4          0.33    0.1
FORCE   110     2               5000.0  0.0     1.0     0.0
FORCE   110     4               5000.0  0.0     1.0     0.0
FORCE   110     6               5000.0  0.0     1.0     0.0
MOMENT  120     2               20.E6   0.0     1.0     0.0
MOMENT  120     4               20.E6   0.0     1.0     0.0
MOMENT  120     6               20.E6   0.0     1.0     0.0
ENDDATA
```

2.31.2 Output

```
1







             GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
            G        E       NN  N   E       S          I     S
            G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
            G    G   E       N  NN   E            S     I          S
             GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                 STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                              COPYRIGHT, 1991-2002

                    VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                         ALL RIGHTS RESERVED, WORLDWIDE

                                  VERSION 7.2

                             BUILD CODE 200212131048



     PROJECT NAME: A031
     RUN STARTED:  Dec 13, 2002 12:50
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    1
 BEAM WITH AND WITHOUT WARPING


                             ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                        6
                   NUMBER OF CBEAM ELEMENTS:                     3
                   TOTAL NUMBER OF NON RIGID ELEMENTS:           3
```

```
                    NUMBER OF ELEMENT PROPERTIES:             3
                    NUMBER OF MATERIALS:                      1
                    NUMBER OF DEGREES OF FREEDOM:            18


                                LOAD CASES SUMMARY

                   NUMBER OF STATIC LOAD CASES:                 2
                   TOTAL NUMBER OF LOAD CASES:                  2

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    2
 BEAM WITH AND WITHOUT WARPING


                 ********************************************
                 *  D E S I G N  C Y C L E      0 (ANALYSIS)*
                 ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    3
 BEAM WITH AND WITHOUT WARPING


                     M A S S / V O L U M E   S U M M A R Y

                     SYSTEM MASS               6.800000E+05
                     SYSTEM VOLUME             6.800000E+06
                     SYSTEM MASS/VOLUME        1.000000E-01
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    4
 BEAM WITH AND WITHOUT WARPING


                    S O L U T I O N   R E S I D U A L S

 LOADCASE         1 ; RESIDUAL : -1.510450E-15 ; STRAIN ENERGY :  2.693356E+03
 LOADCASE         2 ; RESIDUAL : -2.626878E-19 ; STRAIN ENERGY :  3.456426E+09
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    5
 BEAM WITH AND WITHOUT WARPING


                     O L O A D   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1  0.0000E+00  1.5000E+04  0.0000E+00  0.0000E+00  0.0000E+00  1.5000E+07
      2  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  6.0000E+07  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    6
 BEAM WITH AND WITHOUT WARPING


                    S P C F O R C E   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1  0.0000E+00 -1.5000E+04  0.0000E+00 -8.7311E-11  0.0000E+00 -1.5000E+07
      2  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00 -6.0000E+07  0.0000E+00
```

```
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    7
 BEAM WITH AND WITHOUT WARPING


               M A X I M U M   A P P L I E D   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1           T2           T3

      1        2     5.0000E+03  0.0000E+00  5.0000E+03  0.0000E+00
      2              0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    8
 BEAM WITH AND WITHOUT WARPING


                   M A X I M U M   S P C   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1           T2           T3

      1        1     5.0000E+03  0.0000E+00 -5.0000E+03  0.0000E+00
      2              0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    9
 BEAM WITH AND WITHOUT WARPING


                  M A X I M U M   D I S P L A C E M E N T

 LOADCASE GRID ID      MAGNITUDE      T1           T2           T3

      1        6     3.6274E+01 -2.5641E+01  9.5682E-01 -2.5641E+01
      2              0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   10
 BEAM WITH AND WITHOUT WARPING

 FORCE                                                          LOADCASE        1

                     G R I D   D I S P L A C E M E N T S

  GRID ID             T1                 T2                 T3
                      R1                 R2                 R3

       1       0.000000E+00       0.000000E+00       0.000000E+00
               0.000000E+00       0.000000E+00       0.000000E+00

       2       0.000000E+00       1.410998E-02       0.000000E+00
               0.000000E+00       0.000000E+00       0.000000E+00

       3       0.000000E+00       0.000000E+00       0.000000E+00
               0.000000E+00       0.000000E+00       0.000000E+00

       4       0.000000E+00       1.064125E-01       0.000000E+00
               0.000000E+00       0.000000E+00       0.000000E+00

       5       0.000000E+00       0.000000E+00       0.000000E+00
               0.000000E+00       0.000000E+00       0.000000E+00
```

```
       6     -2.564084E+01      9.568200E-01     -2.564084E+01
             -5.128168E-02      0.000000E+00      5.128168E-02

1GENESIS   VERSION  7.2             DATE 12-13-2002  TIME 12:50  PAGE   11
 BEAM WITH AND WITHOUT WARPING

 MOMENT                                                   LOADCASE        2

                    G R I D   D I S P L A C E M E N T S

  GRID ID            T1                 T2                 T3
                     R1                 R2                 R3

       1      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

       2      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      2.437289E-01      0.000000E+00

       3      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

       4      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      1.648525E+01      0.000000E+00

       5      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

       6      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      3.289136E+02      0.000000E+00

1GENESIS   VERSION  7.2             DATE 12-13-2002  TIME 12:50  PAGE   12
 BEAM WITH AND WITHOUT WARPING

 FORCE                                                    LOADCASE        1

               F O R C E S   I N   B E A M   E L E M E N T S

  BEAM ID  X/XB      MOMENT 1        MOMENT 2       AXIAL FORCE      WARPING
                  SHEAR FORCE 1   SHEAR FORCE 2      TORQUE


       1 0.000    0.000000E+00    0.000000E+00    5.000000E+03    0.000000E+00
                   0.000000E+00    0.000000E+00    0.000000E+00

       2 0.000    0.000000E+00    0.000000E+00    5.000000E+03    0.000000E+00
                   0.000000E+00    0.000000E+00    0.000000E+00

       3 0.000    3.409050E+04    3.409050E+04    5.000000E+03    0.000000E+00
                   0.000000E+00   -5.684342E-14    0.000000E+00
1GENESIS   VERSION  7.2             DATE 12-13-2002  TIME 12:50  PAGE   13
 BEAM WITH AND WITHOUT WARPING

 MOMENT                                                   LOADCASE        2
```

```
                F O R C E S   I N   B E A M   E L E M E N T S

 BEAM ID  X/XB       MOMENT 1        MOMENT 2       AXIAL FORCE      WARPING
                  SHEAR FORCE 1   SHEAR FORCE 2       TORQUE


       1 0.000    0.000000E+00    0.000000E+00    0.000000E+00    0.000000E+00
                  0.000000E+00    0.000000E+00    2.000000E+07

       2 0.000    0.000000E+00    0.000000E+00    0.000000E+00    0.000000E+00
                  0.000000E+00    0.000000E+00    2.000000E+07

       3 0.000    0.000000E+00    0.000000E+00    0.000000E+00    0.000000E+00
                  0.000000E+00    0.000000E+00    2.000000E+07
1                           ***** END OF OUTPUT *****
```

2.32 Two Pairs of Beams with and without Warping Coefficients

Example ID:

A032

Analysis Data:

GRID, CBEAM, PBEAM, MAT1, FORCE, MOMENT, SPC1

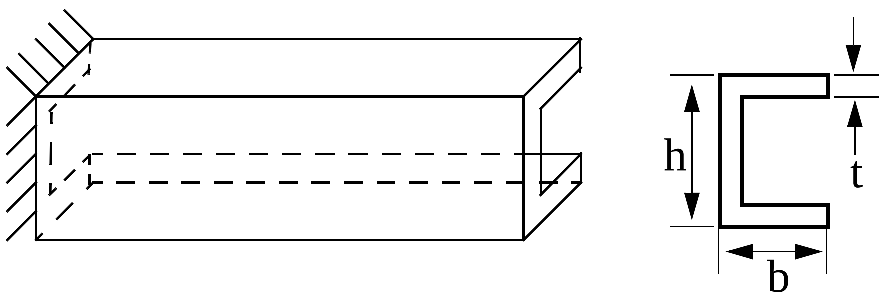
Special Features Used:

Use of warping coefficients in the PBEAM statement.

Problem Statement:

Compare the displacements between two pairs of beams. For each pair of beams, one beam is modeled with warping coefficient and the other one is modeled without warping coefficient.

Structural Analysis Model:



Four CBEAM elements in the x-y plane. For two of the elements, t = 1 mm and for the other two, t = 10 mm. For each pair, $C_w = 0$ for the first one and $C_w \neq 0$ for the second one.

The relevant section properties are:

$$J = \frac{t^3}{3}(2b + h)$$

$$C_w = \frac{tb^3h^2}{12}\left(\frac{3b + 2h}{6b + h}\right)$$

For beam 1: t = 10 mm, C_w = 0.0

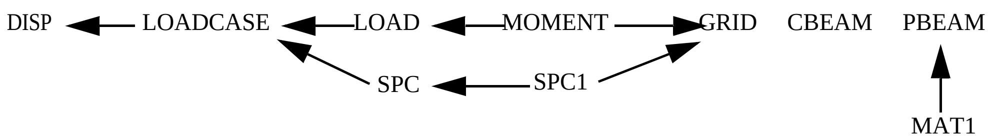
For beam 2: t = 10 mm, C_w = 9.114E7 mm^6

For beam 3: t = 1 mm, C_w = 0.0 mm^6

For beam 4: t = 1 mm, C_w = 9.114E7 mm^6

Material: E=7.06E4 N/mm^2
One moment load case: M=20E6 N.mm
Degrees of freedom are constrained with SPC1 data entries.

Analysis Data Relationships:



Special Modeling Techniques:

None.

Reference Solution:

None.

Calculated Solution:

For the thick-walled sections (beams 1 and 2), the calculated end rotations are 11.3 (without C_w) and 9.14 (with C_w). Thus the effect of including the warping reduced the rotation by 23 %.
For the thin-walled sections (beams 3 & 4), the calculated end rotations are 11303 (without C_w) and 933 (with C_w). Thus the effect of including the warping reduced the rotation by 91 %.
Therefore, as expected, including the effects of warping is more important for thin walled sections than for thick walled sections.

2.32.1 Input Data

```
ID A032
SOL COMPAT1
CEND
TITLE = TAPERED BEAMS
ECHO=NONE
LINE=64,80
DISP = ALL
FORCE = ALL
SPC = 100
SUBCASE 1
  LABEL = MOMENT
  LOAD = 110
$
$
BEGIN BULK
$
$ BOUNDARY CONDITIONS
$
SPC1         100  123456  1       3       5       7
SPC1         100          9       11
$
$  GRID POINTS
$
GRID    1               0.0     0.0     0.0
GRID    2               1000.0  0.0     0.0
GRID    3               0.0     1000.0  0.0
GRID    4               1000.0  1000.0  0.0
GRID    5               0.0     2000.0  0.0
GRID    6               1000.0  2000.0  0.0
GRID    7               0.0     3000.0  0.0
GRID    8               1000.0  3000.0  0.0
$
$  ELEMENT DEFINITION
$
SPOINT  9       10
CBEAM   1       10      1       2       0.0     0.0     -1.0
CBEAM   2       20      3       4       0.0     0.0     -1.0
+
+       9       10
$
SPOINT  11      12
CBEAM   3       30      5       6       0.0     0.0     -1.0
CBEAM   4       40      7       8       0.0     0.0     -1.0
+
+       11      12
$
$  ELEMENTS PROPERTIES
$
PBEAM   10      51      1800.   2460000.392780.       0.066666.
+       NO      1.0     1800.   2460000.392780.       0.066666.
+       0.4727  0.4727                  0.0             0.0     0.0
+       0.0     0.0     0.0     0.0     29.87   0.0     29.87   0.0
```

```
$
$
PBEAM   20      51      1800.   2460000.392780.       0.066666.
+       NO      1.0     1800.   2460000.392780.       0.066666.
+       0.4727  0.4727                  0.0              9.114E8 9.114E8
+       0.0     0.0     0.0     0.0     29.87   0.0      29.87   0.0
$
$
PBEAM   30      51      198.    323466. 50526.        0.066.666
+       NO      1.0     198.    323466. 50526.        0.066.666
+       0.4297  0.4297                  0.0              0.0     0.0
+       0.0     0.0     0.0     0.0     31.12   0.0      31.12   0.0
$
$
PBEAM   40      51      198.    323466. 50526.        0.066.666
+       NO      1.0     198.    323466. 50526.        0.066.666
+       0.4297  0.4297                  0.0              9.114E7 9.114E7
+       0.0     0.0     0.0     0.0     31.12   0.0      31.12   0.0
$
$  MATERIAL, LOADS, BC  DEFINITIONS
$
MAT1    51      7.06E4          0.33    0.1
MOMENT  110     2               20.E6   1.0     0.0      0.0
MOMENT  110     4               20.E6   1.0     0.0      0.0
MOMENT  110     6               20.E6   1.0     0.0      0.0
MOMENT  110     8               20.E6   1.0     0.0      0.0
ENDDATA
```

2.32.2 Output

```
1




                GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
               G        E       NN  N   E       S          I     S
               G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
               G    G   E       N  NN   E            S     I          S
                GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                     STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                                  COPYRIGHT, 1991-2002

                         VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                              ALL RIGHTS RESERVED, WORLDWIDE

                                      VERSION 7.2

                                 BUILD CODE 200212131048



     PROJECT NAME: A032
     RUN STARTED:  Dec 13, 2002 12:50
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    1
 TAPERED BEAMS


                                 ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                       8
                   NUMBER OF SPOINTS:                           4
                   NUMBER OF CBEAM ELEMENTS:                    4
```

```
                    TOTAL NUMBER OF NON RIGID ELEMENTS:         4
                    NUMBER OF ELEMENT PROPERTIES:               4
                    NUMBER OF MATERIALS:                        1
                    NUMBER OF DEGREES OF FREEDOM:              26


                            LOAD CASES SUMMARY

                   NUMBER OF STATIC LOAD CASES:                   1
                   TOTAL NUMBER OF LOAD CASES:                    1

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    2
 TAPERED BEAMS


               *********************************************
               *  D E S I G N  C Y C L E     0 (ANALYSIS)*
               *********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    3
 TAPERED BEAMS


                    M A S S / V O L U M E   S U M M A R Y

                    SYSTEM MASS              3.996000E+05
                    SYSTEM VOLUME            3.996000E+06
                    SYSTEM MASS/VOLUME       1.000000E-01
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    4
 TAPERED BEAMS


                   S O L U T I O N   R E S I D U A L S

 LOADCASE        1 ; RESIDUAL : -5.665803E-17 ; STRAIN ENERGY :  1.225721E+11
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    5
 TAPERED BEAMS


                     O L O A D   R E S U L T A N T S

 LOADCASE     T1          T2          T3          R1          R2          R3

      1  0.0000E+00  0.0000E+00  0.0000E+00  8.0000E+07  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    6
 TAPERED BEAMS


                   S P C F O R C E   R E S U L T A N T S

 LOADCASE     T1          T2          T3          R1          R2          R3

      1  0.0000E+00  0.0000E+00  0.0000E+00 -8.0000E+07  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    7
 TAPERED BEAMS
```

```
              M A X I M U M   A P P L I E D   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1              0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    8
 TAPERED BEAMS


                  M A X I M U M   S P C   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1              0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    9
 TAPERED BEAMS


                 M A X I M U M   D I S P L A C E M E N T

 LOADCASE GRID ID      MAGNITUDE      T1          T2          T3

      1              0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   10
 TAPERED BEAMS

 MOMENT                                                      LOADCASE        1

                     G R I D   D I S P L A C E M E N T S

  GRID ID            T1                 T2                 T3
                     R1                 R2                 R3

       1      0.000000E+00       0.000000E+00       0.000000E+00
              0.000000E+00       0.000000E+00       0.000000E+00

       2      0.000000E+00       0.000000E+00       0.000000E+00
              1.130323E+01       0.000000E+00       0.000000E+00

       3      0.000000E+00       0.000000E+00       0.000000E+00
              0.000000E+00       0.000000E+00       0.000000E+00

       4      0.000000E+00       0.000000E+00       0.000000E+00
              9.147861E+00       0.000000E+00       0.000000E+00

       5      0.000000E+00       0.000000E+00       0.000000E+00
              0.000000E+00       0.000000E+00       0.000000E+00

       6      0.000000E+00       0.000000E+00       0.000000E+00
              1.130323E+04       0.000000E+00       0.000000E+00

       7      0.000000E+00       0.000000E+00       0.000000E+00
              0.000000E+00       0.000000E+00       0.000000E+00
```

```
       8      0.000000E+00      0.000000E+00      0.000000E+00
              9.335328E+02      0.000000E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   11
 TAPERED BEAMS

 MOMENT                                                        LOADCASE         1

                    S P O I N T   D I S P L A C E M E N T S

 SPOINT ID           T

       9      0.000000E+00
      10     -1.118388E-02
      11      0.000000E+00
      12     -1.393973E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   12
 TAPERED BEAMS

 MOMENT                                                        LOADCASE         1

                 F O R C E S   I N   B E A M   E L E M E N T S

  BEAM ID  X/XB      MOMENT 1        MOMENT 2       AXIAL FORCE       WARPING
                   SHEAR FORCE 1   SHEAR FORCE 2      TORQUE


       1 0.000    0.000000E+00    0.000000E+00    0.000000E+00    0.000000E+00
                   0.000000E+00    0.000000E+00    2.000000E+07

       2 0.000    0.000000E+00    0.000000E+00    0.000000E+00   -3.813721E+09
                   0.000000E+00    0.000000E+00    2.000000E+07

       3 0.000    0.000000E+00    0.000000E+00    0.000000E+00    0.000000E+00
                   0.000000E+00    0.000000E+00    2.000000E+07

       4 0.000    0.000000E+00    0.000000E+00    0.000000E+00   -1.834820E+10
                   0.000000E+00    0.000000E+00    2.000000E+07
1                            ***** END OF OUTPUT *****
```

2.33 Two Independant Beams, with and without Offset

Example ID:

A033

Analysis Data:

GRID, CBEAM, PBEAM, MAT1, FORCE, MOMENT, SPC1

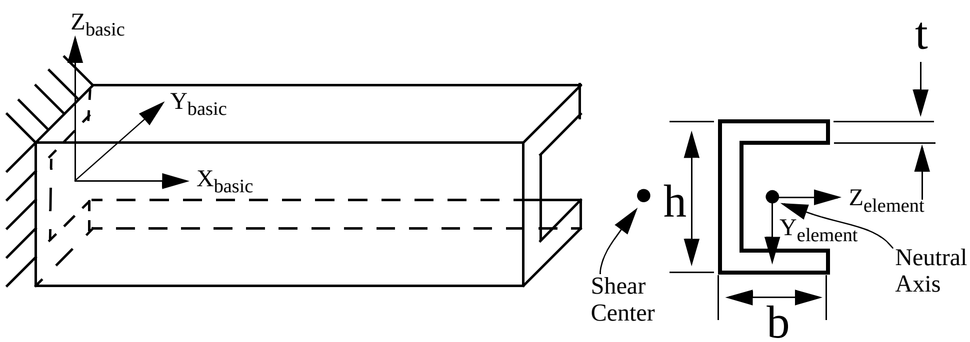
Special Features Used:

Use of offset in the CBEAM statement.

Problem Statement:

Compare the displacements between two beams. One beam is modeled without offset (beam 1) and the other one is modeled with offset (beam 2).

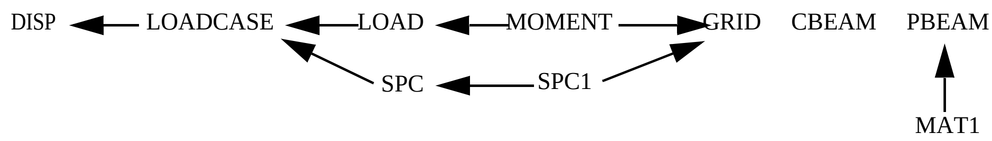
Structural Analysis Model:



Two CBEAM elements in the x-y plane.

The relevant section properties are:
b = 50 mm, h = 100 mm t = 10 mm
Beam 1: No offset (grids are on the shear center axis).
Beam 2: Beam is offset such that the grids are on the neutral axis.
Material: E = 7.06E4 N/mm^2
Three force load cases: F=5,000 N
Three moment load cases: M=20E6 N-mm
Degrees of freedom are constrained with SPC1 data entries.

Analysis Data Relationships:



Special Modeling Techniques:

None.

Reference Solution:

None.

Calculated Solution:

Loadcase 1:
For extensional loading applied at the neutral axis (Beam 2), only extensional displacement is produced. For extensional loading applied at the neutral axis, the results show that, as expected, the beam bends as well as extends.
Loadcase 2:
For shear loading in the y-direction, the beam bends in the x-y plane. Because the beam is symmetric about this plane, and the load is applied in this plane for both beams 1 and 2, the bending displacements are the same for both beams. When the grid is at the shear center (Beam 1), there is extensional displacement caused by the rotation of the end about the neutral axis.
Loadcase 3:
For shear loading in the z-direction, applied at the neutral axis (Beam 2), there is an effective torsion about the shear center and, therefore, a rotation about the x-axis.
Loadcase 4:
For torsional loading, the beam twists about the shear center axis. If the grid is at the neutral axis, then a z-displacement is caused by this rotation.
Loadcase 5:
For moment loading about the y-axis, there are no differences in the displacements measured at the shear center and the neutral axis.
Loadcase 6:
For moment loading about the z-axis, the bending is in the x-y plane about the neutral axis. The rotation of the end causes an extensional displacement at the shear center.

2.33.1 Input Data

```
ID A033
SOL COMPAT1
CEND
TITLE = BEAMS WITH AND WITHOUT OFFSET
ECHO=NONE
LINE=64,80
DISP = ALL
FORCE = ALL
SPC = 100
SUBCASE 1
  LABEL = FORCE X
  LOAD = 110
SUBCASE 2
  LABEL = FORCE Y
  LOAD = 120
SUBCASE 3
  LABEL = FORCE Z
  LOAD = 130
SUBCASE 4
  LABEL = MOMENT X
  LOAD = 140
SUBCASE 5
  LABEL = MOMENT Y
  LOAD = 150
SUBCASE 6
  LABEL = MOMENT Z
  LOAD = 160
$
$
BEGIN BULK
$
$ BOUNDARY CONDITIONS
$
SPC1         100  123456  1       3
$
$  GRID POINTS
$
GRID    1               0.0     0.0     0.0
GRID    2               1000.0  0.0     0.0
GRID    3               0.0     1000.0  0.0
GRID    4               1000.0  1000.0  0.0
$
$  ELEMENT DEFINITION
$
CBEAM   1       10      1       2       0.0     0.0     -1.0
CBEAM   2       20      3       4       0.0     0.0     -1.0
+                       0.0     -29.87   0.0    0.0     -29.87  0.0
$
$  ELEMENTS PROPERTIES
$
PBEAM   10      51      1800.   2460000.392780.      0.066666.
+       NO      1.0     1800.   2460000.392780.      0.066666.
```

```
+       0.4727  0.4727                  0.0             0.0     0.0
+       0.0     0.0     0.0     0.0     0.0     29.87   0.0     29.87
$
$
PBEAM   20      51      1800.   2460000.392780.      0.066666.
+       NO      1.0     1800.   2460000.392780.      0.066666.
+       0.4727  0.4727                  0.0             0.0     0.0
+       0.0     0.0     0.0     0.0     0.0     29.87   0.0     29.87
$
$
$
$  MATERIAL, LOADS, BC  DEFINITIONS
$
MAT1    51      7.06E4          0.33    0.1
FORCE   110     2               5000.0  1.0     0.0     0.0
FORCE   110     4               5000.0  1.0     0.0     0.0
FORCE   120     2               5000.0  0.0     1.0     0.0
FORCE   120     4               5000.0  0.0     1.0     0.0
FORCE   130     2               5000.0  0.0     0.0     1.0
FORCE   130     4               5000.0  0.0     0.0     1.0
MOMENT  140     2               20.E6   1.0     0.0     0.0
MOMENT  140     4               20.E6   1.0     0.0     0.0
MOMENT  150     2               20.E6   0.0     1.0     0.0
MOMENT  150     4               20.E6   0.0     1.0     0.0
MOMENT  160     2               20.E6   0.0     0.0     1.0
MOMENT  160     4               20.E6   0.0     0.0     1.0
ENDDATA
```

2.33.2 Output

```
1





          GGGG     EEEEE    N   N    EEEEE     SSSSS    IIIII     SSSSS
         G         E        NN  N    E        S           I      S
         G   GG    EEEE     N N N    EEEE      SSSS       I       SSSS
         G    G    E        N  NN    E             S      I           S
          GGGG     EEEEE    N   N    EEEEE    SSSSS     IIIII    SSSSS


                  STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                               COPYRIGHT, 1991-2002

                     VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                          ALL RIGHTS RESERVED, WORLDWIDE

                                   VERSION 7.2

                             BUILD CODE 200212131048



     PROJECT NAME: A033
     RUN STARTED:  Dec 13, 2002 12:50
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    1
 BEAMS WITH AND WITHOUT OFFSET


                              ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                      4
                   NUMBER OF CBEAM ELEMENTS:                   2
                   TOTAL NUMBER OF NON RIGID ELEMENTS:         2
```

```
                    NUMBER OF ELEMENT PROPERTIES:             2
                    NUMBER OF MATERIALS:                      1
                    NUMBER OF DEGREES OF FREEDOM:            12


                              LOAD CASES SUMMARY

                   NUMBER OF STATIC LOAD CASES:                 6
                   TOTAL NUMBER OF LOAD CASES:                  6

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    2
 BEAMS WITH AND WITHOUT OFFSET


                ********************************************
                *  D E S I G N  C Y C L E      0 (ANALYSIS)*
                ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    3
 BEAMS WITH AND WITHOUT OFFSET


                    M A S S / V O L U M E   S U M M A R Y

                    SYSTEM MASS              3.600000E+05
                    SYSTEM VOLUME            3.600000E+06
                    SYSTEM MASS/VOLUME       1.000000E-01
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    4
 BEAMS WITH AND WITHOUT OFFSET


                   S O L U T I O N   R E S I D U A L S

 LOADCASE        1 ; RESIDUAL : -8.775710E-16 ; STRAIN ENERGY :  5.989120E+02
 LOADCASE        2 ; RESIDUAL :  7.275958E-16 ; STRAIN ENERGY :  3.016210E+05
 LOADCASE        3 ; RESIDUAL : -4.012475E-16 ; STRAIN ENERGY :  5.539218E+04
 LOADCASE        4 ; RESIDUAL :  1.862645E-16 ; STRAIN ENERGY :  2.260646E+08
 LOADCASE        5 ; RESIDUAL : -3.637979E-16 ; STRAIN ENERGY :  2.303139E+06
 LOADCASE        6 ; RESIDUAL :  3.725290E-16 ; STRAIN ENERGY :  1.442467E+07
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    5
 BEAMS WITH AND WITHOUT OFFSET


                     O L O A D   R E S U L T A N T S

 LOADCASE      T1           T2           T3           R1           R2           R3

      1  1.0000E+04  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00 -5.0000E+06
      2  0.0000E+00  1.0000E+04  0.0000E+00  0.0000E+00  0.0000E+00  1.0000E+07
      3  0.0000E+00  0.0000E+00  1.0000E+04  5.0000E+06 -1.0000E+07  0.0000E+00
      4  0.0000E+00  0.0000E+00  0.0000E+00  4.0000E+07  0.0000E+00  0.0000E+00
      5  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  4.0000E+07  0.0000E+00
      6  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  4.0000E+07
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    6
 BEAMS WITH AND WITHOUT OFFSET
```

S P C F O R C E   R E S U L T A N T S

LOADCASE	T1	T2	T3	R1	R2	R3
1	-1.0000E+04	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	5.0000E+06
2	0.0000E+00	-1.0000E+04	0.0000E+00	0.0000E+00	0.0000E+00	-1.0000E+07
3	0.0000E+00	0.0000E+00	-1.0000E+04	-5.0000E+06	1.0000E+07	0.0000E+00
4	0.0000E+00	0.0000E+00	0.0000E+00	-4.0000E+07	0.0000E+00	0.0000E+00
5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	-4.0000E+07	0.0000E+00
6	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	-4.0000E+07

1GENESIS VERSION 7.2 DATE 12-13-2002 TIME 12:50 PAGE 7

BEAMS WITH AND WITHOUT OFFSET

M A X I M U M   A P P L I E D   F O R C E

LOADCASE	GRID ID	MAGNITUDE	T1	T2	T3
1	2	5.0000E+03	5.0000E+03	0.0000E+00	0.0000E+00
2	2	5.0000E+03	0.0000E+00	5.0000E+03	0.0000E+00
3	2	5.0000E+03	0.0000E+00	0.0000E+00	5.0000E+03
4		0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
5		0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
6		0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

1GENESIS VERSION 7.2 DATE 12-13-2002 TIME 12:50 PAGE 8

BEAMS WITH AND WITHOUT OFFSET

M A X I M U M   S P C   F O R C E

LOADCASE	GRID ID	MAGNITUDE	T1	T2	T3
1	1	5.0000E+03	-5.0000E+03	0.0000E+00	0.0000E+00
2	1	5.0000E+03	0.0000E+00	-5.0000E+03	0.0000E+00
3	3	5.0000E+03	0.0000E+00	0.0000E+00	-5.0000E+03
4		0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
5	1	1.4552E-11	0.0000E+00	0.0000E+00	-1.4552E-11
6		0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

1GENESIS VERSION 7.2 DATE 12-13-2002 TIME 12:50 PAGE 9

BEAMS WITH AND WITHOUT OFFSET

M A X I M U M   D I S P L A C E M E N T

LOADCASE	GRID ID	MAGNITUDE	T1	T2	T3
1	2	2.7003E+00	2.0022E-01	2.6929E+00	0.0000E+00
2	2	6.0384E+01	2.6929E+00	6.0324E+01	0.0000E+00
3	4	1.2339E+01	0.0000E+00	0.0000E+00	1.2339E+01
4	4	3.3763E+02	0.0000E+00	0.0000E+00	3.3763E+02
5	4	5.7578E+01	0.0000E+00	0.0000E+00	-5.7578E+01
6	2	3.6126E+02	2.1543E+01	3.6062E+02	0.0000E+00

1GENESIS VERSION 7.2 DATE 12-13-2002 TIME 12:50 PAGE 10

```
 BEAMS WITH AND WITHOUT OFFSET

 FORCE X                                                       LOADCASE         1

                      G R I D   D I S P L A C E M E N T S

  GRID ID             T1                 T2                 T3
                      R1                 R2                 R3

       1        0.000000E+00       0.000000E+00       0.000000E+00
                0.000000E+00       0.000000E+00       0.000000E+00

       2        2.002195E-01       2.692906E+00       0.000000E+00
                0.000000E+00       0.000000E+00       5.385812E-03

       3        0.000000E+00       0.000000E+00       0.000000E+00
                0.000000E+00       0.000000E+00       0.000000E+00

       4        3.934529E-02       0.000000E+00       0.000000E+00
                0.000000E+00       0.000000E+00       0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   11
 BEAMS WITH AND WITHOUT OFFSET

 FORCE Y                                                       LOADCASE         2

                      G R I D   D I S P L A C E M E N T S

  GRID ID             T1                 T2                 T3
                      R1                 R2                 R3

       1        0.000000E+00       0.000000E+00       0.000000E+00
                0.000000E+00       0.000000E+00       0.000000E+00

       2        2.692906E+00       6.032420E+01       0.000000E+00
                0.000000E+00       0.000000E+00       9.015420E-02

       3        0.000000E+00       0.000000E+00       0.000000E+00
                0.000000E+00       0.000000E+00       0.000000E+00

       4        0.000000E+00       6.032420E+01       0.000000E+00
                0.000000E+00       0.000000E+00       9.015420E-02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   12
 BEAMS WITH AND WITHOUT OFFSET

 FORCE Z                                                       LOADCASE         3

                      G R I D   D I S P L A C E M E N T S

  GRID ID             T1                 T2                 T3
                      R1                 R2                 R3

       1        0.000000E+00       0.000000E+00       0.000000E+00
                0.000000E+00       0.000000E+00       0.000000E+00
```

```
      2      0.000000E+00      0.000000E+00      9.817819E+00
             0.000000E+00     -1.439462E-02      0.000000E+00

      3      0.000000E+00      0.000000E+00      0.000000E+00
             0.000000E+00      0.000000E+00      0.000000E+00

      4      0.000000E+00      0.000000E+00      1.233905E+01
             8.440686E-02     -1.439462E-02      0.000000E+00

1GENESIS   VERSION  7.2                 DATE 12-13-2002  TIME 12:50  PAGE   13
 BEAMS WITH AND WITHOUT OFFSET

 MOMENT X                                                   LOADCASE        4

                      G R I D   D I S P L A C E M E N T S

  GRID ID             T1                 T2                 T3
                      R1                 R2                 R3

      1      0.000000E+00      0.000000E+00      0.000000E+00
             0.000000E+00      0.000000E+00      0.000000E+00

      2      0.000000E+00      0.000000E+00      0.000000E+00
             1.130323E+01      0.000000E+00      0.000000E+00

      3      0.000000E+00      0.000000E+00      0.000000E+00
             0.000000E+00      0.000000E+00      0.000000E+00

      4      0.000000E+00      0.000000E+00      3.376275E+02
             1.130323E+01      0.000000E+00      0.000000E+00

1GENESIS   VERSION  7.2                 DATE 12-13-2002  TIME 12:50  PAGE   14
 BEAMS WITH AND WITHOUT OFFSET

 MOMENT Y                                                   LOADCASE        5

                      G R I D   D I S P L A C E M E N T S

  GRID ID             T1                 T2                 T3
                      R1                 R2                 R3

      1      0.000000E+00      0.000000E+00      0.000000E+00
             0.000000E+00      0.000000E+00      0.000000E+00

      2      0.000000E+00      0.000000E+00     -5.757848E+01
             0.000000E+00      1.151570E-01      0.000000E+00

      3      0.000000E+00      0.000000E+00      0.000000E+00
             0.000000E+00      0.000000E+00      0.000000E+00

      4      0.000000E+00      0.000000E+00     -5.757848E+01
             0.000000E+00      1.151570E-01      0.000000E+00

1GENESIS   VERSION  7.2                 DATE 12-13-2002  TIME 12:50  PAGE   15
```

```
 BEAMS WITH AND WITHOUT OFFSET

 MOMENT Z                                                        LOADCASE        6

                     G R I D   D I S P L A C E M E N T S

  GRID ID           T1                 T2                 T3
                    R1                 R2                 R3

       1      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

       2      2.154325E+01      3.606168E+02      0.000000E+00
              0.000000E+00      0.000000E+00      7.212336E-01

       3      0.000000E+00      0.000000E+00      0.000000E+00
              0.000000E+00      0.000000E+00      0.000000E+00

       4      0.000000E+00      3.606168E+02      0.000000E+00
              0.000000E+00      0.000000E+00      7.212336E-01

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   16
 BEAMS WITH AND WITHOUT OFFSET

 FORCE X                                                         LOADCASE        1

                F O R C E S   I N   B E A M   E L E M E N T S

  BEAM ID  X/XB      MOMENT 1        MOMENT 2       AXIAL FORCE      WARPING
                  SHEAR FORCE 1   SHEAR FORCE 2      TORQUE


       1 0.000    0.000000E+00    1.493500E+05    5.000000E+03    0.000000E+00
                  0.000000E+00    0.000000E+00    0.000000E+00

       2 0.000    0.000000E+00    0.000000E+00    5.000000E+03    0.000000E+00
                  0.000000E+00    0.000000E+00    0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   17
 BEAMS WITH AND WITHOUT OFFSET

 FORCE Y                                                         LOADCASE        2

                F O R C E S   I N   B E A M   E L E M E N T S

  BEAM ID  X/XB      MOMENT 1        MOMENT 2       AXIAL FORCE      WARPING
                  SHEAR FORCE 1   SHEAR FORCE 2      TORQUE


       1 0.000    0.000000E+00    5.000000E+06    0.000000E+00    0.000000E+00
                  0.000000E+00    5.000000E+03    0.000000E+00

       2 0.000    0.000000E+00    5.000000E+06    0.000000E+00    0.000000E+00
                  0.000000E+00    5.000000E+03    0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   18
 BEAMS WITH AND WITHOUT OFFSET
```

```
 FORCE Z                                                    LOADCASE        3

                 F O R C E S   I N   B E A M   E L E M E N T S

  BEAM ID  X/XB      MOMENT 1        MOMENT 2       AXIAL FORCE      WARPING
                   SHEAR FORCE 1   SHEAR FORCE 2      TORQUE


       1 0.000   -5.000000E+06   0.000000E+00   0.000000E+00   0.000000E+00
                 -5.000000E+03   0.000000E+00   0.000000E+00

       2 0.000   -5.000000E+06   0.000000E+00   0.000000E+00   0.000000E+00
                 -5.000000E+03   0.000000E+00   1.493500E+05
1GENESIS   VERSION  7.2               DATE 12-13-2002  TIME 12:50  PAGE   19
 BEAMS WITH AND WITHOUT OFFSET

 MOMENT X                                                   LOADCASE        4

                 F O R C E S   I N   B E A M   E L E M E N T S

  BEAM ID  X/XB      MOMENT 1        MOMENT 2       AXIAL FORCE      WARPING
                   SHEAR FORCE 1   SHEAR FORCE 2      TORQUE


       1 0.000    0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
                  0.000000E+00   0.000000E+00   2.000000E+07

       2 0.000    0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
                  0.000000E+00   0.000000E+00   2.000000E+07
1GENESIS   VERSION  7.2               DATE 12-13-2002  TIME 12:50  PAGE   20
 BEAMS WITH AND WITHOUT OFFSET

 MOMENT Y                                                   LOADCASE        5

                 F O R C E S   I N   B E A M   E L E M E N T S

  BEAM ID  X/XB      MOMENT 1        MOMENT 2       AXIAL FORCE      WARPING
                   SHEAR FORCE 1   SHEAR FORCE 2      TORQUE


       1 0.000    2.000000E+07   0.000000E+00   0.000000E+00   0.000000E+00
                 -1.455192E-11   0.000000E+00   0.000000E+00

       2 0.000    2.000000E+07   0.000000E+00   0.000000E+00   0.000000E+00
                  0.000000E+00   0.000000E+00   0.000000E+00
1GENESIS   VERSION  7.2               DATE 12-13-2002  TIME 12:50  PAGE   21
 BEAMS WITH AND WITHOUT OFFSET

 MOMENT Z                                                   LOADCASE        6

                 F O R C E S   I N   B E A M   E L E M E N T S

  BEAM ID  X/XB      MOMENT 1        MOMENT 2       AXIAL FORCE      WARPING
                   SHEAR FORCE 1   SHEAR FORCE 2      TORQUE
```

```
        1 0.000    0.000000E+00    2.000000E+07    0.000000E+00    0.000000E+00
                    0.000000E+00    0.000000E+00    0.000000E+00

        2 0.000    0.000000E+00    2.000000E+07    0.000000E+00    0.000000E+00
                    0.000000E+00    0.000000E+00    0.000000E+00
1                             ***** END OF OUTPUT *****
```

2.34 Buckling Analysis of a Tripod

Example ID:

A034

Analysis Data:

GRID, CBAR, PBARL, MAT1, SPC, GRAV, CONM2, EIGR, GRAV, CONM2

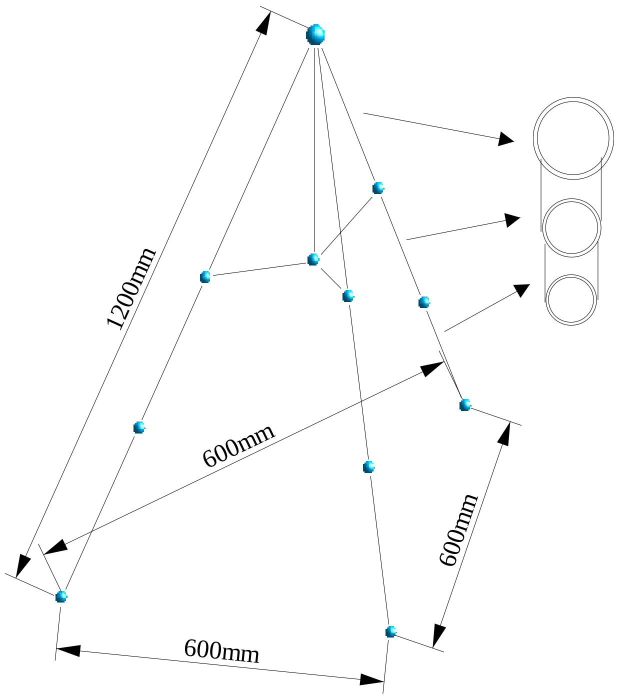
Special Features Used:

STATSUB in solution control for buckling analysis

Problem Statement:

A tripod was modeled using CBAR elements together with PBARL. The dimensions of the each members of tripod and bar cross-sectional areas are shown in the picture.

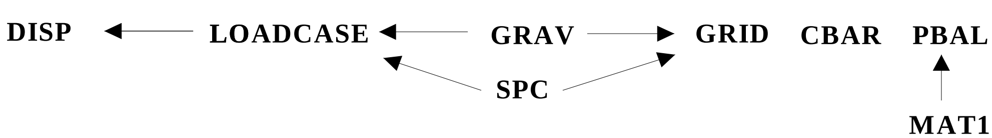
Structural Analysis Model:



Analysis Model Description:

1. The unit used here is the N, mm, Mg and material is Aluminum (E=110.0E3 MPa, ρ=2.79 g/cm^3, ν=0.35).
2. Concentrated mass was used in the connections in each bars.
3. As a load, 1000g of concentrated mass was applied at the tripod top.

Analysis Data Relationships:



Special Modeling Techniques:

None.

Reference Solution:

None.

Calculated Solution:

MODE	BUCKLING LOAD FACTOR
1	9.683800E+00
2	9.684140E+00
3	1.401889E+01
4	1.642446E+01

2.34.1 Input Data

```
ID A034
SOL COMPAT1
POST=PUNCH
CEND
TITLE=TRIPOD BUCKLING ANALYSIS PROBLEM
ECHO = NONE
LINE = *,80
TIMES=SCREEN
$
LOADCASE        1
   LABEL=CASE1
   SPC    =       1
   GRAV   =       1
   DISP   =BOTH,ALL
   STRESS =BOTH,ALL
LOADCASE        2
   LABEL=BACKLING
   METHOD   =       1
   STATLOAD  =       1
   DISP   =BOTH,ALL
   MASS = YES
BEGIN BULK
$
$  --- ANALYSIS DATA ---
$
EIGR1          LAN            1.0E-8                              4
GRAV           1          -980.0     0.0     0.0     1.0
$
CBAR           1       1       4       6       5
CBAR           2       1      10       4       5
CBAR           3       1       8       4       5
CBAR           4       2       6       7       5
CBAR           5       2      10      11       5
CBAR           6       2       8       9       5
CBAR           7       3       7       1       5
CBAR           8       3      11       3       5
CBAR           9       3       9       2       5
CBAR          10       4      10       5       4
CBAR          11       4       6       5       4
CBAR          12       4       8       5       4
CBAR          13       5       4       5       8
$
CONM2         21       1         0.00001
CONM2         22       2         0.00001
CONM2         23       3         0.00001
CONM2         24       4         0.01010
CONM2         25       5         0.00001
CONM2         26       6         0.00001
CONM2         27       7         0.00001
CONM2         28       8         0.00001
CONM2         29       9         0.00001
CONM2         30      10         0.00001
```

```
CONM2         31      11         0.00001
$
PBARL          1       1  CSLIB1  TUBE
+            15.    0.20
PBARL          2       1  CSLIB1  TUBE
+            14.    0.20
PBARL          3       1  CSLIB1  TUBE
+            13.    0.20
PBARL          4       1  CSLIB1  TUBE
+            12.    0.20
PBARL          5       1  CSLIB1  TUBE
+            12.    0.20
$
MAT1           1  7.30E4            0.35 2.79E-9
$
GRID           1             0.0     0.0     0.0
GRID           2        600.0000     0.0     0.0
GRID           3        300.0000519.6000     0.0
GRID           4        300.0000173.20001187.400
GRID           5        300.0000173.2000791.6000
GRID           6        200.0000115.4667791.6000
GRID           7        100.000057.73334395.8000
GRID           8        400.0000115.4667791.6000
GRID           9        500.000057.73334395.8000
GRID          10        300.0000288.6666791.6000
GRID          11        300.0000404.1333395.8000
SPC            1       1    1236     0.0
SPC            1       2       3     0.0
SPC            1       3       3     0.0
ENDDATA
```

2.34.2 Output Data

```
1










              GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
             G        E       NN  N   E       S          I     S
             G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
             G    G   E       N  NN   E            S     I          S
              GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                 STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE



                              COPYRIGHT, 1991-2002

                     VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                          ALL RIGHTS RESERVED, WORLDWIDE

                                  VERSION 7.2

                            BUILD CODE 200212131048




     PROJECT NAME: A034
     RUN STARTED:  Dec 13, 2002 12:50
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    1
 TRIPOD BUCKLING ANALYSIS PROBLEM


                            ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                    11
                   NUMBER OF CBAR ELEMENTS:                  13
                   NUMBER OF CONM2 ELEMENTS:                 11
```

```
                    TOTAL NUMBER OF NON RIGID ELEMENTS:        24
                    NUMBER OF ELEMENT PROPERTIES:               5
                    NUMBER OF MATERIALS:                        1
                    NUMBER OF DEGREES OF FREEDOM:              60


                                LOAD CASES SUMMARY

                   NUMBER OF STATIC LOAD CASES:                   1
                   NUMBER OF BUCKLING LOAD CASES:                 1
                   TOTAL NUMBER OF LOAD CASES:                    2

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    2
 TRIPOD BUCKLING ANALYSIS PROBLEM


                          LANCZOS EIGENSOLUTION STATISTICS

  SHIFT       SHIFT                              EVALUES     NEW     TERM.     CPU
  COUNT       VALUE                               BELOW     FOUND    CODE      TIME
  -----    -------------                         -------   -------   -----   --------
      1     1.000000E+00                               0         4       2       0.03
      2     2.494797E+01                               4         0      10       0.00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    3
 TRIPOD BUCKLING ANALYSIS PROBLEM


                 ********************************************
                 *  D E S I G N  C Y C L E      0 (ANALYSIS)*
                 ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    4
 TRIPOD BUCKLING ANALYSIS PROBLEM


                     M A S S / V O L U M E   S U M M A R Y

                     SYSTEM MASS              1.030824E-02
                     SYSTEM VOLUME            3.879662E+04
                     SYSTEM MASS/VOLUME       2.656995E-07
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    5
 TRIPOD BUCKLING ANALYSIS PROBLEM


                                M A S S   T A B L E


                          ITEM     NUMBER          MASS

                         SYSTEM                 1.030824E-02
                         PBAR           1       3.295804E-05
                         PBAR           2       3.078975E-05
                         PBAR           3       2.862145E-05
                         PBAR           4       7.408462E-06
                         PBAR           5       8.464858E-06
```

```
                        MAT1          1      1.082426E-04

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    6
 TRIPOD BUCKLING ANALYSIS PROBLEM


                   S O L U T I O N   R E S I D U A L S

 LOADCASE        1 ; RESIDUAL :  8.857431E-11 ; STRAIN ENERGY :  1.737482E+01
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    7
 TRIPOD BUCKLING ANALYSIS PROBLEM


                     O L O A D   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1  0.0000E+00  5.2612E-19 -1.0102E+01 -1.7497E+03  3.0306E+03  1.3615E-16
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    8
 TRIPOD BUCKLING ANALYSIS PROBLEM


                   S P C F O R C E   R E S U L T A N T S

 LOADCASE     T1           T2           T3           R1           R2           R3

      1  2.2598E-13 -3.4449E-13  1.0102E+01  1.7497E+03 -3.0306E+03 -2.0367E-10
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    9
 TRIPOD BUCKLING ANALYSIS PROBLEM


               M A X I M U M   A P P L I E D   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1           T2           T3

       1        4     9.9183E+00  0.0000E+00 -2.1684E-19 -9.9183E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   10
 TRIPOD BUCKLING ANALYSIS PROBLEM


                   M A X I M U M   S P C   F O R C E

 LOADCASE GRID ID      MAGNITUDE      T1           T2           T3

       1        1     3.3674E+00  5.5937E-12 -1.9121E-10  3.3674E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   11
 TRIPOD BUCKLING ANALYSIS PROBLEM


                  M A X I M U M   D I S P L A C E M E N T

 LOADCASE GRID ID      MAGNITUDE      T1           T2           T3

       1        2     2.0485E+01  2.0485E+01 -4.5048E-08  0.0000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   12
```

```
 TRIPOD BUCKLING ANALYSIS PROBLEM

 CASE1                                                               LOADCASE         1

                     G R I D   D I S P L A C E M E N T S

  GRID ID             T1                 T2                 T3
                      R1                 R2                 R3

        1      0.000000E+00      0.000000E+00      0.000000E+00
              -1.110259E-02      1.923134E-02      0.000000E+00

        2      2.048533E+01     -4.504767E-08      0.000000E+00
              -1.110259E-02     -1.923134E-02     -1.616128E-10

        3      1.024267E+01      1.774027E+01      0.000000E+00
               2.220605E-02     -5.632925E-13     -7.909560E-11

        4      1.024267E+01      5.913071E+00     -3.460630E+00
               3.071618E-07     -5.451122E-13     -7.922978E-11

        5      1.024267E+01      5.913192E+00     -3.472425E+00
               3.090593E-07     -6.289193E-13     -7.904107E-11

        6      1.024200E+01      5.912805E+00     -3.454534E+00
              -7.976579E-04      1.382153E-03     -1.338904E-10

        7      6.922066E+00      3.996219E+00     -2.334071E+00
              -8.075706E-03      1.398847E-02      2.116870E-12

        8      1.024333E+01      5.912805E+00     -3.454534E+00
              -7.976579E-04     -1.382153E-03     -2.439540E-11

        9      1.356326E+01      3.996219E+00     -2.334071E+00
              -8.075706E-03     -1.398847E-02     -1.616128E-10

       10      1.024267E+01      5.913965E+00     -3.454481E+00
               1.596218E-03     -5.632925E-13     -7.909560E-11

       11      1.024267E+01      9.747488E+00     -2.334017E+00
               1.615229E-02     -5.632925E-13     -7.909560E-11

1GENESIS   VERSION  7.2                 DATE 12-13-2002  TIME 12:50  PAGE   13
 TRIPOD BUCKLING ANALYSIS PROBLEM

 CASE1                                                               LOADCASE         1

            S T R E S S E S   I N   B A R   E L E M E N T S

   BAR ID  END     STRESS-C       STRESS-D       STRESS-E       STRESS-F

        1    A  -1.000364E+00  -5.239680E+00  -1.000355E+00   3.238961E+00
             B  -1.001443E+00   7.583741E+00  -1.001440E+00  -9.586624E+00

        2    A  -1.001440E+00   7.583500E+00  -1.001440E+00  -9.586379E+00
```

```
              B  -1.000357E+00  -5.239566E+00  -1.000357E+00   3.238851E+00

         3    A  -1.001443E+00   7.583741E+00  -1.001440E+00  -9.586624E+00
              B  -1.000364E+00  -5.239679E+00  -1.000355E+00   3.238961E+00

         4    A  -3.581261E-01   2.435578E+01  -3.581065E-01  -2.507201E+01
              B  -3.592025E-01   1.203379E+01  -3.591945E-01  -1.275219E+01

         5    A  -3.581169E-01   2.435524E+01  -3.581169E-01  -2.507148E+01
              B  -3.591991E-01   1.203352E+01  -3.591991E-01  -1.275192E+01

         6    A  -3.581065E-01   2.435578E+01  -3.581261E-01  -2.507201E+01
              B  -3.591945E-01   1.203379E+01  -3.592025E-01  -1.275219E+01

         7    A  -3.875471E-01   1.396894E+01  -3.875426E-01  -1.474403E+01
              B  -3.886270E-01  -3.886270E-01  -3.886270E-01  -3.886270E-01

         8    A  -3.875455E-01   1.396863E+01  -3.875455E-01  -1.474372E+01
              B  -3.886277E-01  -3.886277E-01  -3.886277E-01  -3.886277E-01

         9    A  -3.875426E-01   1.396894E+01  -3.875471E-01  -1.474403E+01
              B  -3.886270E-01  -3.886270E-01  -3.886270E-01  -3.886270E-01

        10    A   4.887905E-01  -1.969791E+01   4.887905E-01   2.067549E+01
              B   4.887905E-01   8.166385E+00   4.887905E-01  -7.188804E+00

        11    A   4.888013E-01  -1.969825E+01   4.888023E-01   2.067585E+01
              B   4.888027E-01   8.166606E+00   4.888009E-01  -7.189002E+00

        12    A   4.888023E-01  -1.969825E+01   4.888013E-01   2.067585E+01
              B   4.888009E-01   8.166606E+00   4.888027E-01  -7.189002E+00

        13    A   2.175858E+00   2.175863E+00   2.175882E+00   2.175877E+00
              B   2.174804E+00   2.174797E+00   2.174772E+00   2.174779E+00
1GENESIS   VERSION  7.2                DATE 12-13-2002  TIME 12:50  PAGE   14
 TRIPOD BUCKLING ANALYSIS PROBLEM

 BACKLING                                                    LOADCASE        2

                 B U C K L I N G   L O A D   F A C T O R S

     MODE  BUCKLING LOAD FACTOR

         1     9.685081E+00
         2     9.694449E+00
         3     1.428663E+01
         4     1.642446E+01
1GENESIS   VERSION  7.2                DATE 12-13-2002  TIME 12:50  PAGE   15
 TRIPOD BUCKLING ANALYSIS PROBLEM

 BACKLING                                                    LOADCASE        2
                       B U C K L I N G   M O D E S

 MODE NUMBER        1      BUCKLING LOAD FACTOR =   9.685081E+00
```

```
 GRID ID            T1                 T2                 T3
                    R1                 R2                 R3

       1     0.000000E+00      0.000000E+00      0.000000E+00
            -9.913269E-04      1.826365E-03      0.000000E+00

       2     1.861754E+00      3.158330E+00      0.000000E+00
             4.806850E-03     -1.595634E-03      6.468675E-04

       3     3.660510E+00     -3.312731E-02      0.000000E+00
            -1.055707E-03     -4.907358E-03     -6.279140E-04

       4     1.602126E-02     -3.501411E-02     -7.886030E-06
             7.912720E-04     -1.340903E-03      6.192928E-06

       5     5.675375E-01      2.904379E-01     -7.906696E-06
             9.044078E-04     -1.532627E-03      6.023956E-06

       6     5.677976E-01      2.898581E-01     -1.862615E-01
             6.990331E-04     -1.168926E-03      5.701595E-06

       7     5.949646E-01      3.202626E-01     -1.973070E-01
            -4.497668E-04      8.669080E-04      2.292304E-06

       8     5.709710E-01      2.964487E-01      9.158662E-02
             1.310649E-03     -1.530000E-03      4.417984E-05

       9     1.199917E+00      1.347729E+00      9.702210E-02
             3.695865E-03     -1.579791E-03      3.914153E-04

      10     5.730023E-01      2.904051E-01      9.465124E-02
             6.921434E-04     -1.879629E-03     -3.171819E-05

      11     1.783360E+00      3.101018E-01      1.002687E-01
            -4.958066E-04     -3.947719E-03     -3.752137E-04

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   16
 TRIPOD BUCKLING ANALYSIS PROBLEM

 BACKLING                                                    LOADCASE        2
                      B U C K L I N G   M O D E S

 MODE NUMBER        2      BUCKLING LOAD FACTOR =   9.694449E+00

 GRID ID            T1                 T2                 T3
                    R1                 R2                 R3

       1     0.000000E+00      0.000000E+00      0.000000E+00
             4.991001E-03      2.858797E-03      0.000000E+00

       2     3.152130E+00     -1.519026E+00      0.000000E+00
             1.487777E-03     -2.949054E-03      9.913259E-04

       3    -3.300739E-01     -3.489280E+00      0.000000E+00
```

```
          -1.790238E-03      2.856641E-03      1.003423E-03

     4     2.016418E+00     -3.492479E+00     -1.338589E-05
           1.341704E-03      7.916807E-04      6.521111E-04

     5     1.690789E+00     -2.940618E+00     -1.342097E-05
           1.533576E-03      9.048972E-04      6.341314E-04

     6     1.724067E+00     -2.998258E+00      1.755272E-03
           1.899318E-03      1.111477E-03      6.003482E-04

     7     1.053218E+00     -1.837044E+00      1.864336E-03
           4.008560E-03      2.303650E-03      2.414897E-04

     8     1.729157E+00     -2.874272E+00     -1.622932E-01
           1.508500E-03      4.992143E-04      6.555148E-04

     9     2.077265E+00     -2.203794E+00     -1.719215E-01
           1.499423E-03     -1.847243E-03      8.489274E-04

    10     1.614032E+00     -2.940673E+00      1.604979E-01
           1.173676E-03      1.092644E-03      6.562334E-04

    11     8.362217E-01     -2.907252E+00      1.700296E-01
          -8.407061E-04      2.297496E-03      8.561998E-04
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   17
 TRIPOD BUCKLING ANALYSIS PROBLEM

 BACKLING                                                    LOADCASE        2
                       B U C K L I N G   M O D E S

 MODE NUMBER        3      BUCKLING LOAD FACTOR =   1.428663E+01

  GRID ID            T1                 T2                 T3
                     R1                 R2                 R3

     1     0.000000E+00      0.000000E+00      0.000000E+00
           3.307093E-03      1.909304E-03      0.000000E+00

     2    -2.072654E-02     -3.166899E+00      0.000000E+00
          -3.452128E-03      2.021998E-03      5.271223E-04

     3     2.752918E+00     -1.565504E+00      0.000000E+00
           2.507114E-05     -4.000571E-03      5.271377E-04

     4     9.037939E-01     -1.565466E+00      4.802701E-07
          -1.811651E-05     -1.046856E-05      1.364071E-03

     5     9.081340E-01     -1.572977E+00      4.816373E-07
          -2.082361E-05     -1.203309E-05      9.128722E-04

     6     9.618464E-01     -1.666012E+00     -4.569113E-07
           4.420599E-04      2.552079E-04      9.987487E-04
```

```
       7      6.709104E-01     -1.162080E+00     -6.924335E-07
              2.374785E-03      1.371046E-03      5.516395E-04

       8      9.632701E-01     -1.477474E+00      2.186816E-03
             -4.887116E-04      2.635102E-04      1.049718E-03

       9      6.656339E-01     -1.994215E+00      2.360139E-03
             -2.473214E-03      1.440919E-03      8.116848E-04

      10      7.978609E-01     -1.572976E+00     -2.184920E-03
             -1.613621E-05     -5.549920E-04      1.049715E-03

      11      1.394184E+00     -1.573580E+00     -2.358447E-03
              1.129268E-05     -2.862286E-03      8.116895E-04

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   18
 TRIPOD BUCKLING ANALYSIS PROBLEM

 BACKLING                                                 LOADCASE         2
                      B U C K L I N G   M O D E S

 MODE NUMBER        4      BUCKLING LOAD FACTOR =   1.642446E+01

  GRID ID            T1                T2                T3
                     R1                R2                R3

       1      0.000000E+00      0.000000E+00      0.000000E+00
             -1.971522E-03      3.414695E-03      0.000000E+00

       2      3.450666E+00     -6.546675E-06      0.000000E+00
             -1.971525E-03     -3.414693E-03     -1.821950E-08

       3      1.725339E+00      2.988435E+00      0.000000E+00
              3.943038E-03     -2.302179E-09     -7.867541E-09

       4      1.725335E+00      9.961387E-01     -5.817608E-01
              1.252881E-08     -3.977412E-11     -7.723314E-09

       5      1.725335E+00      9.961429E-01     -5.834814E-01
              6.997061E-09     -4.293790E-11     -7.660474E-09

       6      1.725263E+00      9.961025E-01     -5.811891E-01
             -1.137479E-04      1.970162E-04     -8.975730E-09

       7      1.203823E+00      6.950436E-01     -4.055318E-01
             -1.337276E-03      2.316177E-03     -5.798110E-09

       8      1.725406E+00      9.961010E-01     -5.811891E-01
             -1.137480E-04     -1.970162E-04     -6.376498E-09

       9      2.246844E+00      6.950399E-01     -4.055318E-01
             -1.337279E-03     -2.316176E-03     -1.076072E-08

      10      1.725336E+00      9.962252E-01     -5.811872E-01
              2.275128E-04     -7.909535E-11     -7.551336E-09
```

```
      11       1.725337E+00       1.598349E+00      -4.055298E-01
               2.674555E-03      -1.572732E-09      -7.656940E-09

1                             ***** END OF OUTPUT *****
```

2.35 Enforced Dynamic Displacement with the Large Mass Method

Example ID:

A035

Analysis Data:

GRID, CBAR, PBARL, MAT1, SPC, CONM2, EIGR, FREQ1, RLOAD1, DAREA, TABLED4

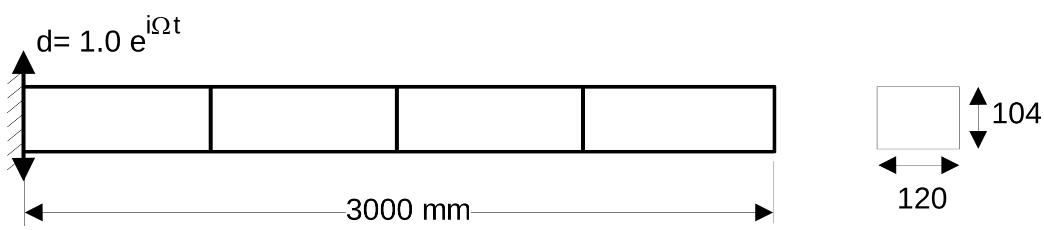
Special Features Used:

Large Mass Method

Problem Statement:

A cantilevered beam is modeled using CBAR elements together with PBARL. Calculate the response of the tip when the root is subjected to enforced dynamic displacement.

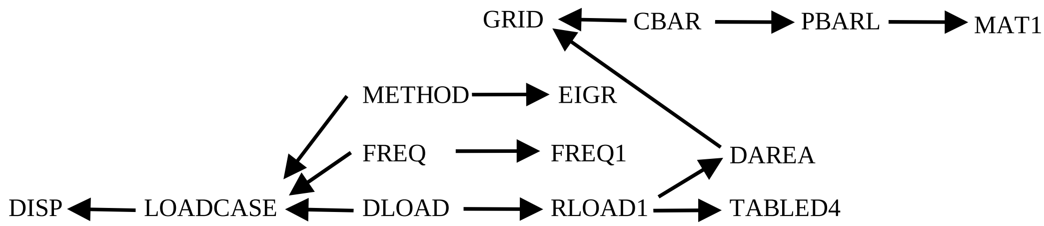
Structural Analysis Model:



Analysis Model Description:

1. The unit used here is the N, mm, Mg and material is Steel (E=207.0E3 MPa, ρ=8.0 g/cm^3, ν=0.3).

Analysis Data Relationships:



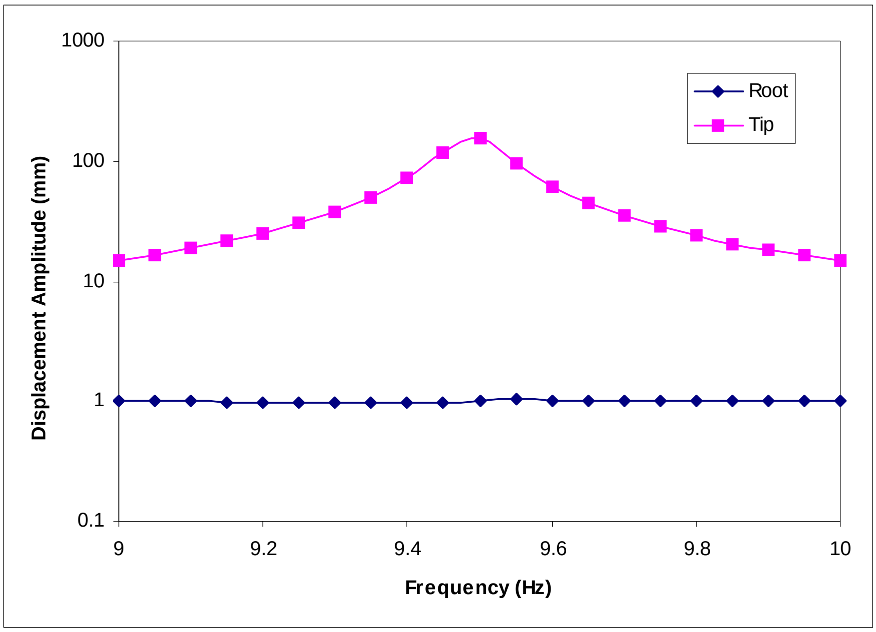
Special Modeling Techniques:

The Large Mass Method is used to apply an enforced dynamic displacement.

Reference Solution:

None.

Calculated Solution:



2.35.1 Input Data

```
SOL COMPAT0
CEND
TITLE=ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
SUBTITLE=EXAMPLE USING LARGE MASS METHOD
LINE=64,80
ECHO=NONE
$
DYNOUTPUT = MAGNITUDE
$
SET 5 = 1,5
SPC = 1
FREQ = 30
$
LOADCASE 2
LABEL = SOLUTION USING:  MODAL FREQUENCY RESPONSE
DLOAD = 22
DISP=5
METHOD=4
$
LOADCASE 3
LABEL = SOLUTION USING:  DIRECT FREQUENCY RESPONSE
DLOAD = 22
DISP=5
$
BEGIN BULK
PARAM,G,.01
PARAM,MODACC,1
$
$ The dynamical system of equations is:
$
$ [ -W^2 M + i W B + (1+ig) K + i KE ] U = P
$
$ where W is the loading frequency
$       M is the system mass matrix
$       B is the system viscous damping matrix
$       K is the system stiffness matrix
$       KE is the system structural damping matrix
$       g is the global structural damping coefficient
$       U is the complex displacement vector
$       P is the complex load vector
$       i is sqrt(-1)
$
$       Note, the real loads and displacements are usually taken as
$          p(t) = Re( P e^(i W t) )
$          u(t) = Re( U e^(i W t) )
$
$ to enforce U = D, a penalty mass, Mp is added to the left side, and
$ a corresponding penalty load is added to the right side of the
$ dynamical equation:
$
$ [ -W^2 M + i W B + (1+iG) K + i KE -W^2 Mp ] U = P - W^2 Mp D
$
```

```
$ Here, a penaly mass of about 1000.0 times the total system mass
$ is added to the grid where displacements are to be enforced.
$------12------23------34------45------56------67------78------89------9X-----
-X
CONM2       1001       1           300.0
$
$   LOADING FREQUENCIES
$
FREQ1         30     9.0     .05      20
$
$   LOAD DEFINITION
$
$   A load = - W^2 Mp D is applied to the grid with the penaly mass
$   Here, D = 1.0 is used to enforce U = 1.0
$
$------12------23------34------45------56------67------78------89------9X-----
-X
RLOAD1        22       2                       4
$
$------12------23------34------45------56------67------78------89------9X-----
-X
DAREA          2       1       3     1.0
$
$    C(W) = - W^2 Mp
$
$    TABLED4 makes a polynomial: y(x) = sum Ai ((x-X1)/X2)^i  {X3 < x < X4}
$
$    Here, X2 = 1/(2 PI) to convert W from cycles/sec to radians/sec
$    A2 comes from the value of the penalty mass that was used.
$
$------12------23------34------45------56------67------78------89------9X-----
-X
$TABLED4      ID      X1      X2      X3      X4
$+            A0      A1      A2      A3     ...
$------12------23------34------45------56------67------78------89------9X-----
-X
TABLED4        4     0.0 .159155     0.0 1.0E+30
+            0.0     0.0  -300.0
$
$   GRID DATA
$
GRID    1               0.00    0.      0.0
GRID    2               750.0   0.      0.0
GRID    3               1500.0  0.      0.0
GRID    4               2250.0  0.      0.0
GRID    5               3000.0  0.      0.0
SPC     1       1       12456
$
$   ELEMENT DEFINITIONS
$
CBAR    1       1       1       2       0.      1.0     0.
CBAR    2       1       2       3       0.      1.0     0.
CBAR    3       1       3       4       0.      1.0     0.
CBAR    4       1       4       5       0.      1.0     0.
$
$   PROPERTY DEFINITIONS
```

```
$
$------12------23------34------45------56------67------78------89------9X-----
-X
PBARL   1       1       CSLIB1   RECT
+       120.0   104.0
$
$   MATERIAL DATA
$
$------12------23------34------45------56------67------78------89------9X-----
-X
MAT1    1       2.07+5          0.3     8.0-9
$
$   EIGENVALUES DATA
$
$------12------23------34------45------56------67------78------89------9X-----
-X
EIGR    4       SMS             200.0                   10
$
ENDDATA
```

2.35.2 Output Data

```
1







         GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
        G        E       NN  N   E       S          I     S
        G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
        G    G   E       N  NN   E            S     I          S
         GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


            STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                       COPYRIGHT, 1991-2002

              VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                   ALL RIGHTS RESERVED, WORLDWIDE

                            VERSION 7.2

                      BUILD CODE 200212131048




     PROJECT NAME: A035
     RUN STARTED:  Dec 13, 2002 12:50
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    1
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD

                             ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                      5
                   NUMBER OF CBAR ELEMENTS:                    4
                   NUMBER OF CONM2 ELEMENTS:                   1
```

```
                TOTAL NUMBER OF NON RIGID ELEMENTS:        5
                NUMBER OF ELEMENT PROPERTIES:              1
                NUMBER OF MATERIALS:                       1
                NUMBER OF DEGREES OF FREEDOM:             25



                            LOAD CASES SUMMARY

               NUMBER OF USER FREQUENCY LOAD CASES:          0
               NUMBER OF INTERNAL FREQUENCY LOAD CASES:      1
               NUMBER OF DIRECT DYNAMIC LOAD CASES:          1
               NUMBER OF MODAL  DYNAMIC LOAD CASES:          1
               TOTAL NUMBER OF LOAD CASES:                   3

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    2
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD

            ********************************************
            *  D E S I G N  C Y C L E     0 (ANALYSIS)*
            ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    3
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD

                M A S S / V O L U M E   S U M M A R Y

                SYSTEM MASS              3.002995E+02
                SYSTEM VOLUME            3.744000E+07
                SYSTEM MASS/VOLUME       8.020821E-06
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    4
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 MODES FOR METHOD OF LOADCASE 2                             LOADCASE        4

                       E I G E N V A L U E S

                                                     GENERALIZED   GENERALIZED
   MODE       CYCLES      EIGENVALUE      RADIANS        MASS        STIFFNESS

        1  2.742409E-06  2.969096E-10  1.723107E-05  1.000000E+00  2.969096E-10
        2  9.489702E+00  3.555207E+03  5.962556E+01  1.000000E+00  3.555207E+03
        3  1.094293E+01  4.727447E+03  6.875643E+01  1.000000E+00  4.727447E+03
        4  5.921225E+01  1.384149E+05  3.720416E+02  1.000000E+00  1.384149E+05
        5  6.817606E+01  1.834947E+05  4.283628E+02  1.000000E+00  1.834947E+05
        6  1.656957E+02  1.083882E+06  1.041097E+03  1.000000E+00  1.083882E+06
        7  1.903513E+02  1.430447E+06  1.196013E+03  1.000000E+00  1.430447E+06

     NOTE FROM ROUTINE GN42PE:
     ALTHOUGH       10 EIGENVALUES HAVE BEEN REQUESTED,
     ONLY        7 EIGENVALUES EXISTED IN THE RANGE
     SPECIFIED.

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    5
```

```
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                     LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.0000E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                  (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      9.935827E-01
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.105782E-02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   7.256227E-13      5.137384E-11      1.489824E+01
           MAGN   2.358203E-13      6.355027E-03      4.370223E-14
           PHASE  3.594199E+02      3.538246E+02      3.546938E+02
           PHASE  3.594194E+02      1.742966E+02      3.563845E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    6
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                     LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.0500E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                  (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      9.929302E-01
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.867848E-02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   7.338189E-13      5.820605E-11      1.659279E+01
           MAGN   2.384863E-13      7.132347E-03      4.706776E-14
           PHASE  3.594182E+02      3.531636E+02      3.540682E+02
           PHASE  3.594176E+02      1.736723E+02      3.558497E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    7
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                     LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.1000E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                  (MAGNITUDE/PHASE)
```

```
       1  MAGN   0.000000E+00      0.000000E+00      9.921166E-01
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      4.939977E-02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   7.420894E-13      6.682172E-11      1.871388E+01
          MAGN   2.411771E-13      8.105470E-03      5.125111E-14
          PHASE  3.594158E+02      3.523424E+02      3.532845E+02
          PHASE  3.594150E+02      1.728899E+02      3.551624E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    8
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.1500E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      9.910758E-01
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      6.513780E-02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   7.504464E-13      7.799013E-11      2.144378E+01
          MAGN   2.438970E-13      9.358107E-03      5.660262E-14
          PHASE  3.594122E+02      3.512923E+02      3.522745E+02
          PHASE  3.594113E+02      1.718812E+02      3.542545E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    9
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.2000E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      9.897001E-01
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      8.953178E-02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   7.589097E-13      9.298639E-11      2.508417E+01
          MAGN   2.466527E-13      1.102884E-02      6.370147E-14
          PHASE  3.594068E+02      3.498994E+02      3.509242E+02
          PHASE  3.594055E+02      1.705323E+02      3.530126E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   10
```

```
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.2500E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      9.878062E-01
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      1.301634E-01
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   7.675130E-13      1.140778E-10      3.017060E+01
          MAGN   2.494559E-13      1.336377E-02      7.357382E-14
          PHASE  3.593978E+02      3.479592E+02      3.490294E+02
          PHASE  3.593959E+02      1.686388E+02      3.512326E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   11
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.3000E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      9.850612E-01
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      2.048816E-01
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   7.763178E-13      1.456794E-10      3.774392E+01
          MAGN   2.523281E-13      1.684143E-02      8.820748E-14
          PHASE  3.593813E+02      3.450665E+02      3.461853E+02
          PHASE  3.593783E+02      1.657960E+02      3.485102E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   12
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.3500E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                 (MAGNITUDE/PHASE)
```

```
       1  MAGN   0.000000E+00      0.000000E+00      9.808410E-01
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.632828E-01
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   7.854412E-13      1.974723E-10      5.007962E+01
          MAGN   2.553098E-13      2.250879E-02      1.119235E-13
          PHASE  3.593465E+02      3.403030E+02      3.414737E+02
          PHASE  3.593412E+02      1.610857E+02      3.439273E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   13
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE         2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.4000E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                  (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      9.742317E-01
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      7.768880E-01
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   7.950652E-13      2.938736E-10      7.288475E+01
          MAGN   2.584641E-13      3.299586E-02      1.554294E-13
          PHASE  3.592566E+02      3.311453E+02      3.323718E+02
          PHASE  3.592452E+02      1.519851E+02      3.349611E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   14
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE         2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.4500E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                  (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      9.698332E-01
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      2.110417E+00
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   8.044700E-13      4.939002E-10      1.196808E+02
          MAGN   2.615418E-13      5.456971E-02      2.429660E-13
          PHASE  3.589670E+02      3.089347E+02      3.102211E+02
          PHASE  3.589365E+02      1.298357E+02      3.129530E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   15
```

```
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                    LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.5000E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      1.013390E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.309351E+00
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   8.052868E-13      6.467721E-10      1.529688E+02
          MAGN   2.616416E-13      7.024379E-02      2.949121E-13
          PHASE  3.586665E+02      2.567555E+02      2.581064E+02
          PHASE  3.586154E+02      7.772238E+01      2.609874E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   16
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                    LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.5500E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      1.029329E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      1.312704E+00
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   8.105259E-13      4.206316E-10      9.699376E+01
          MAGN   2.632713E-13      4.485388E-02      1.771364E-13
          PHASE  3.591191E+02      2.170468E+02      2.184673E+02
          PHASE  3.590983E+02      3.808454E+01      2.215029E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   17
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                    LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.6000E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                (MAGNITUDE/PHASE)
```

```
       1  MAGN   0.000000E+00      0.000000E+00      1.021660E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      5.425083E-01
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   8.204185E-13      2.763060E-10      6.204531E+01
          MAGN   2.665145E-13      2.889283E-02      1.070595E-13
          PHASE  3.593008E+02      2.020154E+02      2.035110E+02
          PHASE  3.592923E+02      2.312959E+01      2.067050E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   18
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.6500E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      1.016090E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      2.827238E-01
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   8.300332E-13      2.042821E-10      4.461394E+01
          MAGN   2.696606E-13      2.091947E-02      7.254456E-14
          PHASE  3.593615E+02      1.951340E+02      1.967112E+02
          PHASE  3.593571E+02      1.633109E+01      2.000646E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   19
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.7000E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      1.012577E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      1.714210E-01
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   8.393288E-13      1.633023E-10      3.463799E+01
          MAGN   2.726951E-13      1.635332E-02      5.294022E-14
          PHASE  3.593874E+02      1.912651E+02      1.929311E+02
          PHASE  3.593847E+02      1.255222E+01      1.964405E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   20
```

```
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                       LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.7500E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                   (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      1.010238E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      1.146280E-01
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   8.484581E-13      1.373837E-10      2.825931E+01
          MAGN   2.756710E-13      1.343269E-02      4.049751E-14
          PHASE  3.594005E+02      1.887812E+02      1.905438E+02
          PHASE  3.593987E+02      1.016627E+01      1.941994E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   21
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                       LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.8000E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                   (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      1.008588E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      8.197415E-02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   8.575078E-13      1.197656E-10      2.385129E+01
          MAGN   2.786183E-13      1.141395E-02      3.197867E-14
          PHASE  3.594080E+02      1.870361E+02      1.889045E+02
          PHASE  3.594067E+02      8.528186E+00      1.926864E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   22
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                       LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.8500E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                   (MAGNITUDE/PHASE)
```

```
       1  MAGN   0.000000E+00      0.000000E+00      1.007368E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      6.153774E-02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   8.665247E-13      1.071899E-10      2.063039E+01
          MAGN   2.815532E-13      9.938697E-03      2.583369E-14
          PHASE  3.594127E+02      1.857263E+02      1.877108E+02
          PHASE  3.594117E+02      7.335779E+00      1.915849E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   23
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.9000E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      1.006432E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      4.791779E-02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   8.755350E-13      9.791568E-11      1.817704E+01
          MAGN   2.844849E-13      8.814926E-03      2.123770E-14
          PHASE  3.594158E+02      1.846909E+02      1.868034E+02
          PHASE  3.594151E+02      6.429672E+00      1.907145E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   24
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.9500E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      1.005692E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.839162E-02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   8.845547E-13      9.093731E-11      1.624752E+01
          MAGN   2.874189E-13      7.931071E-03      1.771563E-14
          PHASE  3.594180E+02      1.838365E+02      1.860906E+02
          PHASE  3.594174E+02      5.718137E+00      1.899543E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   25
```

```
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  1.0000E+01)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      1.005092E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.146934E-02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   8.935936E-13      8.563992E-11      1.469098E+01
           MAGN   2.903586E-13      7.218065E-03      1.497749E-14
           PHASE  3.594196E+02      1.831045E+02      1.855159E+02
           PHASE  3.594191E+02      5.144744E+00      1.892077E+02
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   26
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.0000E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      9.935827E-01
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.105782E-02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   0.000000E+00      0.000000E+00      1.489824E+01
           MAGN   0.000000E+00      6.355043E-03      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.546938E+02
           PHASE  0.000000E+00      1.742966E+02      0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   27
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.0500E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                (MAGNITUDE/PHASE)
```

```
       1  MAGN   0.000000E+00      0.000000E+00      9.929302E-01
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.867848E-02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   0.000000E+00      0.000000E+00      1.659279E+01
          MAGN   0.000000E+00      7.132366E-03      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.540682E+02
          PHASE  0.000000E+00      1.736723E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   28
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                   LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.1000E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      9.921166E-01
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      4.939977E-02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   0.000000E+00      0.000000E+00      1.871388E+01
          MAGN   0.000000E+00      8.105494E-03      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.532845E+02
          PHASE  0.000000E+00      1.728899E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   29
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                   LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.1500E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      9.910758E-01
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      6.513780E-02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   0.000000E+00      0.000000E+00      2.144379E+01
          MAGN   0.000000E+00      9.358135E-03      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.522745E+02
          PHASE  0.000000E+00      1.718812E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   30
```

```
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.2000E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      9.897001E-01
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      8.953178E-02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   0.000000E+00      0.000000E+00      2.508418E+01
           MAGN   0.000000E+00      1.102887E-02      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.509242E+02
           PHASE  0.000000E+00      1.705323E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   31
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.2500E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      9.878062E-01
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      1.301634E-01
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   0.000000E+00      0.000000E+00      3.017061E+01
           MAGN   0.000000E+00      1.336381E-02      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.490294E+02
           PHASE  0.000000E+00      1.686388E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   32
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.3000E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                 (MAGNITUDE/PHASE)
```

```
       1  MAGN   0.000000E+00      0.000000E+00      9.850612E-01
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      2.048816E-01
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   0.000000E+00      0.000000E+00      3.774392E+01
          MAGN   0.000000E+00      1.684148E-02      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.461853E+02
          PHASE  0.000000E+00      1.657960E+02      0.000000E+00

1GENESIS   VERSION  7.2                 DATE 12-13-2002  TIME 12:50  PAGE   33
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.3500E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      9.808410E-01
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.632828E-01
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   0.000000E+00      0.000000E+00      5.007963E+01
          MAGN   0.000000E+00      2.250887E-02      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.414737E+02
          PHASE  0.000000E+00      1.610857E+02      0.000000E+00

1GENESIS   VERSION  7.2                 DATE 12-13-2002  TIME 12:50  PAGE   34
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.4000E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      9.742317E-01
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      7.768880E-01
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   0.000000E+00      0.000000E+00      7.288476E+01
          MAGN   0.000000E+00      3.299598E-02      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.323718E+02
          PHASE  0.000000E+00      1.519851E+02      0.000000E+00

1GENESIS   VERSION  7.2                 DATE 12-13-2002  TIME 12:50  PAGE   35
```

```
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.4500E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      9.698332E-01
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      2.110417E+00
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   0.000000E+00      0.000000E+00      1.196808E+02
           MAGN   0.000000E+00      5.456991E-02      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.102211E+02
           PHASE  0.000000E+00      1.298357E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   36
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.5000E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      1.013390E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.309351E+00
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   0.000000E+00      0.000000E+00      1.529688E+02
           MAGN   0.000000E+00      7.024404E-02      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      2.581064E+02
           PHASE  0.000000E+00      7.772237E+01      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   37
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.5500E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                 (MAGNITUDE/PHASE)
```

```
       1  MAGN   0.000000E+00      0.000000E+00      1.029329E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      1.312704E+00
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   0.000000E+00      0.000000E+00      9.699377E+01
          MAGN   0.000000E+00      4.485404E-02      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      2.184673E+02
          PHASE  0.000000E+00      3.808453E+01      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   38
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                    LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.6000E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                   (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      1.021660E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      5.425083E-01
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   0.000000E+00      0.000000E+00      6.204531E+01
          MAGN   0.000000E+00      2.889294E-02      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      2.035110E+02
          PHASE  0.000000E+00      2.312959E+01      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   39
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                    LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.6500E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                   (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      1.016090E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      2.827238E-01
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   0.000000E+00      0.000000E+00      4.461395E+01
          MAGN   0.000000E+00      2.091955E-02      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      1.967112E+02
          PHASE  0.000000E+00      1.633109E+01      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   40
```

```
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                    LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.7000E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                   (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      1.012577E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      1.714210E-01
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   0.000000E+00      0.000000E+00      3.463800E+01
           MAGN   0.000000E+00      1.635339E-02      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      1.929311E+02
           PHASE  0.000000E+00      1.255221E+01      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   41
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                    LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.7500E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                   (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      1.010238E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      1.146280E-01
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   0.000000E+00      0.000000E+00      2.825932E+01
           MAGN   0.000000E+00      1.343274E-02      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      1.905438E+02
           PHASE  0.000000E+00      1.016627E+01      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   42
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                    LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.8000E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                   (MAGNITUDE/PHASE)
```

```
       1  MAGN   0.000000E+00      0.000000E+00      1.008588E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      8.197415E-02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   0.000000E+00      0.000000E+00      2.385129E+01
          MAGN   0.000000E+00      1.141400E-02      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      1.889045E+02
          PHASE  0.000000E+00      8.528180E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   43
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.8500E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      1.007368E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      6.153774E-02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   0.000000E+00      0.000000E+00      2.063039E+01
          MAGN   0.000000E+00      9.938740E-03      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      1.877108E+02
          PHASE  0.000000E+00      7.335774E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   44
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.9000E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      1.006432E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      4.791779E-02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   0.000000E+00      0.000000E+00      1.817704E+01
          MAGN   0.000000E+00      8.814966E-03      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      1.868034E+02
          PHASE  0.000000E+00      6.429667E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   45
```

```
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.9500E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                  (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      1.005692E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.839161E-02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   0.000000E+00      0.000000E+00      1.624752E+01
           MAGN   0.000000E+00      7.931107E-03      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      1.860906E+02
           PHASE  0.000000E+00      5.718131E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   46
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LARGE MASS METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  1.0000E+01)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                  (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      1.005092E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.146934E-02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   0.000000E+00      0.000000E+00      1.469098E+01
           MAGN   0.000000E+00      7.218098E-03      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      1.855159E+02
           PHASE  0.000000E+00      5.144738E+00      0.000000E+00

1                             ***** END OF OUTPUT *****
```

2.36 Enforced Dynamic Displacement with the Lagrange Multiplier Method

Example ID:

A036

Analysis Data:

GRID, CBAR, PBARL, MAT1, SPC, CONM2, EIGR, FREQ1, RLOAD1, DAREA, TABLED1, DMIG

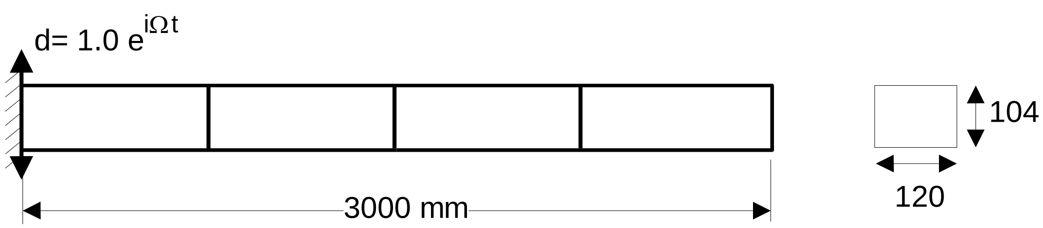
Special Features Used:

Lagrange Multiplier constraint equations via DMIG

Problem Statement:

A cantilevered beam is modeled using CBAR elements together with PBARL. Calculate the response of the tip when the root is subjected to enforced dynamic displacement.

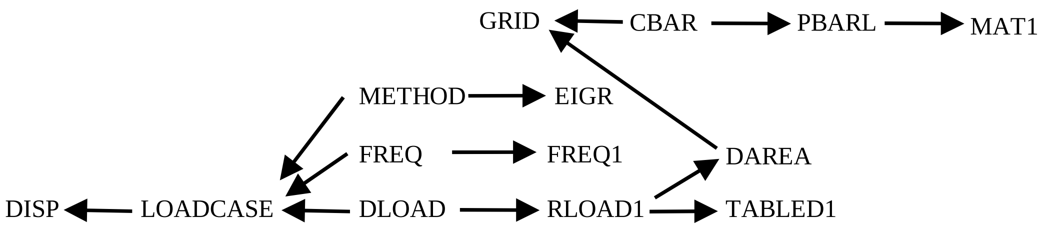
Structural Analysis Model:



Analysis Model Description:

1. The unit used here is the N, mm, Mg and material is Steel (E=207.0E3 MPa, ρ=8.0 g/cm^3, ν=0.3).

Analysis Data Relationships:



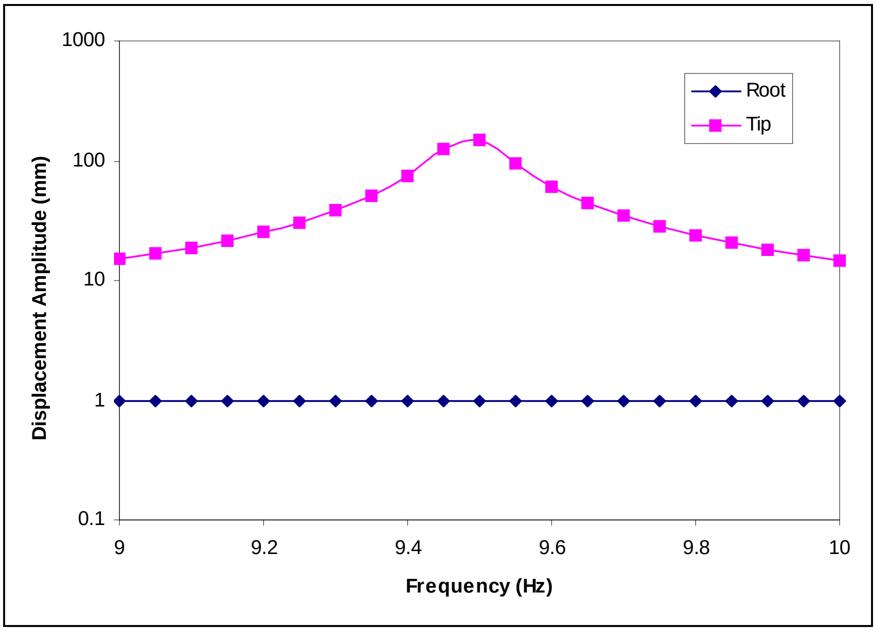
Special Modeling Techniques:

The Lagrange Multiplier Method is used to apply an enforced dynamic displacement.

Reference Solution:

None.

Calculated Solution:



2.36.1 Input Data

```
SOL COMPAT0
CEND
TITLE=ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
SUBTITLE=EXAMPLE USING LAGRANGE MULTIPLIER METHOD
LINE=64,80
ECHO=NONE
$
DYNOUTPUT = MAGNITUDE
$
K2PP=ENFORCEP
K2GG=ENFORCE
$
SET 5 = 1,5
SPC = 1
FREQ = 30
$
LOADCASE 2
LABEL = SOLUTION USING:  MODAL FREQUENCY RESPONSE
DLOAD = 22
DISP=5
METHOD=4
$
LOADCASE 3
LABEL = SOLUTION USING:  DIRECT FREQUENCY RESPONSE
DLOAD = 22
DISP=5
$
BEGIN BULK
PARAM,G,.01
PARAM,MODACC,1
$
$ The dynamical system of equations is:
$
$ [ -W^2 M + i W B + (1+ig) K + i KE ] U = P
$
$ where W is the loading frequency
$       M is the system mass matrix
$       B is the system viscous damping matrix
$       K is the system stiffness matrix
$       KE is the system structural damping matrix
$       g is the global structural damping coefficient
$       U is the complex displacement vector
$       P is the complex load vector
$       i is sqrt(-1)
$
$       Note, the real loads and displacements are usually taken as
$          p(t) = Re( P e^(i W t) )
$          u(t) = Re( U e^(i W t) )
$
$ To enforce the constraint: C U = d, an extra degree of freedom, q,
$ (the lagrange multiplier) is introduced, and the dynamical system
$ is augmented as follows:
```

```
$
$ [ -W^2 M + i W B + (1+ig) K + i KE | C^t ] {U}   {P}
$ [--------------------------------+-----] {-} = {-}
$ [               C                |  0  ] {q}   {d}
$
$  Here, an SPOINT is added to be the lagrange multiplier dof.
$  DMIG and K2PP is used to enter the C matrix (which has only one non-zero
$  term - a 1.0 in the column corresponding to the displacement we want to
$  enforce).  We would like to use K2PP here instead of K2GG so that
$  PARAM,G will not affect our constraint equation.  However, if we
$  want to use modal frequency response, we must also use K2GG, because
$  K2PP does not apply to the modal solution, and the modal solution
$  needs to have the constraint equation.  Also, for modal frequency
$  response, we MUST have PARAM,MODACC,1 (the default) to augment the modes
$  with an extra basis vector that moves the enforced dof (all the
$  eigenvectors have 0.0 for the enforced dof because of the constraint
$  equation).
$  Note that when we use K2GG to add a constraint equation, the augmented
$  stiffness matrix is NOT positive definite. Therefore, the SMS method
$  cannot be used for the modal solution.
$
SPOINT  10000001
$------12------23------34------45------56------67------78------89------9X-----
-X
DMIG    ENFORCEP       0       6       2
DMIG    ENFORCEP       1       3        10000001            .999
$------12------23------34------45------56------67------78------89------9X-----
-X
DMIG    ENFORCE        0       6       2
DMIG    ENFORCE        1       3        10000001            .001
$
$   LOADING FREQUENCIES
$
FREQ1   30             9.0     .05      20
$
$   LOAD DEFINITION
$
$   A load = d is applied to the lagrange multiplier degree of freedom
$   Here, d = 1.0 is used to enforce U = 1.0
$
$------12------23------34------45------56------67------78------89------9X-----
-X
RLOAD1        22       2                       4
$
$------12------23------34------45------56------67------78------89------9X-----
-X
DAREA          210000001            1.0
$
$    C(W) = 1.0
$
$------12------23------34------45------56------67------78------89------9X-----
-X
TABLED1        4
+            0.0     1.0     1.0     1.0
$
$   GRID DATA
```

```
$
GRID    1               0.00    0.      0.0
GRID    2               750.0   0.      0.0
GRID    3               1500.0  0.      0.0
GRID    4               2250.0  0.      0.0
GRID    5               3000.0  0.      0.0
SPC     1       1       12456
$
$   ELEMENT DEFINITIONS
$
CBAR    1       1       1       2       0.      1.0     0.
CBAR    2       1       2       3       0.      1.0     0.
CBAR    3       1       3       4       0.      1.0     0.
CBAR    4       1       4       5       0.      1.0     0.
$
$   PROPERTY DEFINITIONS
$
$------12------23------34------45------56------67------78------89------9X-----
-X
PBARL   1       1       CSLIB1   RECT
+       120.0   104.0
$
$   MATERIAL DATA
$
$------12------23------34------45------56------67------78------89------9X-----
-X
MAT1    1       2.07+5          0.3     8.0-9
$
$   EIGENVALUES DATA
$
$------12------23------34------45------56------67------78------89------9X-----
-X
EIGR    4       LAN             200.0                   10
$
ENDDATA
```

2.36.2 Output Data

```
1

              GGGG     EEEEE    N    N    EEEEE     SSSSS    IIIII     SSSSS
             G         E        NN   N    E        S           I      S
             G   GG    EEEE     N N N     EEEE      SSSS       I       SSSS
             G    G    E        N  NN     E             S      I           S
              GGGG     EEEEE    N    N    EEEEE    SSSSS     IIIII    SSSSS


                  STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                               COPYRIGHT, 1991-2002

                     VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                          ALL RIGHTS RESERVED, WORLDWIDE

                                   VERSION 7.2

                             BUILD CODE 200212131048



     PROJECT NAME: A036
     RUN STARTED:  Dec 13, 2002 12:50
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:        40000000


     LICENSED TO: Vanderplaats R&D Inc.
     LICENSE EXPIRES: Dec 31, 2020

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    1
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD

                            ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                      5
                   NUMBER OF SPOINTS:                          1
                   NUMBER OF CBAR ELEMENTS:                    4
```

```
                TOTAL NUMBER OF NON RIGID ELEMENTS:         4
                NUMBER OF ELEMENT PROPERTIES:               1
                NUMBER OF MATERIALS:                        1
                NUMBER OF DEGREES OF FREEDOM:              26



                         LOAD CASES SUMMARY

               NUMBER OF USER FREQUENCY LOAD CASES:           0
               NUMBER OF INTERNAL FREQUENCY LOAD CASES:       1
               NUMBER OF DIRECT DYNAMIC LOAD CASES:           1
               NUMBER OF MODAL  DYNAMIC LOAD CASES:           1
               TOTAL NUMBER OF LOAD CASES:                    3

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    2
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD

                      LANCZOS EIGENSOLUTION STATISTICS

  SHIFT       SHIFT          FREQUENCY     EVALUES     NEW     TERM.     CPU
  COUNT       VALUE         (CYC./TIME)     BELOW     FOUND    CODE      TIME
  -----   -------------   -------------   -------   -------   -----   --------
      1    1.579137E+06    2.000000E+02         7         0      10       0.02
      2   -1.000000E+01   -5.032921E-01         1         6       4       0.01
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    3
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD

              ********************************************
              *  D E S I G N  C Y C L E     0 (ANALYSIS)*
              ********************************************
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    4
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD

                M A S S / V O L U M E   S U M M A R Y

                SYSTEM MASS              2.995200E-01
                SYSTEM VOLUME            3.744000E+07
                SYSTEM MASS/VOLUME       8.000000E-09
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    5
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 MODES FOR METHOD OF LOADCASE 2                              LOADCASE        4

                        E I G E N V A L U E S

                                                     GENERALIZED   GENERALIZED
   MODE       CYCLES       EIGENVALUE      RADIANS       MASS        STIFFNESS

        1  9.486800E+00  3.553033E+03  5.960733E+01  1.000000E+00  3.553033E+03
        2  1.094293E+01  4.727447E+03  6.875643E+01  1.000000E+00  4.727447E+03
        3  5.920663E+01  1.383886E+05  3.720062E+02  1.000000E+00  1.383886E+05
```

```
      4  6.817606E+01  1.834947E+05  4.283628E+02  1.000000E+00  1.834947E+05
      5  1.656853E+02  1.083746E+06  1.041031E+03  1.000000E+00  1.083746E+06
      6  1.903507E+02  1.430437E+06  1.196009E+03  1.000000E+00  1.430437E+06

     NOTE FROM ROUTINE GN42PE:
     ALTHOUGH       10 EIGENVALUES HAVE BEEN REQUESTED,
     ONLY        6 EIGENVALUES EXISTED IN THE RANGE
     SPECIFIED.

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    6
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.0000E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                    (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      1.000171E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.599987E+02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   2.084616E-18      2.391205E-12      1.240110E+01
           MAGN   3.571670E-18      5.190590E-03      3.853423E-16
           PHASE  3.553694E+02      1.796798E+02      3.556038E+02
           PHASE  1.753862E+02      1.752016E+02      1.819248E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    7
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.0500E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                    (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      1.000187E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.599986E+02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   2.287980E-18      2.403062E-12      1.354994E+01
           MAGN   3.918823E-18      5.715675E-03      3.683198E-16
           PHASE  3.549477E+02      1.798528E+02      3.551784E+02
           PHASE  1.749647E+02      1.747775E+02      1.831110E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    8
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
```

```
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.1000E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                     (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      1.000207E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.599984E+02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   2.531985E-18      2.405679E-12      1.492929E+01
          MAGN   4.335319E-18      6.346190E-03      3.429887E-16
          PHASE  3.544405E+02      1.801027E+02      3.546676E+02
          PHASE  1.744579E+02      1.742680E+02      1.849749E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE    9
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.1500E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                     (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      1.000231E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.599981E+02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   2.830130E-18      2.395024E-12      1.661567E+01
          MAGN   4.844189E-18      7.117163E-03      3.066585E-16
          PHASE  3.538195E+02      1.804731E+02      3.540429E+02
          PHASE  1.738371E+02      1.736445E+02      1.881628E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   10
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.2000E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                     (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      1.000260E+00
```

```
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.599978E+02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   3.202583E-18      2.365071E-12      1.872348E+01
           MAGN   5.479845E-18      8.080936E-03      2.563714E-16
           PHASE  3.530417E+02      1.810425E+02      3.532614E+02
           PHASE  1.730597E+02      1.728643E+02      1.943657E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   11
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.2500E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      1.000298E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.599972E+02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   3.680839E-18      2.306571E-12      2.143127E+01
           MAGN   6.296018E-18      9.319251E-03      1.927591E-16
           PHASE  3.520401E+02      1.819641E+02      3.522560E+02
           PHASE  1.720583E+02      1.718602E+02      2.091419E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   12
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.3000E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      1.000348E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.599964E+02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   4.316830E-18      2.205017E-12      2.503349E+01
           MAGN   7.381313E-18      1.096691E-02      1.506285E-16
           PHASE  3.507030E+02      1.835687E+02      3.509152E+02
           PHASE  1.707216E+02      1.705207E+02      2.502203E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   13
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
```

```
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S  (FREQUENCY =  9.3500E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      1.000417E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.599950E+02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   5.202301E-18      2.037885E-12      3.005020E+01
           MAGN   8.892253E-18      1.326211E-02      2.554424E-16
           PHASE  3.488315E+02      1.866819E+02      3.490398E+02
           PHASE  1.688504E+02      1.686466E+02      2.993928E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   14
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S  (FREQUENCY =  9.4000E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      1.000516E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.599924E+02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   6.514387E-18      1.776906E-12      3.748527E+01
           MAGN   1.113104E-17      1.666482E-02      5.461065E-16
           PHASE  3.460337E+02      1.938061E+02      3.462382E+02
           PHASE  1.660529E+02      1.658462E+02      3.170638E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   15
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S  (FREQUENCY =  9.4500E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      1.000667E+00
```

```
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.599871E+02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   8.636840E-18      1.464286E-12      4.951273E+01
          MAGN   1.475234E-17      2.217198E-02      1.090097E-15
          PHASE  3.414300E+02      2.141457E+02      3.416307E+02
          PHASE  1.614496E+02      1.612400E+02      3.209043E+02

1GENESIS   VERSION  7.2                 DATE 12-13-2002  TIME 12:50  PAGE   16
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.5000E+00)

  GRID ID              T1                T2                T3
                       R1                R2                R3

                                  (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      1.000907E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.599733E+02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   1.252135E-17      1.879657E-12      7.152003E+01
          MAGN   2.137959E-17      3.225791E-02      2.175195E-15
          PHASE  3.326403E+02      2.596244E+02      3.328371E+02
          PHASE  1.526602E+02      1.524477E+02      3.164951E+02

1GENESIS   VERSION  7.2                 DATE 12-13-2002  TIME 12:50  PAGE   17
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.5500E+00)

  GRID ID              T1                T2                T3
                       R1                R2                R3

                                  (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      1.001115E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.599293E+02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   2.045363E-17      5.140901E-12      1.164128E+02
          MAGN   3.491070E-17      5.288149E-02      4.622604E-15
          PHASE  3.116343E+02      2.740626E+02      3.118272E+02
          PHASE  1.316546E+02      1.314390E+02      2.981188E+02

1GENESIS   VERSION  7.2                 DATE 12-13-2002  TIME 12:50  PAGE   18
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
```

```
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                    LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.6000E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                    (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      9.996932E-01
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.598748E+02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   2.716310E-17      1.085628E-11      1.540644E+02
           MAGN   4.634528E-17      7.048123E-02      7.694672E-15
           PHASE  2.612499E+02      2.370057E+02      2.614389E+02
           PHASE  8.127051E+01      8.105192E+01      2.494634E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   19
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                    LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.6500E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                    (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      9.989147E-01
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.599461E+02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   1.770382E-17      1.006799E-11      1.000741E+02
           MAGN   3.019460E-17      4.610363E-02      6.124923E-15
           PHASE  2.199078E+02      2.018454E+02      2.200928E+02
           PHASE  3.992882E+01      3.970717E+01      2.093275E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   20
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                    LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.7000E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                    (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      9.991722E-01
```

```
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.599775E+02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   1.131005E-17      8.524337E-12      6.372203E+01
           MAGN   1.928240E-17      2.956106E-02      4.689693E-15
           PHASE  2.040957E+02      1.894858E+02      2.042767E+02
           PHASE  2.411702E+01      2.389228E+01      1.943901E+02
1GENESIS   VERSION  7.2                 DATE 12-13-2002  TIME 12:50  PAGE   21
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.7500E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                              (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      9.993772E-01
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.599881E+02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   8.121295E-18      7.751362E-12      4.560990E+01
           MAGN   1.384056E-17      2.130497E-02      3.979681E-15
           PHASE  1.969818E+02      1.845334E+02      1.971588E+02
           PHASE  1.700352E+01      1.677563E+01      1.879264E+02
1GENESIS   VERSION  7.2                 DATE 12-13-2002  TIME 12:50  PAGE   22
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.8000E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                              (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      9.995078E-01
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.599925E+02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   6.305366E-18      7.390653E-12      3.530136E+01
           MAGN   1.074159E-17      1.660274E-02      3.612744E-15
           PHASE  1.930593E+02      1.820643E+02      1.932323E+02
           PHASE  1.308144E+01      1.285037E+01      1.844932E+02
1GENESIS   VERSION  7.2                 DATE 12-13-2002  TIME 12:50  PAGE   23
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
```

```
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                    LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.8500E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      9.995949E-01
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.599948E+02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   5.148736E-18      7.252611E-12      2.873870E+01
           MAGN   8.767722E-18      1.360809E-02      3.421148E-15
           PHASE  1.905965E+02      1.806234E+02      1.907654E+02
           PHASE  1.061903E+01      1.038475E+01      1.823990E+02
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   24
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                    LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.9000E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      9.996563E-01
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.599961E+02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   4.351611E-18      7.251721E-12      2.421810E+01
           MAGN   7.407332E-18      1.154482E-02      3.332242E-15
           PHASE  1.889126E+02      1.796772E+02      1.890774E+02
           PHASE  8.935550E+00      8.698010E+00      1.809890E+02
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   25
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                    LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.9500E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      9.997017E-01
```

```
            MAGN   0.000000E+00      0.000000E+00      0.000000E+00
            PHASE  0.000000E+00      0.000000E+00      3.599969E+02
            PHASE  0.000000E+00      0.000000E+00      0.000000E+00

         5  MAGN   3.770252E-18      7.347137E-12      2.092290E+01
            MAGN   6.415133E-18      1.004066E-02      3.311358E-15
            PHASE  1.876909E+02      1.789930E+02      1.878515E+02
            PHASE  7.714226E+00      7.473387E+00      1.799639E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   26
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  MODAL FREQUENCY RESPONSE                   LOADCASE        2

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  1.0000E+01)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

         1  MAGN   0.000000E+00      0.000000E+00      9.997366E-01
            MAGN   0.000000E+00      0.000000E+00      0.000000E+00
            PHASE  0.000000E+00      0.000000E+00      3.599975E+02
            PHASE  0.000000E+00      0.000000E+00      0.000000E+00

         5  MAGN   3.327996E-18      7.518784E-12      1.841762E+01
            MAGN   5.660297E-18      8.896982E-03      3.340814E-15
            PHASE  1.867651E+02      1.784560E+02      1.869216E+02
            PHASE  6.788816E+00      6.544636E+00      1.791687E+02

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   27
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.0000E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

         1  MAGN   0.000000E+00      0.000000E+00      1.000000E+00
            MAGN   0.000000E+00      0.000000E+00      0.000000E+00
            PHASE  0.000000E+00      0.000000E+00      3.599994E+02
            PHASE  0.000000E+00      0.000000E+00      0.000000E+00

         5  MAGN   0.000000E+00      0.000000E+00      1.499447E+01
            MAGN   0.000000E+00      6.396089E-03      0.000000E+00
            PHASE  0.000000E+00      0.000000E+00      3.546622E+02
            PHASE  0.000000E+00      1.742649E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   28
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
```

```
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                    LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.0500E+00)

  GRID ID               T1                  T2                  T3
                        R1                  R2                  R3

                               (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      1.000000E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.599994E+02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   0.000000E+00      0.000000E+00      1.671093E+01
           MAGN   0.000000E+00      7.183150E-03      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.540289E+02
           PHASE  0.000000E+00      1.736330E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   29
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                    LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.1000E+00)

  GRID ID               T1                  T2                  T3
                        R1                  R2                  R3

                               (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      1.000000E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.599994E+02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   0.000000E+00      0.000000E+00      1.886258E+01
           MAGN   0.000000E+00      8.169900E-03      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.532345E+02
           PHASE  0.000000E+00      1.728400E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   30
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                    LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.1500E+00)

  GRID ID               T1                  T2                  T3
                        R1                  R2                  R3

                               (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      1.000000E+00
```

```
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.599994E+02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   0.000000E+00      0.000000E+00      2.163688E+01
          MAGN   0.000000E+00      9.442401E-03      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.522087E+02
          PHASE  0.000000E+00      1.718155E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   31
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE         3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.2000E+00)

  GRID ID              T1                T2                T3
                       R1                R2                R3

                                   (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      1.000000E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.599994E+02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   0.000000E+00      0.000000E+00      2.534523E+01
          MAGN   0.000000E+00      1.114365E-02      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.508341E+02
          PHASE  0.000000E+00      1.704421E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   32
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE         3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.2500E+00)

  GRID ID              T1                T2                T3
                       R1                R2                R3

                                   (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      1.000000E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.599994E+02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   0.000000E+00      0.000000E+00      3.054304E+01
          MAGN   0.000000E+00      1.352878E-02      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.488986E+02
          PHASE  0.000000E+00      1.685080E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   33
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
```

```
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                    LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.3000E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      1.000000E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.599994E+02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   0.000000E+00      0.000000E+00      3.831632E+01
           MAGN   0.000000E+00      1.709689E-02      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.459798E+02
           PHASE  0.000000E+00      1.655905E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   34
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                    LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.3500E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      1.000000E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.599994E+02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   0.000000E+00      0.000000E+00      5.105785E+01
           MAGN   0.000000E+00      2.294854E-02      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.411099E+02
           PHASE  0.000000E+00      1.607219E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   35
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                    LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.4000E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      1.000000E+00
```

```
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.599994E+02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   0.000000E+00      0.000000E+00      7.481255E+01
          MAGN   0.000000E+00      3.386871E-02      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.315943E+02
          PHASE  0.000000E+00      1.512077E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   36
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.4500E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                   (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      1.000000E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.599994E+02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   0.000000E+00      0.000000E+00      1.234035E+02
          MAGN   0.000000E+00      5.626731E-02      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.081101E+02
          PHASE  0.000000E+00      1.277247E+02      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   37
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.5000E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                   (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      1.000000E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.599994E+02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   0.000000E+00      0.000000E+00      1.509477E+02
          MAGN   0.000000E+00      6.931593E-02      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      2.547965E+02
          PHASE  0.000000E+00      7.441245E+01      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   38
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
```

```
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.5500E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      1.000000E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.599994E+02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   0.000000E+00      0.000000E+00      9.423014E+01
           MAGN   0.000000E+00      4.357602E-02      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      2.171540E+02
           PHASE  0.000000E+00      3.677125E+01      0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   39
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.6000E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      1.000000E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.599994E+02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   0.000000E+00      0.000000E+00      6.072992E+01
           MAGN   0.000000E+00      2.828039E-02      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      2.029680E+02
           PHASE  0.000000E+00      2.258650E+01      0.000000E+00
1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   40
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.6500E+00)

  GRID ID               T1                 T2                 T3
                        R1                 R2                 R3

                                 (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      1.000000E+00
```

```
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.599994E+02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   0.000000E+00      0.000000E+00      4.390747E+01
          MAGN   0.000000E+00      2.058828E-02      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      1.964279E+02
          PHASE  0.000000E+00      1.604779E+01      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   41
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.7000E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                     (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      1.000000E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.599994E+02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   0.000000E+00      0.000000E+00      3.420778E+01
          MAGN   0.000000E+00      1.615028E-02      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      1.927591E+02
          PHASE  0.000000E+00      1.238022E+01      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   42
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.7500E+00)

  GRID ID              T1                 T2                 T3
                       R1                 R2                 R3

                                     (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      1.000000E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.599994E+02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   0.000000E+00      0.000000E+00      2.797294E+01
          MAGN   0.000000E+00      1.329661E-02      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      1.904286E+02
          PHASE  0.000000E+00      1.005106E+01      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   43
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
```

```
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.8000E+00)

  GRID ID              T1                  T2                  T3
                       R1                  R2                  R3

                                (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      1.000000E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.599994E+02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   0.000000E+00      0.000000E+00      2.364820E+01
           MAGN   0.000000E+00      1.131681E-02      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      1.888219E+02
           PHASE  0.000000E+00      8.445633E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   44
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.8500E+00)

  GRID ID              T1                  T2                  T3
                       R1                  R2                  R3

                                (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      1.000000E+00
           MAGN   0.000000E+00      0.000000E+00      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      3.599994E+02
           PHASE  0.000000E+00      0.000000E+00      0.000000E+00

        5  MAGN   0.000000E+00      0.000000E+00      2.047950E+01
           MAGN   0.000000E+00      9.866047E-03      0.000000E+00
           PHASE  0.000000E+00      0.000000E+00      1.876487E+02
           PHASE  0.000000E+00      7.273663E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   45
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE        3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.9000E+00)

  GRID ID              T1                  T2                  T3
                       R1                  R2                  R3

                                (MAGNITUDE/PHASE)

        1  MAGN   0.000000E+00      0.000000E+00      1.000000E+00
```

```
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.599994E+02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   0.000000E+00      0.000000E+00      1.806088E+01
          MAGN   0.000000E+00      8.758632E-03      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      1.867549E+02
          PHASE  0.000000E+00      6.381176E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   46
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE         3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  9.9500E+00)

  GRID ID              T1                T2                T3
                       R1                R2                R3

                                     (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      1.000000E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.599994E+02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   0.000000E+00      0.000000E+00      1.615557E+01
          MAGN   0.000000E+00      7.886222E-03      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      1.860516E+02
          PHASE  0.000000E+00      5.679166E+00      0.000000E+00

1GENESIS   VERSION  7.2                  DATE 12-13-2002  TIME 12:50  PAGE   47
 ENFORCED DYNAMIC DISPLACEMENT OF BUILT-IN END OF A CANTILEVER BEAM
 EXAMPLE USING LAGRANGE MULTIPLIER METHOD
 SOLUTION USING:  DIRECT FREQUENCY RESPONSE                  LOADCASE         3

 G R I D   D Y N A M I C   D I S P L A C E M E N T S   (FREQUENCY =  1.0000E+01)

  GRID ID              T1                T2                T3
                       R1                R2                R3

                                     (MAGNITUDE/PHASE)

       1  MAGN   0.000000E+00      0.000000E+00      1.000000E+00
          MAGN   0.000000E+00      0.000000E+00      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      3.599994E+02
          PHASE  0.000000E+00      0.000000E+00      0.000000E+00

       5  MAGN   0.000000E+00      0.000000E+00      1.461655E+01
          MAGN   0.000000E+00      7.181528E-03      0.000000E+00
          PHASE  0.000000E+00      0.000000E+00      1.854838E+02
          PHASE  0.000000E+00      5.112696E+00      0.000000E+00

1                             ***** END OF OUTPUT *****
```

2.37 Random Response of a Simple Spring/Mass/Damper Structure

Example ID:

A037

Analysis Data:

GRID, CELAS2 CDAMP2, CONM2, SPC, FREQ1, RLOAD1, DAREA, TABLED1, RANDOM,RANDT1, TABRND1

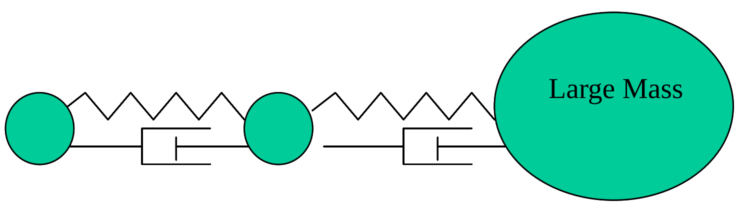
Special Features Used:

Random response using large mass method.

Problem Statement:

A simple structure assambled with elastics, damping and mass elements. Calculate the random responses of the system subjected to random loads.

Structural Analysis Model:



Analysis Model Description:

1. Three mass connected with two springs and two dampers.

Random Analysis Data Relationships:

Special Modeling Techniques:

The Large Mass Method is used to apply an enforced dynamic motion.

Reference Solution:

None.

Calculated Solution:

1. Power spectral density functions (PSDF) , $S_j(\omega)$
2. Autocorrelation function (ATOC), Rj(t)
3. Root mean square (RMS), u_j
4. Cumulative root mean square (CRMS),$u_j(\omega)$
5. Number of zero crossings, N0

The above analyses are calculate for the following user requested responses:

1. Displacements
2. Velocities
3. Accelerations
4. Forces in CELAS2 and CDAMP2
5. Stresses CELAS2

The above results are printed in the A037.out file.

2.37.1 Input Data

```
ID A037
SOL COMPAT1
CEND
$
TITLE=RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
SUBTITLE=LARGE MASS METHOD TO ENFORCE DISPLACEMENTS AT BASE
LINE=64,80
ECHO=NONE
$
FREQUENCY = 1
RANDOM=1
$
SUBCASE 1
   LABEL = FORCE IN GRID 2
   DLOAD = 1
   DISP(SORT2,RPRINT,PSDF,CRMS) = ALL
   VELO(SORT2,RPRINT,PSDF,CRMS) = ALL
   ACCE(SORT2,RPRINT,PSDF,CRMS) = ALL
   FORCE(SORT2,RPRINT,PSDF,CRMS) = ALL
   STRESS(SORT2,RPRINT,PSDF,CRMS) = ALL
$
SUBCASE 2
   LABEL = ENFORCED DISPLACEMENT AT GRID 1 (LARGE MASS
     LOCATION)
   DLOAD = 2
$
BEGIN BULK
$
$ --- ANALYSIS DATA
$
GRID1              0.00.0      0.0                 23456
GRID2              1.00.0      0.0                 23456
GRID3              2.00.0      0.0                 23456
$
CONM21 1              1.0+8
CONM22 2              1.0
CONM23 3              1.0
$
CELAS2  4       5.0E61121                1.0
CELAS2  5       1.0E72131                1.0
```

```
$
CDAMP2  6       10.001121
CDAMP2  7       50.002131
$
$    FREQUENCIES
$
FREQ1   1       200.010.020
$
$ LOAD DEFINITION FOR DYNAMIC LOADCASE 1
$
DAREA102             1100.0
RLOAD1110                       10
TABLED110
+1.0 1.0        10000.01.0       ENDT
$
$ LOAD DEFINITION FOR DYNAMIC LOADCASE 2
$
DAREA201             11.0E8
RLOAD1220                       20
TABLED4200.0       1.01.0       10000.0
+0.0 0.0           40.0ENDT
$
$RANDOM ANALYSIS DATA
$
RANDPS11             11.0E5               30
RANDPS12             21.0E-4              30
RANDPS11             22.0                 30
$
TABRND130
+0.0 0.0         199.990.0       200.0     1.0       400.0
     1.0
+400.010.0      10000.00.0     ENDT
$
RANDT11100          0.0.1
$
ENDDATA
```

2.37.2 Output Data

```
1




             GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
            G        E       NN  N   E       S          I     S
            G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
            G    G   E       N  NN   E            S     I          S
             GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                 STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                              COPYRIGHT, 1991-2005

                   VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                        ALL RIGHTS RESERVED, WORLDWIDE

                                  VERSION 8.0

                           BUILD CODE 200512131710



     PROJECT NAME: A037
     RUN STARTED:  Dec 13, 2005 18:22
     SYSTEM TYPE:  ix86 (or compatible) Windows NT
     LENVEC:           11000000


     LICENSED TO: Vanderplaats R&D, Inc.
     LICENSE EXPIRES: Dec 31, 2020


     INFORMATIONAL MESSAGE FROM SUBROUTINE     GN12E2

     CELAS1 AND PELAS DATA WERE CREATED TO REPLACE CELAS2
     DATA. THE ID USED FOR CELAS1 IS THE SAME AS THE CELAS2.
     THE ID OF PELAS COULD BE EITHER THE SAME AS THE CELAS2
     OR AN ARBITRARY NUMBER.
     THE ID USED.
     NOTE: THE USEFULNESS OF THE PELAS ID IS THAT WITH IT
```

```
     THE PROPERTIES OF THE CELAS2 ELEMENT CAN BE DESIGNED
     BY REFERENCING THE PELAS.

     TOTAL NUMBER OF PELAS CREATED FOR CELAS2:       2
     TOTAL NUMBER OF PELAS CREATED FOR CELAS2 THAT USE CELAS2 ID:           2
     TOTAL NUMBER OF PELAS CREATED FOR CELAS2 THAT DO NOT USE CELAS2 ID:    0


     INFORMATIONAL MESSAGE FROM SUBROUTINE     GN12D2

     CDAMP1 AND PDAMP DATA WERE CREATED TO REPLACE CDAMP2
     DATA. THE ID USED FOR CDAMP1 IS THE SAME AS THE CDAMP2.
     THE ID OF PDAMP COULD BE EITHER THE SAME AS THE CDAMP2
     OR AN ARBITRARY NUMBER.
     THE ID USED.
     NOTE: THE USEFULNESS OF THE PDAMP ID IS THAT WITH IT
     THE PROPERTIES OF THE CDAMP2 ELEMENT CAN BE DESIGNED
     BY REFERENCING THE PDAMP.

     TOTAL NUMBER OF PDAMP CREATED FOR CDAMP2:       2
     TOTAL NUMBER OF PDAMP CREATED FOR CDAMP2 THAT USE CDAMP2 ID:           2
     TOTAL NUMBER OF PDAMP CREATED FOR CDAMP2 THAT DO NOT USE CDAMP2 ID:    0

1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE    1
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
 LARGE MASS METHOD TO ENFORCE DISPLACEMENTS AT BASE

                              ANALYSIS PROBLEM SUMMARY

                    NUMBER OF GRID POINTS:                         3
                    NUMBER OF CELAS1/2 ELEMENTS:                   2
                    NUMBER OF CONM2 ELEMENTS:                      3
                    NUMBER OF CDAMP1/2 ELEMENTS:                   2
                    TOTAL NUMBER OF NON RIGID ELEMENTS:            7
                    NUMBER OF ELEMENT PROPERTIES:                  4
                    NUMBER OF DEGREES OF FREEDOM:                  3



                                LOAD CASES SUMMARY

                   NUMBER OF DIRECT DYNAMIC LOAD CASES:              2
                   TOTAL NUMBER OF LOAD CASES:                       2

1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE    2
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
 LARGE MASS METHOD TO ENFORCE DISPLACEMENTS AT BASE

                ****************************************************
                *  D E S I G N  C Y C L E      0 (ANALYSIS SUMMARY)*
                ****************************************************
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE    3
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
 LARGE MASS METHOD TO ENFORCE DISPLACEMENTS AT BASE
```

```
                    M A S S / V O L U M E   S U M M A R Y

                    SYSTEM MASS             1.000000E+08
                    SYSTEM VOLUME           0.000000E+00
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE    4
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
 LARGE MASS METHOD TO ENFORCE DISPLACEMENTS AT BASE

                    E N C L O S I N G   B O X   S U M M A R Y

    LENGTH X   LENGTH Y   LENGTH Z    AREA XY    AREA YZ    AREA XZ VOLUME XYZ
   2.000E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00

1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE    5
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
 LARGE MASS METHOD TO ENFORCE DISPLACEMENTS AT BASE

               ********************************************
               *  D E S I G N  C Y C L E     0 (ANALYSIS)*
               ********************************************
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE    6
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
 LARGE MASS METHOD TO ENFORCE DISPLACEMENTS AT BASE
 FORCE IN GRID 2                                            LOADCASE         1

-------------------------------------------------------------------
Dynamic responses have been deleted to save space
-------------------------------------------------------------------

1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  132
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                        RANDOM               1
      POINT-ID =         1
                      D I S P L A C E M E N T   V E C T O R
                      ( POWER SPECTRAL DENSITY FUNCTION )

   FREQUENCY   TYPE          T1                 T2                 T3
                             R1                 R2                 R3
    2.000000E+02 G      1.026598E-04      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    2.100000E+02 G      1.026598E-04      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    2.200000E+02 G      1.026598E-04      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    2.300000E+02 G      1.026598E-04      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    2.400000E+02 G      1.026599E-04      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    2.500000E+02 G      1.026598E-04      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    2.600000E+02 G      1.026598E-04      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    2.700000E+02 G      1.026598E-04      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    2.800000E+02 G      1.026598E-04      0.000000E+00      0.000000E+00
```

```
                     0.000000E+00         0.000000E+00         0.000000E+00
    2.900000E+02 G   1.026598E-04         0.000000E+00         0.000000E+00
                     0.000000E+00         0.000000E+00         0.000000E+00
    3.000000E+02 G   1.026598E-04         0.000000E+00         0.000000E+00
                     0.000000E+00         0.000000E+00         0.000000E+00
    3.100000E+02 G   1.026598E-04         0.000000E+00         0.000000E+00
                     0.000000E+00         0.000000E+00         0.000000E+00
    3.200000E+02 G   1.026598E-04         0.000000E+00         0.000000E+00
                     0.000000E+00         0.000000E+00         0.000000E+00
    3.300000E+02 G   1.026598E-04         0.000000E+00         0.000000E+00
                     0.000000E+00         0.000000E+00         0.000000E+00
    3.400000E+02 G   1.026598E-04         0.000000E+00         0.000000E+00
                     0.000000E+00         0.000000E+00         0.000000E+00
    3.500000E+02 G   1.026598E-04         0.000000E+00         0.000000E+00
                     0.000000E+00         0.000000E+00         0.000000E+00
    3.600000E+02 G   1.026598E-04         0.000000E+00         0.000000E+00
                     0.000000E+00         0.000000E+00         0.000000E+00
    3.700000E+02 G   1.026598E-04         0.000000E+00         0.000000E+00
                     0.000000E+00         0.000000E+00         0.000000E+00
    3.800000E+02 G   1.026598E-04         0.000000E+00         0.000000E+00
                     0.000000E+00         0.000000E+00         0.000000E+00
    3.900000E+02 G   1.026598E-04         0.000000E+00         0.000000E+00
                     0.000000E+00         0.000000E+00         0.000000E+00
    4.000000E+02 G   1.026598E-04         0.000000E+00         0.000000E+00
                     0.000000E+00         0.000000E+00         0.000000E+00
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  133
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                             RANDOM               1
      POINT-ID =         2
                   D I S P L A C E M E N T   V E C T O R
                   ( POWER SPECTRAL DENSITY FUNCTION )

   FREQUENCY   TYPE          T1                   T2                   T3
                             R1                   R2                   R3
    2.000000E+02 G   6.446210E-04         0.000000E+00         0.000000E+00
                     0.000000E+00         0.000000E+00         0.000000E+00
    2.100000E+02 G   1.162229E-03         0.000000E+00         0.000000E+00
                     0.000000E+00         0.000000E+00         0.000000E+00
    2.200000E+02 G   2.910726E-03         0.000000E+00         0.000000E+00
                     0.000000E+00         0.000000E+00         0.000000E+00
    2.300000E+02 G   2.071692E-02         0.000000E+00         0.000000E+00
                     0.000000E+00         0.000000E+00         0.000000E+00
    2.400000E+02 G   3.234677E-02         0.000000E+00         0.000000E+00
                     0.000000E+00         0.000000E+00         0.000000E+00
    2.500000E+02 G   2.787265E-03         0.000000E+00         0.000000E+00
                     0.000000E+00         0.000000E+00         0.000000E+00
    2.600000E+02 G   8.986428E-04         0.000000E+00         0.000000E+00
                     0.000000E+00         0.000000E+00         0.000000E+00
    2.700000E+02 G   4.182093E-04         0.000000E+00         0.000000E+00
                     0.000000E+00         0.000000E+00         0.000000E+00
    2.800000E+02 G   2.318012E-04         0.000000E+00         0.000000E+00
                     0.000000E+00         0.000000E+00         0.000000E+00
    2.900000E+02 G   1.422467E-04         0.000000E+00         0.000000E+00
                     0.000000E+00         0.000000E+00         0.000000E+00
    3.000000E+02 G   9.324227E-05         0.000000E+00         0.000000E+00
```

```
                     0.000000E+00       0.000000E+00       0.000000E+00
    3.100000E+02 G   6.396847E-05       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    3.200000E+02 G   4.534328E-05       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    3.300000E+02 G   3.291870E-05       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    3.400000E+02 G   2.432090E-05       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    3.500000E+02 G   1.819596E-05       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    3.600000E+02 G   1.372970E-05       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    3.700000E+02 G   1.041094E-05       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    3.800000E+02 G   7.907064E-06       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    3.900000E+02 G   5.994981E-06       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    4.000000E+02 G   4.521221E-06       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
1GENESIS   VERSION  8.0                 DATE 12-13-2005  TIME 18:22  PAGE  134
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                           RANDOM             1
      POINT-ID =         3
                    D I S P L A C E M E N T   V E C T O R
                    ( POWER SPECTRAL DENSITY FUNCTION )

   FREQUENCY   TYPE          T1                 T2                 T3
                             R1                 R2                 R3
    2.000000E+02 G   9.090424E-04       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    2.100000E+02 G   1.703836E-03       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    2.200000E+02 G   4.448100E-03       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    2.300000E+02 G   3.309664E-02       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    2.400000E+02 G   5.418760E-02       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    2.500000E+02 G   4.912111E-03       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    2.600000E+02 G   1.671880E-03       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    2.700000E+02 G   8.244351E-04       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    2.800000E+02 G   4.861441E-04       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    2.900000E+02 G   3.187587E-04       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    3.000000E+02 G   2.243112E-04       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    3.100000E+02 G   1.660578E-04       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    3.200000E+02 G   1.277374E-04       0.000000E+00       0.000000E+00
```

```
                      0.000000E+00      0.000000E+00      0.000000E+00
    3.300000E+02 G    1.012684E-04      0.000000E+00      0.000000E+00
                      0.000000E+00      0.000000E+00      0.000000E+00
    3.400000E+02 G    8.227267E-05      0.000000E+00      0.000000E+00
                      0.000000E+00      0.000000E+00      0.000000E+00
    3.500000E+02 G    6.821438E-05      0.000000E+00      0.000000E+00
                      0.000000E+00      0.000000E+00      0.000000E+00
    3.600000E+02 G    5.754452E-05      0.000000E+00      0.000000E+00
                      0.000000E+00      0.000000E+00      0.000000E+00
    3.700000E+02 G    4.927465E-05      0.000000E+00      0.000000E+00
                      0.000000E+00      0.000000E+00      0.000000E+00
    3.800000E+02 G    4.275074E-05      0.000000E+00      0.000000E+00
                      0.000000E+00      0.000000E+00      0.000000E+00
    3.900000E+02 G    3.752657E-05      0.000000E+00      0.000000E+00
                      0.000000E+00      0.000000E+00      0.000000E+00
    4.000000E+02 G    3.328962E-05      0.000000E+00      0.000000E+00
                      0.000000E+00      0.000000E+00      0.000000E+00
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  135
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                          RANDOM             1

                     D I S P L A C E M E N T   V E C T O R
                              ( ROOT MEAN SQUARE )

    POINT-ID   TYPE          T1                 T2                 T3
                             R1                 R2                 R3
         1       G    1.432898E-01      0.000000E+00      0.000000E+00
                      0.000000E+00      0.000000E+00      0.000000E+00
         2       G    7.890210E-01      0.000000E+00      0.000000E+00
                      0.000000E+00      0.000000E+00      0.000000E+00
         3       G    1.015272E+00      0.000000E+00      0.000000E+00
                      0.000000E+00      0.000000E+00      0.000000E+00
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  136
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                          RANDOM             1

                     D I S P L A C E M E N T   V E C T O R
                          ( NUMBER OF ZERO CROSSINGS )

    POINT-ID   TYPE          T1                 T2                 T3
                             R1                 R2                 R3
         1       G    3.055323E+02      0.000000E+00      0.000000E+00
                      0.000000E+00      0.000000E+00      0.000000E+00
         2       G    2.368747E+02      0.000000E+00      0.000000E+00
                      0.000000E+00      0.000000E+00      0.000000E+00
         3       G    2.378739E+02      0.000000E+00      0.000000E+00
                      0.000000E+00      0.000000E+00      0.000000E+00
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  137
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                          RANDOM             1
      POINT-ID =          1
                     D I S P L A C E M E N T   V E C T O R
                        ( CUMULATIVE ROOT MEAN SQUARE )

   FREQUENCY   TYPE          T1                 T2                 T3
```

```
                            R1                  R2                  R3
   2.000000E+02 G      0.000000E+00        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
   2.100000E+02 G      3.204057E-02        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
   2.200000E+02 G      4.531221E-02        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
   2.300000E+02 G      5.549589E-02        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
   2.400000E+02 G      6.408114E-02        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
   2.500000E+02 G      7.164489E-02        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
   2.600000E+02 G      7.848305E-02        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
   2.700000E+02 G      8.477139E-02        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
   2.800000E+02 G      9.062442E-02        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
   2.900000E+02 G      9.612171E-02        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
   3.000000E+02 G      1.013212E-01        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
   3.100000E+02 G      1.062666E-01        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
   3.200000E+02 G      1.109918E-01        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
   3.300000E+02 G      1.155239E-01        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
   3.400000E+02 G      1.198848E-01        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
   3.500000E+02 G      1.240926E-01        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
   3.600000E+02 G      1.281623E-01        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
   3.700000E+02 G      1.321067E-01        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
   3.800000E+02 G      1.359366E-01        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
   3.900000E+02 G      1.396616E-01        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
   4.000000E+02 G      1.432898E-01        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  138
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                              RANDOM             1
      POINT-ID =         2
                                  D I S P L A C E M E N T   V E C T O R
                                     ( CUMULATIVE ROOT MEAN SQUARE )

   FREQUENCY   TYPE         T1                  T2                  T3
                            R1                  R2                  R3
   2.000000E+02 G      0.000000E+00        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
   2.100000E+02 G      9.504867E-02        0.000000E+00        0.000000E+00
```

```
                     0.000000E+00      0.000000E+00      0.000000E+00
   2.200000E+02 G    1.714614E-01      0.000000E+00      0.000000E+00
                     0.000000E+00      0.000000E+00      0.000000E+00
   2.300000E+02 G    3.841058E-01      0.000000E+00      0.000000E+00
                     0.000000E+00      0.000000E+00      0.000000E+00
   2.400000E+02 G    6.425385E-01      0.000000E+00      0.000000E+00
                     0.000000E+00      0.000000E+00      0.000000E+00
   2.500000E+02 G    7.671544E-01      0.000000E+00      0.000000E+00
                     0.000000E+00      0.000000E+00      0.000000E+00
   2.600000E+02 G    7.790734E-01      0.000000E+00      0.000000E+00
                     0.000000E+00      0.000000E+00      0.000000E+00
   2.700000E+02 G    7.832877E-01      0.000000E+00      0.000000E+00
                     0.000000E+00      0.000000E+00      0.000000E+00
   2.800000E+02 G    7.853596E-01      0.000000E+00      0.000000E+00
                     0.000000E+00      0.000000E+00      0.000000E+00
   2.900000E+02 G    7.865494E-01      0.000000E+00      0.000000E+00
                     0.000000E+00      0.000000E+00      0.000000E+00
   3.000000E+02 G    7.872975E-01      0.000000E+00      0.000000E+00
                     0.000000E+00      0.000000E+00      0.000000E+00
   3.100000E+02 G    7.877966E-01      0.000000E+00      0.000000E+00
                     0.000000E+00      0.000000E+00      0.000000E+00
   3.200000E+02 G    7.881434E-01      0.000000E+00      0.000000E+00
                     0.000000E+00      0.000000E+00      0.000000E+00
   3.300000E+02 G    7.883916E-01      0.000000E+00      0.000000E+00
                     0.000000E+00      0.000000E+00      0.000000E+00
   3.400000E+02 G    7.885731E-01      0.000000E+00      0.000000E+00
                     0.000000E+00      0.000000E+00      0.000000E+00
   3.500000E+02 G    7.887079E-01      0.000000E+00      0.000000E+00
                     0.000000E+00      0.000000E+00      0.000000E+00
   3.600000E+02 G    7.888091E-01      0.000000E+00      0.000000E+00
                     0.000000E+00      0.000000E+00      0.000000E+00
   3.700000E+02 G    7.888855E-01      0.000000E+00      0.000000E+00
                     0.000000E+00      0.000000E+00      0.000000E+00
   3.800000E+02 G    7.889436E-01      0.000000E+00      0.000000E+00
                     0.000000E+00      0.000000E+00      0.000000E+00
   3.900000E+02 G    7.889876E-01      0.000000E+00      0.000000E+00
                     0.000000E+00      0.000000E+00      0.000000E+00
   4.000000E+02 G    7.890210E-01      0.000000E+00      0.000000E+00
                     0.000000E+00      0.000000E+00      0.000000E+00
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  139
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                              RANDOM             1
     POINT-ID =         3
                    D I S P L A C E M E N T   V E C T O R
                       ( CUMULATIVE ROOT MEAN SQUARE )

  FREQUENCY   TYPE          T1                T2                T3
                            R1                R2                R3
   2.000000E+02 G    0.000000E+00      0.000000E+00      0.000000E+00
                     0.000000E+00      0.000000E+00      0.000000E+00
   2.100000E+02 G    1.142996E-01      0.000000E+00      0.000000E+00
                     0.000000E+00      0.000000E+00      0.000000E+00
   2.200000E+02 G    2.093420E-01      0.000000E+00      0.000000E+00
                     0.000000E+00      0.000000E+00      0.000000E+00
   2.300000E+02 G    4.811941E-01      0.000000E+00      0.000000E+00
```

```
                    0.000000E+00      0.000000E+00      0.000000E+00
  2.400000E+02 G    8.172937E-01      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  2.500000E+02 G    9.815639E-01      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  2.600000E+02 G    9.981921E-01      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  2.700000E+02 G    1.004425E+00      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  2.800000E+02 G    1.007681E+00      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  2.900000E+02 G    1.009676E+00      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  3.000000E+02 G    1.011020E+00      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  3.100000E+02 G    1.011985E+00      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  3.200000E+02 G    1.012711E+00      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  3.300000E+02 G    1.013276E+00      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  3.400000E+02 G    1.013728E+00      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  3.500000E+02 G    1.014099E+00      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  3.600000E+02 G    1.014410E+00      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  3.700000E+02 G    1.014673E+00      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  3.800000E+02 G    1.014899E+00      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  3.900000E+02 G    1.015097E+00      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  4.000000E+02 G    1.015272E+00      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  140
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                         RANDOM             1
      POINT-ID =          1
                          V E L O C I T Y   V E C T O R
                        ( POWER SPECTRAL DENSITY FUNCTION )

   FREQUENCY   TYPE          T1                T2                T3
                             R1                R2                R3
  2.000000E+02 G    1.621139E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  2.100000E+02 G    1.787305E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  2.200000E+02 G    1.961578E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  2.300000E+02 G    2.143955E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  2.400000E+02 G    2.334442E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  2.500000E+02 G    2.533030E+02      0.000000E+00      0.000000E+00
```

```
                    0.000000E+00      0.000000E+00      0.000000E+00
  2.600000E+02 G    2.739725E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  2.700000E+02 G    2.954526E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  2.800000E+02 G    3.177433E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  2.900000E+02 G    3.408445E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  3.000000E+02 G    3.647563E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  3.100000E+02 G    3.894786E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  3.200000E+02 G    4.150116E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  3.300000E+02 G    4.413551E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  3.400000E+02 G    4.685092E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  3.500000E+02 G    4.964738E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  3.600000E+02 G    5.252490E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  3.700000E+02 G    5.548348E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  3.800000E+02 G    5.852311E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  3.900000E+02 G    6.164381E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  4.000000E+02 G    6.484556E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  141
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                            RANDOM            1
     POINT-ID =          2
                      V E L O C I T Y   V E C T O R
                  ( POWER SPECTRAL DENSITY FUNCTION )

   FREQUENCY   TYPE        T1                T2                T3
                           R1                R2                R3
  2.000000E+02 G    1.017945E+03      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  2.100000E+02 G    2.023438E+03      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  2.200000E+02 G    5.561687E+03      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  2.300000E+02 G    4.326539E+04      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  2.400000E+02 G    7.355515E+04      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  2.500000E+02 G    6.877302E+03      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  2.600000E+02 G    2.398245E+03      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
  2.700000E+02 G    1.203596E+03      0.000000E+00      0.000000E+00
```

```
                     0.000000E+00       0.000000E+00       0.000000E+00
    2.800000E+02 G   7.174498E+02       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    2.900000E+02 G   4.722781E+02       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    3.000000E+02 G   3.312952E+02       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    3.100000E+02 G   2.426885E+02       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    3.200000E+02 G   1.833043E+02       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    3.300000E+02 G   1.415241E+02       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    3.400000E+02 G   1.109934E+02       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    3.500000E+02 G   8.799758E+01       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    3.600000E+02 G   7.024666E+01       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    3.700000E+02 G   5.626694E+01       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    3.800000E+02 G   4.507567E+01       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    3.900000E+02 G   3.599787E+01       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    4.000000E+02 G   2.855850E+01       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  142
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                            RANDOM              1
      POINT-ID =          3
                      V E L O C I T Y   V E C T O R
                    ( POWER SPECTRAL DENSITY FUNCTION )

   FREQUENCY   TYPE          T1                 T2                 T3
                             R1                 R2                 R3
    2.000000E+02 G   1.435502E+03       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    2.100000E+02 G   2.966375E+03       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    2.200000E+02 G   8.499230E+03       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    2.300000E+02 G   6.911930E+04       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    2.400000E+02 G   1.232203E+05       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    2.500000E+02 G   1.212015E+04       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    2.600000E+02 G   4.461814E+03       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    2.700000E+02 G   2.372705E+03       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    2.800000E+02 G   1.504668E+03       0.000000E+00       0.000000E+00
                     0.000000E+00       0.000000E+00       0.000000E+00
    2.900000E+02 G   1.058322E+03       0.000000E+00       0.000000E+00
```

```
                    0.000000E+00      0.000000E+00      0.000000E+00
    3.000000E+02 G      7.969907E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
    3.100000E+02 G      6.300028E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
    3.200000E+02 G      5.163900E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
    3.300000E+02 G      4.353732E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
    3.400000E+02 G      3.754682E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
    3.500000E+02 G      3.298920E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
    3.600000E+02 G      2.944210E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
    3.700000E+02 G      2.663095E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
    3.800000E+02 G      2.437084E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
    3.900000E+02 G      2.253346E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
    4.000000E+02 G      2.102754E+02      0.000000E+00      0.000000E+00
                    0.000000E+00      0.000000E+00      0.000000E+00
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  143
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                          RANDOM               1

                          V E L O C I T Y   V E C T O R
                               ( ROOT MEAN SQUARE )

    POINT-ID   TYPE          T1                T2                T3
                             R1                R2                R3
         1       G      1.015272E+00      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
         2       G      1.015272E+00      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
         3       G      1.015272E+00      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  144
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                          RANDOM               1

                          V E L O C I T Y   V E C T O R
                           ( NUMBER OF ZERO CROSSINGS )

    POINT-ID   TYPE          T1                T2                T3
                             R1                R2                R3
         1       G      2.378739E+02      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
         2       G      2.378739E+02      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
         3       G      2.378739E+02      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  145
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
```

POINT-ID = 1

VELOCITY VECTOR
(CUMULATIVE ROOT MEAN SQUARE)

FREQUENCY	TYPE	T1 R1	T2 R2	T3 R3
2.000000E+02	G	0.000000E+00	0.000000E+00	0.000000E+00
		0.000000E+00	0.000000E+00	0.000000E+00
2.100000E+02	G	4.128223E+01	0.000000E+00	0.000000E+00
		0.000000E+00	0.000000E+00	0.000000E+00
2.200000E+02	G	5.982193E+01	0.000000E+00	0.000000E+00
		0.000000E+00	0.000000E+00	0.000000E+00
2.300000E+02	G	7.504285E+01	0.000000E+00	0.000000E+00
		0.000000E+00	0.000000E+00	0.000000E+00
2.400000E+02	G	8.871656E+01	0.000000E+00	0.000000E+00
		0.000000E+00	0.000000E+00	0.000000E+00
2.500000E+02	G	1.015104E+02	0.000000E+00	0.000000E+00
		0.000000E+00	0.000000E+00	0.000000E+00
2.600000E+02	G	1.137574E+02	0.000000E+00	0.000000E+00
		0.000000E+00	0.000000E+00	0.000000E+00
2.700000E+02	G	1.256498E+02	0.000000E+00	0.000000E+00
		0.000000E+00	0.000000E+00	0.000000E+00
2.800000E+02	G	1.373093E+02	0.000000E+00	0.000000E+00
		0.000000E+00	0.000000E+00	0.000000E+00
2.900000E+02	G	1.488180E+02	0.000000E+00	0.000000E+00
		0.000000E+00	0.000000E+00	0.000000E+00
3.000000E+02	G	1.602336E+02	0.000000E+00	0.000000E+00
		0.000000E+00	0.000000E+00	0.000000E+00
3.100000E+02	G	1.715983E+02	0.000000E+00	0.000000E+00
		0.000000E+00	0.000000E+00	0.000000E+00
3.200000E+02	G	1.829438E+02	0.000000E+00	0.000000E+00
		0.000000E+00	0.000000E+00	0.000000E+00
3.300000E+02	G	1.942942E+02	0.000000E+00	0.000000E+00
		0.000000E+00	0.000000E+00	0.000000E+00
3.400000E+02	G	2.056686E+02	0.000000E+00	0.000000E+00
		0.000000E+00	0.000000E+00	0.000000E+00
3.500000E+02	G	2.170817E+02	0.000000E+00	0.000000E+00
		0.000000E+00	0.000000E+00	0.000000E+00
3.600000E+02	G	2.285456E+02	0.000000E+00	0.000000E+00
		0.000000E+00	0.000000E+00	0.000000E+00
3.700000E+02	G	2.400698E+02	0.000000E+00	0.000000E+00
		0.000000E+00	0.000000E+00	0.000000E+00
3.800000E+02	G	2.516622E+02	0.000000E+00	0.000000E+00
		0.000000E+00	0.000000E+00	0.000000E+00
3.900000E+02	G	2.633291E+02	0.000000E+00	0.000000E+00
		0.000000E+00	0.000000E+00	0.000000E+00
4.000000E+02	G	2.750757E+02	0.000000E+00	0.000000E+00
		0.000000E+00	0.000000E+00	0.000000E+00

1GENESIS VERSION 8.0 DATE 12-13-2005 TIME 18:22 PAGE 146
RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
RANDOM 1

POINT-ID = 2

VELOCITY VECTOR
(CUMULATIVE ROOT MEAN SQUARE)

```
   FREQUENCY   TYPE          T1                 T2                 T3
                             R1                 R2                 R3
    2.000000E+02 G      0.000000E+00       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.100000E+02 G      1.233163E+02       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.200000E+02 G      2.305050E+02       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.300000E+02 G      5.452228E+02       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.400000E+02 G      9.388134E+02       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.500000E+02 G      1.132931E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.600000E+02 G      1.153218E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.700000E+02 G      1.161000E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.800000E+02 G      1.165129E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.900000E+02 G      1.167679E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.000000E+02 G      1.169398E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.100000E+02 G      1.170624E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.200000E+02 G      1.171534E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.300000E+02 G      1.172227E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.400000E+02 G      1.172765E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.500000E+02 G      1.173189E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.600000E+02 G      1.173526E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.700000E+02 G      1.173796E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.800000E+02 G      1.174012E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.900000E+02 G      1.174184E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    4.000000E+02 G      1.174322E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
1GENESIS   VERSION  8.0                 DATE 12-13-2005  TIME 18:22  PAGE  147
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                                   RANDOM              1
      POINT-ID =         3
                          V E L O C I T Y   V E C T O R
                         ( CUMULATIVE ROOT MEAN SQUARE )

   FREQUENCY   TYPE          T1                 T2                 T3
                             R1                 R2                 R3
    2.000000E+02 G      0.000000E+00       0.000000E+00       0.000000E+00
```

```
                    0.000000E+00       0.000000E+00       0.000000E+00
    2.100000E+02 G      1.483556E+02       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.200000E+02 G      2.816690E+02       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.300000E+02 G      6.836886E+02       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.400000E+02 G      1.195461E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.500000E+02 G      1.451148E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.600000E+02 G      1.479439E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.700000E+02 G      1.490943E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.800000E+02 G      1.497431E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.900000E+02 G      1.501704E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.000000E+02 G      1.504789E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.100000E+02 G      1.507158E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.200000E+02 G      1.509059E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.300000E+02 G      1.510635E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.400000E+02 G      1.511976E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.500000E+02 G      1.513142E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.600000E+02 G      1.514173E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.700000E+02 G      1.515098E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.800000E+02 G      1.515940E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.900000E+02 G      1.516713E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    4.000000E+02 G      1.517431E+03       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  148
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                                RANDOM              1
     POINT-ID =         1
                      A C C E L E R A T I O N     V E C T O R
                      ( POWER SPECTRAL DENSITY FUNCTION )

   FREQUENCY    TYPE          T1                 T2                 T3
                              R1                 R2                 R3
    2.000000E+02 G      2.560000E+08       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.100000E+02 G      3.111696E+08       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.200000E+02 G      3.748095E+08       0.000000E+00       0.000000E+00
```

```
                    0.000000E+00     0.000000E+00     0.000000E+00
  2.300000E+02 G    4.477454E+08     0.000000E+00     0.000000E+00
                    0.000000E+00     0.000000E+00     0.000000E+00
  2.400000E+02 G    5.308420E+08     0.000000E+00     0.000000E+00
                    0.000000E+00     0.000000E+00     0.000000E+00
  2.500000E+02 G    6.250001E+08     0.000000E+00     0.000000E+00
                    0.000000E+00     0.000000E+00     0.000000E+00
  2.600000E+02 G    7.311617E+08     0.000000E+00     0.000000E+00
                    0.000000E+00     0.000000E+00     0.000000E+00
  2.700000E+02 G    8.503057E+08     0.000000E+00     0.000000E+00
                    0.000000E+00     0.000000E+00     0.000000E+00
  2.800000E+02 G    9.834497E+08     0.000000E+00     0.000000E+00
                    0.000000E+00     0.000000E+00     0.000000E+00
  2.900000E+02 G    1.131650E+09     0.000000E+00     0.000000E+00
                    0.000000E+00     0.000000E+00     0.000000E+00
  3.000000E+02 G    1.296000E+09     0.000000E+00     0.000000E+00
                    0.000000E+00     0.000000E+00     0.000000E+00
  3.100000E+02 G    1.477634E+09     0.000000E+00     0.000000E+00
                    0.000000E+00     0.000000E+00     0.000000E+00
  3.200000E+02 G    1.677722E+09     0.000000E+00     0.000000E+00
                    0.000000E+00     0.000000E+00     0.000000E+00
  3.300000E+02 G    1.897474E+09     0.000000E+00     0.000000E+00
                    0.000000E+00     0.000000E+00     0.000000E+00
  3.400000E+02 G    2.138138E+09     0.000000E+00     0.000000E+00
                    0.000000E+00     0.000000E+00     0.000000E+00
  3.500000E+02 G    2.401000E+09     0.000000E+00     0.000000E+00
                    0.000000E+00     0.000000E+00     0.000000E+00
  3.600000E+02 G    2.687386E+09     0.000000E+00     0.000000E+00
                    0.000000E+00     0.000000E+00     0.000000E+00
  3.700000E+02 G    2.998658E+09     0.000000E+00     0.000000E+00
                    0.000000E+00     0.000000E+00     0.000000E+00
  3.800000E+02 G    3.336218E+09     0.000000E+00     0.000000E+00
                    0.000000E+00     0.000000E+00     0.000000E+00
  3.900000E+02 G    3.701506E+09     0.000000E+00     0.000000E+00
                    0.000000E+00     0.000000E+00     0.000000E+00
  4.000000E+02 G    4.096000E+09     0.000000E+00     0.000000E+00
                    0.000000E+00     0.000000E+00     0.000000E+00
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  149
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                             RANDOM              1
      POINT-ID =         2
                      A C C E L E R A T I O N    V E C T O R
                      ( POWER SPECTRAL DENSITY FUNCTION )

   FREQUENCY   TYPE          T1               T2               T3
                             R1               R2               R3
  2.000000E+02 G    1.607474E+09     0.000000E+00     0.000000E+00
                    0.000000E+00     0.000000E+00     0.000000E+00
  2.100000E+02 G    3.522802E+09     0.000000E+00     0.000000E+00
                    0.000000E+00     0.000000E+00     0.000000E+00
  2.200000E+02 G    1.062702E+10     0.000000E+00     0.000000E+00
                    0.000000E+00     0.000000E+00     0.000000E+00
  2.300000E+02 G    9.035579E+10     0.000000E+00     0.000000E+00
                    0.000000E+00     0.000000E+00     0.000000E+00
  2.400000E+02 G    1.672612E+11     0.000000E+00     0.000000E+00
```

```
                       0.000000E+00        0.000000E+00        0.000000E+00
    2.500000E+02 G     1.696906E+10        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
    2.600000E+02 G     6.400294E+09        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
    2.700000E+02 G     3.463923E+09        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
    2.800000E+02 G     2.220584E+09        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
    2.900000E+02 G     1.568027E+09        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
    3.000000E+02 G     1.177111E+09        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
    3.100000E+02 G     9.207299E+08        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
    3.200000E+02 G     7.410240E+08        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
    3.300000E+02 G     6.084403E+08        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
    3.400000E+02 G     5.065413E+08        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
    3.500000E+02 G     4.255657E+08        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
    3.600000E+02 G     3.594102E+08        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
    3.700000E+02 G     3.041001E+08        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
    3.800000E+02 G     2.569621E+08        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
    3.900000E+02 G     2.161552E+08        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
    4.000000E+02 G     1.803911E+08        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  150
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                              RANDOM              1
      POINT-ID =          3
                     A C C E L E R A T I O N    V E C T O R
                     ( POWER SPECTRAL DENSITY FUNCTION )

   FREQUENCY   TYPE          T1                  T2                  T3
                             R1                  R2                  R3
    2.000000E+02 G     2.266854E+09        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
    2.100000E+02 G     5.164453E+09        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
    2.200000E+02 G     1.623995E+10        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
    2.300000E+02 G     1.443493E+11        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
    2.400000E+02 G     2.801976E+11        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
    2.500000E+02 G     2.990527E+10        0.000000E+00        0.000000E+00
                       0.000000E+00        0.000000E+00        0.000000E+00
    2.600000E+02 G     1.190743E+10        0.000000E+00        0.000000E+00
```

```
                      0.000000E+00       0.000000E+00       0.000000E+00
    2.700000E+02 G    6.828590E+09       0.000000E+00       0.000000E+00
                      0.000000E+00       0.000000E+00       0.000000E+00
    2.800000E+02 G    4.657112E+09       0.000000E+00       0.000000E+00
                      0.000000E+00       0.000000E+00       0.000000E+00
    2.900000E+02 G    3.513771E+09       0.000000E+00       0.000000E+00
                      0.000000E+00       0.000000E+00       0.000000E+00
    3.000000E+02 G    2.831754E+09       0.000000E+00       0.000000E+00
                      0.000000E+00       0.000000E+00       0.000000E+00
    3.100000E+02 G    2.390152E+09       0.000000E+00       0.000000E+00
                      0.000000E+00       0.000000E+00       0.000000E+00
    3.200000E+02 G    2.087553E+09       0.000000E+00       0.000000E+00
                      0.000000E+00       0.000000E+00       0.000000E+00
    3.300000E+02 G    1.871757E+09       0.000000E+00       0.000000E+00
                      0.000000E+00       0.000000E+00       0.000000E+00
    3.400000E+02 G    1.713526E+09       0.000000E+00       0.000000E+00
                      0.000000E+00       0.000000E+00       0.000000E+00
    3.500000E+02 G    1.595393E+09       0.000000E+00       0.000000E+00
                      0.000000E+00       0.000000E+00       0.000000E+00
    3.600000E+02 G    1.506376E+09       0.000000E+00       0.000000E+00
                      0.000000E+00       0.000000E+00       0.000000E+00
    3.700000E+02 G    1.439295E+09       0.000000E+00       0.000000E+00
                      0.000000E+00       0.000000E+00       0.000000E+00
    3.800000E+02 G    1.389305E+09       0.000000E+00       0.000000E+00
                      0.000000E+00       0.000000E+00       0.000000E+00
    3.900000E+02 G    1.353059E+09       0.000000E+00       0.000000E+00
                      0.000000E+00       0.000000E+00       0.000000E+00
    4.000000E+02 G    1.328215E+09       0.000000E+00       0.000000E+00
                      0.000000E+00       0.000000E+00       0.000000E+00
1GENESIS   VERSION  8.0                DATE 12-13-2005  TIME 18:22  PAGE  151
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                        RANDOM            1

                       A C C E L E R A T I O N    V E C T O R
                                ( ROOT MEAN SQUARE )

    POINT-ID   TYPE          T1                 T2                 T3
                             R1                 R2                 R3
         1       G    5.636831E+05       0.000000E+00       0.000000E+00
                      0.000000E+00       0.000000E+00       0.000000E+00
         2       G    1.757267E+06       0.000000E+00       0.000000E+00
                      0.000000E+00       0.000000E+00       0.000000E+00
         3       G    2.286349E+06       0.000000E+00       0.000000E+00
                      0.000000E+00       0.000000E+00       0.000000E+00
1GENESIS   VERSION  8.0                DATE 12-13-2005  TIME 18:22  PAGE  152
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                        RANDOM            1

                       A C C E L E R A T I O N    V E C T O R
                            ( NUMBER OF ZERO CROSSINGS )

    POINT-ID   TYPE          T1                 T2                 T3
                             R1                 R2                 R3
         1       G    3.423308E+02       0.000000E+00       0.000000E+00
                      0.000000E+00       0.000000E+00       0.000000E+00
```

```
        2       G      2.400047E+02      0.000000E+00      0.000000E+00
                       0.000000E+00      0.000000E+00      0.000000E+00
        3       G      2.430016E+02      0.000000E+00      0.000000E+00
                       0.000000E+00      0.000000E+00      0.000000E+00
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  153
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                             RANDOM              1
      POINT-ID =         1
                      A C C E L E R A T I O N    V E C T O R
                         ( CUMULATIVE ROOT MEAN SQUARE )

   FREQUENCY   TYPE          T1                T2                T3
                             R1                R2                R3
    2.000000E+02 G      0.000000E+00      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    2.100000E+02 G      5.325268E+04      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    2.200000E+02 G      7.915645E+04      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    2.300000E+02 G      1.018750E+05      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    2.400000E+02 G      1.235777E+05      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    2.500000E+02 G      1.450885E+05      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    2.600000E+02 G      1.668277E+05      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    2.700000E+02 G      1.890471E+05      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    2.800000E+02 G      2.119141E+05      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    2.900000E+02 G      2.355485E+05      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    3.000000E+02 G      2.600410E+05      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    3.100000E+02 G      2.854637E+05      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    3.200000E+02 G      3.118754E+05      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    3.300000E+02 G      3.393262E+05      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    3.400000E+02 G      3.678591E+05      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    3.500000E+02 G      3.975122E+05      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    3.600000E+02 G      4.283199E+05      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    3.700000E+02 G      4.603131E+05      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    3.800000E+02 G      4.935205E+05      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    3.900000E+02 G      5.279689E+05      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
    4.000000E+02 G      5.636831E+05      0.000000E+00      0.000000E+00
                        0.000000E+00      0.000000E+00      0.000000E+00
```

```
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  154
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                                RANDOM          1
      POINT-ID =          2
                      A C C E L E R A T I O N    V E C T O R
                         ( CUMULATIVE ROOT MEAN SQUARE )

   FREQUENCY   TYPE          T1                 T2                 T3
                             R1                 R2                 R3
    2.000000E+02 G      0.000000E+00       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.100000E+02 G      1.601605E+05       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.200000E+02 G      3.104843E+05       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.300000E+02 G      7.754448E+05       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.400000E+02 G      1.374554E+06       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.500000E+02 G      1.676470E+06       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.600000E+02 G      1.710964E+06       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.700000E+02 G      1.725317E+06       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.800000E+02 G      1.733534E+06       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    2.900000E+02 G      1.738990E+06       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.000000E+02 G      1.742932E+06       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.100000E+02 G      1.745938E+06       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.200000E+02 G      1.748316E+06       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.300000E+02 G      1.750244E+06       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.400000E+02 G      1.751836E+06       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.500000E+02 G      1.753166E+06       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.600000E+02 G      1.754285E+06       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.700000E+02 G      1.755230E+06       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.800000E+02 G      1.756029E+06       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    3.900000E+02 G      1.756703E+06       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
    4.000000E+02 G      1.757267E+06       0.000000E+00       0.000000E+00
                        0.000000E+00       0.000000E+00       0.000000E+00
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  155
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                                RANDOM          1
      POINT-ID =          3
```

```
                 A C C E L E R A T I O N   V E C T O R
                   ( CUMULATIVE ROOT MEAN SQUARE )

  FREQUENCY   TYPE          T1                 T2                 T3
                            R1                 R2                 R3
   2.000000E+02 G      0.000000E+00       0.000000E+00       0.000000E+00
                       0.000000E+00       0.000000E+00       0.000000E+00
   2.100000E+02 G      1.927603E+05       0.000000E+00       0.000000E+00
                       0.000000E+00       0.000000E+00       0.000000E+00
   2.200000E+02 G      3.797085E+05       0.000000E+00       0.000000E+00
                       0.000000E+00       0.000000E+00       0.000000E+00
   2.300000E+02 G      9.732034E+05       0.000000E+00       0.000000E+00
                       0.000000E+00       0.000000E+00       0.000000E+00
   2.400000E+02 G      1.752101E+06       0.000000E+00       0.000000E+00
                       0.000000E+00       0.000000E+00       0.000000E+00
   2.500000E+02 G      2.149505E+06       0.000000E+00       0.000000E+00
                       0.000000E+00       0.000000E+00       0.000000E+00
   2.600000E+02 G      2.197598E+06       0.000000E+00       0.000000E+00
                       0.000000E+00       0.000000E+00       0.000000E+00
   2.700000E+02 G      2.218810E+06       0.000000E+00       0.000000E+00
                       0.000000E+00       0.000000E+00       0.000000E+00
   2.800000E+02 G      2.231714E+06       0.000000E+00       0.000000E+00
                       0.000000E+00       0.000000E+00       0.000000E+00
   2.900000E+02 G      2.240848E+06       0.000000E+00       0.000000E+00
                       0.000000E+00       0.000000E+00       0.000000E+00
   3.000000E+02 G      2.247916E+06       0.000000E+00       0.000000E+00
                       0.000000E+00       0.000000E+00       0.000000E+00
   3.100000E+02 G      2.253716E+06       0.000000E+00       0.000000E+00
                       0.000000E+00       0.000000E+00       0.000000E+00
   3.200000E+02 G      2.258678E+06       0.000000E+00       0.000000E+00
                       0.000000E+00       0.000000E+00       0.000000E+00
   3.300000E+02 G      2.263056E+06       0.000000E+00       0.000000E+00
                       0.000000E+00       0.000000E+00       0.000000E+00
   3.400000E+02 G      2.267013E+06       0.000000E+00       0.000000E+00
                       0.000000E+00       0.000000E+00       0.000000E+00
   3.500000E+02 G      2.270659E+06       0.000000E+00       0.000000E+00
                       0.000000E+00       0.000000E+00       0.000000E+00
   3.600000E+02 G      2.274072E+06       0.000000E+00       0.000000E+00
                       0.000000E+00       0.000000E+00       0.000000E+00
   3.700000E+02 G      2.277308E+06       0.000000E+00       0.000000E+00
                       0.000000E+00       0.000000E+00       0.000000E+00
   3.800000E+02 G      2.280411E+06       0.000000E+00       0.000000E+00
                       0.000000E+00       0.000000E+00       0.000000E+00
   3.900000E+02 G      2.283415E+06       0.000000E+00       0.000000E+00
                       0.000000E+00       0.000000E+00       0.000000E+00
   4.000000E+02 G      2.286349E+06       0.000000E+00       0.000000E+00
                       0.000000E+00       0.000000E+00       0.000000E+00
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  156
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                           RANDOM             1
      ELEMENT-ID =        6
                 F O R C E S   I N   S C A L A R   D A M P E R S
                      ( POWER SPECTRAL DENSITY FUNCTION )

      FREQUENCY       FORCE             FREQUENCY       FORCE
```

```
    2.000000E+02   5.453018E+04      2.100000E+02   1.262520E+05
    2.200000E+02   4.126058E+05      2.300000E+02   3.873134E+06
    2.400000E+02   8.022849E+06      2.500000E+02   9.191536E+05
    2.600000E+02   3.938394E+05      2.700000E+02   2.430640E+05
    2.800000E+02   1.781116E+05      2.900000E+02   1.439948E+05
    3.000000E+02   1.239155E+05      3.100000E+02   1.112498E+05
    3.200000E+02   1.029229E+05      3.300000E+02   9.733413E+04
    3.400000E+02   9.357666E+04      3.500000E+02   9.110141E+04
    3.600000E+02   8.955787E+04      3.700000E+02   8.871218E+04
    3.800000E+02   8.840232E+04      3.900000E+02   8.851228E+04
    4.000000E+02   8.895648E+04
1GENESIS   VERSION  8.0                 DATE 12-13-2005  TIME 18:22  PAGE  157
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                          RANDOM              1
      ELEMENT-ID =        7
                 F O R C E S   I N   S C A L A R   D A M P E R S
                       ( POWER SPECTRAL DENSITY FUNCTION )

      FREQUENCY       FORCE             FREQUENCY       FORCE
    2.000000E+02   8.948829E+04      2.100000E+02   2.247728E+05
    2.200000E+02   7.757273E+05      2.300000E+02   7.536114E+06
    2.400000E+02   1.592802E+07      2.500000E+02   1.844594E+06
    2.600000E+02   7.943929E+05      2.700000E+02   4.912777E+05
    2.800000E+02   3.603287E+05      2.900000E+02   2.916306E+05
    3.000000E+02   2.515123E+05      3.100000E+02   2.266770E+05
    3.200000E+02   2.109567E+05      3.300000E+02   2.011548E+05
    3.400000E+02   1.954784E+05      3.500000E+02   1.928639E+05
    3.600000E+02   1.926561E+05      3.700000E+02   1.944439E+05
    3.800000E+02   1.979714E+05      3.900000E+02   2.030863E+05
    4.000000E+02   2.097101E+05
1GENESIS   VERSION  8.0                 DATE 12-13-2005  TIME 18:22  PAGE  158
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                          RANDOM              1
      ELEMENT-ID =        4
                 F O R C E S   I N   S C A L A R   S P R I N G S
                       ( POWER SPECTRAL DENSITY FUNCTION )

      FREQUENCY       FORCE             FREQUENCY       FORCE
    2.000000E+02   8.632909E+09      2.100000E+02   1.812925E+10
    2.200000E+02   5.398465E+10      2.300000E+02   4.636466E+11
    2.400000E+02   8.820362E+11      2.500000E+02   9.312973E+10
    2.600000E+02   3.689375E+10      2.700000E+02   2.111414E+10
    2.800000E+02   1.438655E+10      2.900000E+02   1.084254E+10
    3.000000E+02   8.718934E+09      3.100000E+02   7.330883E+09
    3.200000E+02   6.364910E+09      3.300000E+02   5.660014E+09
    3.400000E+02   5.126134E+09      3.500000E+02   4.709440E+09
    3.600000E+02   4.376017E+09      3.700000E+02   4.103553E+09
    3.800000E+02   3.876830E+09      3.900000E+02   3.685145E+09
    4.000000E+02   3.520772E+09
1GENESIS   VERSION  8.0                 DATE 12-13-2005  TIME 18:22  PAGE  159
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                          RANDOM              1
      ELEMENT-ID =        5
                 F O R C E S   I N   S C A L A R   S P R I N G S
                       ( POWER SPECTRAL DENSITY FUNCTION )
```

```
     FREQUENCY       FORCE            FREQUENCY       FORCE
   2.000000E+02   2.266765E+09     2.100000E+02   5.164229E+09
   2.200000E+02   1.623918E+10     2.300000E+02   1.443418E+11
   2.400000E+02   2.801817E+11     2.500000E+02   2.990343E+10
   2.600000E+02   1.190663E+10     2.700000E+02   6.828099E+09
   2.800000E+02   4.656751E+09     2.900000E+02   3.513479E+09
   3.000000E+02   2.831502E+09     3.100000E+02   2.389926E+09
   3.200000E+02   2.087342E+09     3.300000E+02   1.871555E+09
   3.400000E+02   1.713331E+09     3.500000E+02   1.595200E+09
   3.600000E+02   1.506184E+09     3.700000E+02   1.439101E+09
   3.800000E+02   1.389107E+09     3.900000E+02   1.352856E+09
   4.000000E+02   1.328005E+09
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  160
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                            RANDOM              1

                 F O R C E S   I N   S C A L A R   D A M P E R S
                              ( ROOT MEAN SQUARE )

    ELEMENT-ID       FORCE           ELEMENT-ID       FORCE
             6    1.239356E+04                7    1.745373E+04
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  161
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                            RANDOM              1

                 F O R C E S   I N   S C A L A R   S P R I N G S
                              ( ROOT MEAN SQUARE )

    ELEMENT-ID       FORCE           ELEMENT-ID       FORCE
             4    4.067176E+06                5    2.286282E+06
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  162
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                            RANDOM              1

                 F O R C E S   I N   S C A L A R   D A M P E R S
                          ( NUMBER OF ZERO CROSSINGS )

    ELEMENT-ID       FORCE           ELEMENT-ID       FORCE
             6    2.478490E+02                7    2.487480E+02
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  163
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                            RANDOM              1

                 F O R C E S   I N   S C A L A R   S P R I N G S
                          ( NUMBER OF ZERO CROSSINGS )

    ELEMENT-ID       FORCE           ELEMENT-ID       FORCE
             4    2.424897E+02                5    2.430012E+02
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  164
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                            RANDOM              1
     ELEMENT-ID =        6
                 F O R C E S   I N   S C A L A R   D A M P E R S
                        ( CUMULATIVE ROOT MEAN SQUARE )
```

```
     FREQUENCY       FORCE            FREQUENCY       FORCE
   2.000000E+02   0.000000E+00     2.100000E+02   9.507422E+02
   2.200000E+02   1.641719E+03     2.300000E+02   4.629291E+03
   2.400000E+02   7.712622E+03     2.500000E+02   6.687131E+03
   2.600000E+02   2.563523E+03     2.700000E+02   1.785240E+03
   2.800000E+02   1.451779E+03     2.900000E+02   1.269639E+03
   3.000000E+02   1.157938E+03     3.100000E+02   1.084889E+03
   3.200000E+02   1.035349E+03     3.300000E+02   1.001160E+03
   3.400000E+02   9.775250E+02     3.500000E+02   9.614405E+02
   3.600000E+02   9.509247E+02     3.700000E+02   9.446170E+02
   3.800000E+02   9.415504E+02     3.900000E+02   9.410178E+02
   4.000000E+02   9.424886E+02
1GENESIS   VERSION  8.0                DATE 12-13-2005  TIME 18:22  PAGE  165
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                          RANDOM             1
     ELEMENT-ID =        7
                F O R C E S   I N   S C A L A R   D A M P E R S
                        ( CUMULATIVE ROOT MEAN SQUARE )

     FREQUENCY       FORCE            FREQUENCY       FORCE
   2.000000E+02   0.000000E+00     2.100000E+02   1.253517E+03
   2.200000E+02   2.236907E+03     2.300000E+02   6.446817E+03
   2.400000E+02   1.083177E+04     2.500000E+02   9.427297E+03
   2.600000E+02   3.633780E+03     2.700000E+02   2.536136E+03
   2.800000E+02   2.064114E+03     2.900000E+02   1.806062E+03
   3.000000E+02   1.648490E+03     3.100000E+02   1.546802E+03
   3.200000E+02   1.479769E+03     3.300000E+02   1.435979E+03
   3.400000E+02   1.408759E+03     3.500000E+02   1.393958E+03
   3.600000E+02   1.388882E+03     3.700000E+02   1.391722E+03
   3.800000E+02   1.401238E+03     3.900000E+02   1.416577E+03
   4.000000E+02   1.437149E+03
1GENESIS   VERSION  8.0                DATE 12-13-2005  TIME 18:22  PAGE  166
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                          RANDOM             1
     ELEMENT-ID =        4
                F O R C E S   I N   S C A L A R   S P R I N G S
                        ( CUMULATIVE ROOT MEAN SQUARE )

     FREQUENCY       FORCE            FREQUENCY       FORCE
   2.000000E+02   0.000000E+00     2.100000E+02   3.658016E+05
   2.200000E+02   6.004747E+05     2.300000E+02   1.608775E+06
   2.400000E+02   2.593919E+06     2.500000E+02   2.208129E+06
   2.600000E+02   8.062999E+05     2.700000E+02   5.385538E+05
   2.800000E+02   4.213122E+05     2.900000E+02   3.551702E+05
   3.000000E+02   3.127423E+05     3.100000E+02   2.832832E+05
   3.200000E+02   2.616854E+05     3.300000E+02   2.452038E+05
   3.400000E+02   2.322305E+05     3.500000E+02   2.217614E+05
   3.600000E+02   2.131373E+05     3.700000E+02   2.059079E+05
   3.800000E+02   1.997552E+05     3.900000E+02   1.944481E+05
   4.000000E+02   1.898151E+05
1GENESIS   VERSION  8.0                DATE 12-13-2005  TIME 18:22  PAGE  167
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                          RANDOM             1
     ELEMENT-ID =        5
```

```
                 F O R C E S   I N   S C A L A R   S P R I N G S
                         ( CUMULATIVE ROOT MEAN SQUARE )

      FREQUENCY       FORCE               FREQUENCY       FORCE
    2.000000E+02   0.000000E+00      2.100000E+02   1.927562E+05
    2.200000E+02   3.271349E+05      2.300000E+02   8.960497E+05
    2.400000E+02   1.456921E+06      2.500000E+02   1.245161E+06
    2.600000E+02   4.572215E+05      2.700000E+02   3.060623E+05
    2.800000E+02   2.396342E+05      2.900000E+02   2.021173E+05
    3.000000E+02   1.781154E+05      3.100000E+02   1.615776E+05
    3.200000E+02   1.496212E+05      3.300000E+02   1.406934E+05
    3.400000E+02   1.338827E+05      3.500000E+02   1.286188E+05
    3.600000E+02   1.245273E+05      3.700000E+02   1.213530E+05
    3.800000E+02   1.189166E+05      3.900000E+02   1.170894E+05
    4.000000E+02   1.157775E+05
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  168
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                             RANDOM             1
      ELEMENT-ID =        4
               S T R E S S E S   I N   S C A L A R   S P R I N G S
                       ( POWER SPECTRAL DENSITY FUNCTION )

      FREQUENCY      STRESS               FREQUENCY      STRESS
    2.000000E+02   8.632909E+09      2.100000E+02   1.812925E+10
    2.200000E+02   5.398465E+10      2.300000E+02   4.636466E+11
    2.400000E+02   8.820362E+11      2.500000E+02   9.312973E+10
    2.600000E+02   3.689375E+10      2.700000E+02   2.111414E+10
    2.800000E+02   1.438655E+10      2.900000E+02   1.084254E+10
    3.000000E+02   8.718934E+09      3.100000E+02   7.330883E+09
    3.200000E+02   6.364910E+09      3.300000E+02   5.660014E+09
    3.400000E+02   5.126134E+09      3.500000E+02   4.709440E+09
    3.600000E+02   4.376017E+09      3.700000E+02   4.103553E+09
    3.800000E+02   3.876830E+09      3.900000E+02   3.685145E+09
    4.000000E+02   3.520772E+09
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  169
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                             RANDOM             1
      ELEMENT-ID =        5
               S T R E S S E S   I N   S C A L A R   S P R I N G S
                       ( POWER SPECTRAL DENSITY FUNCTION )

      FREQUENCY      STRESS               FREQUENCY      STRESS
    2.000000E+02   2.266765E+09      2.100000E+02   5.164229E+09
    2.200000E+02   1.623918E+10      2.300000E+02   1.443418E+11
    2.400000E+02   2.801817E+11      2.500000E+02   2.990343E+10
    2.600000E+02   1.190663E+10      2.700000E+02   6.828099E+09
    2.800000E+02   4.656751E+09      2.900000E+02   3.513479E+09
    3.000000E+02   2.831502E+09      3.100000E+02   2.389926E+09
    3.200000E+02   2.087342E+09      3.300000E+02   1.871555E+09
    3.400000E+02   1.713331E+09      3.500000E+02   1.595200E+09
    3.600000E+02   1.506184E+09      3.700000E+02   1.439101E+09
    3.800000E+02   1.389107E+09      3.900000E+02   1.352856E+09
    4.000000E+02   1.328005E+09
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  170
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
```

```
                                                                RANDOM              1

              S T R E S S E S   I N   S C A L A R   S P R I N G S
                               ( ROOT MEAN SQUARE )

     ELEMENT-ID      STRESS          ELEMENT-ID      STRESS
              4    4.067176E+06               5    2.286282E+06
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  171
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                                RANDOM              1

              S T R E S S E S   I N   S C A L A R   S P R I N G S
                           ( NUMBER OF ZERO CROSSINGS )

     ELEMENT-ID      STRESS          ELEMENT-ID      STRESS
              4    2.424897E+02               5    2.430012E+02
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  172
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                                RANDOM              1
      ELEMENT-ID =        4
              S T R E S S E S   I N   S C A L A R   S P R I N G S
                         ( CUMULATIVE ROOT MEAN SQUARE )

      FREQUENCY      STRESS           FREQUENCY      STRESS
    2.000000E+02   0.000000E+00     2.100000E+02   3.658016E+05
    2.200000E+02   6.004747E+05     2.300000E+02   1.608775E+06
    2.400000E+02   2.593919E+06     2.500000E+02   2.208129E+06
    2.600000E+02   8.062999E+05     2.700000E+02   5.385538E+05
    2.800000E+02   4.213122E+05     2.900000E+02   3.551702E+05
    3.000000E+02   3.127423E+05     3.100000E+02   2.832832E+05
    3.200000E+02   2.616854E+05     3.300000E+02   2.452038E+05
    3.400000E+02   2.322305E+05     3.500000E+02   2.217614E+05
    3.600000E+02   2.131373E+05     3.700000E+02   2.059079E+05
    3.800000E+02   1.997552E+05     3.900000E+02   1.944481E+05
    4.000000E+02   1.898151E+05
1GENESIS   VERSION  8.0                  DATE 12-13-2005  TIME 18:22  PAGE  173
 RANDOM RESPONSE OF A SIMPLE ELAS/DAMP/MASS STRUCTURE
                                                                RANDOM              1
      ELEMENT-ID =        5
              S T R E S S E S   I N   S C A L A R   S P R I N G S
                         ( CUMULATIVE ROOT MEAN SQUARE )

      FREQUENCY      STRESS           FREQUENCY      STRESS
    2.000000E+02   0.000000E+00     2.100000E+02   1.927562E+05
    2.200000E+02   3.271349E+05     2.300000E+02   8.960497E+05
    2.400000E+02   1.456921E+06     2.500000E+02   1.245161E+06
    2.600000E+02   4.572215E+05     2.700000E+02   3.060623E+05
    2.800000E+02   2.396342E+05     2.900000E+02   2.021173E+05
    3.000000E+02   1.781154E+05     3.100000E+02   1.615776E+05
    3.200000E+02   1.496212E+05     3.300000E+02   1.406934E+05
    3.400000E+02   1.338827E+05     3.500000E+02   1.286188E+05
    3.600000E+02   1.245273E+05     3.700000E+02   1.213530E+05
    3.800000E+02   1.189166E+05     3.900000E+02   1.170894E+05
    4.000000E+02   1.157775E+05
 ***** THERE WERE        4 INFORMATION MESSAGES *****
```

1 ***** END OF OUTPUT *****

2.38 Random Response of a Cantilever Plate

Example ID:

A038

Analysis Data:

GRID, CQUAD4, SPC, EIGR, FREQ1, RLOAD1, DAREA, TABLED1, TABDMP1, RANDPS, RANDOM, TABRND1

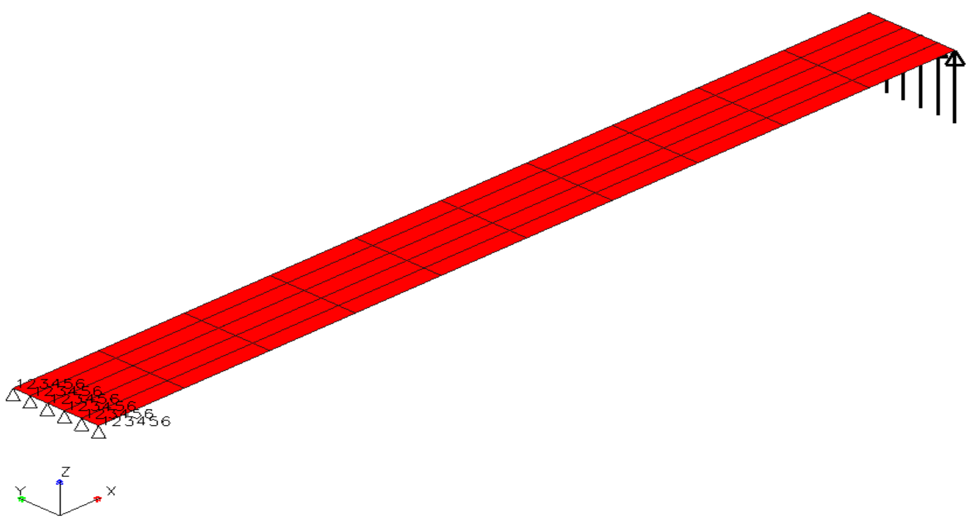
Special Features Used:

Random response analysis.

Problem Statement:

Find the random respones of a simple cantilevered plate assembled with quadilateral elements.

Structural Analysis Model:



Analysis Model Description:

1. A simple cantilevered plate modeled with 50 quadilateral elements.

Random Analysis Data Relationships:

RANDOM → RANDPS → TABRND1

Special Modeling Techniques:

None.

Reference Solution:

None.

Calculated Solution:

1. Power spectral density functions (PSDF) , $S_j(\omega)$
2. Root mean square (RMS), u_j
3. Cumulative root mean square (CRMS),$u_j(\omega)$
4. Number of zero crossings, N0

The above analyses are calculate for the following user requested responses:

1. Displacements
2. Velocities
3. Accelerations
4. Stresses CQUAD4

The above results are printed in the A038.out file.

2.38.1 Input Data

```
ID A038
SOL COMPAT1
CEND
$
TITLE = RANDOM RESPONSE OF A CANTILEVERED PLATE
LINE = 64,80
ECHO = NONE
SET 1 = 44
SET 2 = 21
$
FREQUENCY = 40
RANDOM = 30
$
SUBCASE 1
     LABEL = DYNAMIC LOADING AT THE FREE END OF THE PLATE
     SPC     = 1
     METHOD  = 1
     DLOAD   = 10
     SDAMPING = 20
     DISP(SORT2,RPRINT,PSDF,CRMS) = 1
     VELO(SORT2,RPRINT,PSDF,CRMS) = 1
     ACCE(SORT2,RPRINT,PSDF,CRMS) = 1
     STRESS(SORT2,RPRINT,PSDF,CRMS) = 2
$
BEGIN BULK
$
$ LOAD DEFINITION FOR DYNAMIC LOADING
$
RLOAD1        10      11                      12
DAREA         11      66       3-.200000      11       3-.200000
DAREA         11      55       3-.400000      44       3-.400000
DAREA         11      33       3-.400000      22       3-.400000
TABLED1       12                                                        +
+            2.0     1.0   200.0     1.0    ENDT
TABDMP1       20                                                        +
+            2.0    0.05   200.0    0.05    ENDT
FREQ1         40     2.0     2.0      99
$
$ RANDOM ANALYSIS DATA
$
RANDPS        30       1       1     1.0     0.0      31
TABRND1       31                                                        +
+       1.999    0.01     2.0   0.475   200.0   0.475  200.1    0.01+
+          ENDT
$
$ EIGEN VALUE DATA
$
EIGR           1     LAN        400.0000
```

```
$
$ LOADING DATA
$
FORCE          2      66        .2000000     0.0     0.0-1.00000
FORCE          2      11        .2000000     0.0     0.0-1.00000
FORCE          2      55        .4000000     0.0     0.0-1.00000
FORCE          2      44        .4000000     0.0     0.0-1.00000
FORCE          2      33        .4000000     0.0     0.0-1.00000
FORCE          2      22        .4000000     0.0     0.0-1.00000
$
$ BOUNDARY CONDITIONS
$
SPC            1      56  123456     0.0
SPC            1      45  123456     0.0
SPC            1      34  123456     0.0
SPC            1      23  123456     0.0
SPC            1      12  123456     0.0
SPC            1       1  123456     0.0
$
$ PROPERTIES
$
PSHELL         1       17.000000       1               1
$
$ MATERIAL
$
MAT1           168900.00        .30000002.8500-6
$
$ GRIDS
$
GRID           1             0.0     0.0     0.0
GRID           2        15.00000     0.0     0.0
GRID           3        30.00000     0.0     0.0
GRID           4        45.00000     0.0     0.0
GRID           5        60.00000     0.0     0.0
GRID           6        75.00000     0.0     0.0
GRID           7        90.00000     0.0     0.0
GRID           8        105.0000     0.0     0.0
GRID           9        120.0000     0.0     0.0
GRID          10        135.0000     0.0     0.0
GRID          11        150.0000     0.0     0.0
GRID          12             0.03.000000     0.0
GRID          13        15.000003.000000     0.0
GRID          14        30.000003.000000     0.0
GRID          15        45.000003.000000     0.0
GRID          16        60.000003.000000     0.0
GRID          17        75.000003.000000     0.0
GRID          18        90.000003.000000     0.0
GRID          19        105.00003.000000     0.0
GRID          20        120.00003.000000     0.0
GRID          21        135.00003.000000     0.0
GRID          22        150.00003.000000     0.0
```

```
GRID          23          0.06.000000     0.0
GRID          24     15.000006.000000     0.0
GRID          25     30.000006.000000     0.0
GRID          26     45.000006.000000     0.0
GRID          27     60.000006.000000     0.0
GRID          28     75.000006.000000     0.0
GRID          29     90.000006.000000     0.0
GRID          30     105.00006.000000     0.0
GRID          31     120.00006.000000     0.0
GRID          32     135.00006.000000     0.0
GRID          33     150.00006.000000     0.0
GRID          34          0.09.000000     0.0
GRID          35     15.000009.000000     0.0
GRID          36     30.000009.000000     0.0
GRID          37     45.000009.000000     0.0
GRID          38     60.000009.000000     0.0
GRID          39     75.000009.000000     0.0
GRID          40     90.000009.000000     0.0
GRID          41     105.00009.000000     0.0
GRID          42     120.00009.000000     0.0
GRID          43     135.00009.000000     0.0
GRID          44     150.00009.000000     0.0
GRID          45          0.012.00000     0.0
GRID          46     15.0000012.00000     0.0
GRID          47     30.0000012.00000     0.0
GRID          48     45.0000012.00000     0.0
GRID          49     60.0000012.00000     0.0
GRID          50     75.0000012.00000     0.0
GRID          51     90.0000012.00000     0.0
GRID          52     105.000012.00000     0.0
GRID          53     120.000012.00000     0.0
GRID          54     135.000012.00000     0.0
GRID          55     150.000012.00000     0.0
GRID          56          0.015.00000     0.0
GRID          57     15.0000015.00000     0.0
GRID          58     30.0000015.00000     0.0
GRID          59     45.0000015.00000     0.0
GRID          60     60.0000015.00000     0.0
GRID          61     75.0000015.00000     0.0
GRID          62     90.0000015.00000     0.0
GRID          63     105.000015.00000     0.0
GRID          64     120.000015.00000     0.0
GRID          65     135.000015.00000     0.0
GRID          66     150.000015.00000     0.0
$
$ ELEMENTS
$
CQUAD4         1       1       1       2      13      12     0.0
CQUAD4         2       1       2       3      14      13     0.0
CQUAD4         3       1       3       4      15      14     0.0
CQUAD4         4       1       4       5      16      15     0.0
```

```
CQUAD4        5       1       5       6      17      16     0.0
CQUAD4        6       1       6       7      18      17     0.0
CQUAD4        7       1       7       8      19      18     0.0
CQUAD4        8       1       8       9      20      19     0.0
CQUAD4        9       1       9      10      21      20     0.0
CQUAD4       10       1      10      11      22      21     0.0
CQUAD4       11       1      12      13      24      23     0.0
CQUAD4       12       1      13      14      25      24     0.0
CQUAD4       13       1      14      15      26      25     0.0
CQUAD4       14       1      15      16      27      26     0.0
CQUAD4       15       1      16      17      28      27     0.0
CQUAD4       16       1      17      18      29      28     0.0
CQUAD4       17       1      18      19      30      29     0.0
CQUAD4       18       1      19      20      31      30     0.0
CQUAD4       19       1      20      21      32      31     0.0
CQUAD4       20       1      21      22      33      32     0.0
CQUAD4       21       1      23      24      35      34     0.0
CQUAD4       22       1      24      25      36      35     0.0
CQUAD4       23       1      25      26      37      36     0.0
CQUAD4       24       1      26      27      38      37     0.0
CQUAD4       25       1      27      28      39      38     0.0
CQUAD4       26       1      28      29      40      39     0.0
CQUAD4       27       1      29      30      41      40     0.0
CQUAD4       28       1      30      31      42      41     0.0
CQUAD4       29       1      31      32      43      42     0.0
CQUAD4       30       1      32      33      44      43     0.0
CQUAD4       31       1      34      35      46      45     0.0
CQUAD4       32       1      35      36      47      46     0.0
CQUAD4       33       1      36      37      48      47     0.0
CQUAD4       34       1      37      38      49      48     0.0
CQUAD4       35       1      38      39      50      49     0.0
CQUAD4       36       1      39      40      51      50     0.0
CQUAD4       37       1      40      41      52      51     0.0
CQUAD4       38       1      41      42      53      52     0.0
CQUAD4       39       1      42      43      54      53     0.0
CQUAD4       40       1      43      44      55      54     0.0
CQUAD4       41       1      45      46      57      56     0.0
CQUAD4       42       1      46      47      58      57     0.0
CQUAD4       43       1      47      48      59      58     0.0
CQUAD4       44       1      48      49      60      59     0.0
CQUAD4       45       1      49      50      61      60     0.0
CQUAD4       46       1      50      51      62      61     0.0
CQUAD4       47       1      51      52      63      62     0.0
CQUAD4       48       1      52      53      64      63     0.0
CQUAD4       49       1      53      54      65      64     0.0
CQUAD4       50       1      54      55      66      65     0.0
ENDDATA
```

2.38.2 Output Data

```
1








                 GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
                G        E       NN  N   E       S          I     S
                G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
                G    G   E       N  NN   E            S     I          S
                 GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                    STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE



                                 COPYRIGHT, 1991-2008

                       VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                            ALL RIGHTS RESERVED, WORLDWIDE

                                     VERSION 10.1

                                BUILD CODE r106         BETA




     PROJECT NAME: A038
     RUN STARTED:  Dec  4, 2008 10:05
     SYSTEM TYPE:  Linux 2.6.18.8-0.9-default x86_64 4-CPU (LP64)
     LENVEC:             40000000
     IOBUFF:               256,64K
     THREADS:                    1

     LICENSED TO: VR&D
     LICENSE EXPIRES: Apr 17, 2009


     WARNING MESSAGE FROM GN1245:
     LOADS AND/OR BOUNDARY CONDITIONS AND/OR EIGENVALUE DATA
     STATEMENTS ARE NOT REFERENCED.
     A SUMMARY OF THEM ARE GIVEN BELOW.
     THE NON REFERENCED BULK DATA STATEMENTS WERE IGNORED.

     DATA STATEMENT  REFERENCED        TOTAL
```

```
      FORCE                0          6


1GENESIS   VERSION 10.1                  DATE 12-04-2008  TIME 10:05  PAGE    1
 RANDOM RESPONSE OF A CANTILEVERED PLATE


                                   ANALYSIS PROBLEM SUMMARY

                         NUMBER OF GRID POINTS:                     66
                         NUMBER OF CQUAD4->PSHELL ELEMENTS:         50
                         TOTAL NUMBER OF NON RIGID ELEMENTS:        50
                         NUMBER OF ELEMENT PROPERTIES:               1
                         NUMBER OF MATERIALS:                        1
                         NUMBER OF DEGREES OF FREEDOM:             360



                                     LOAD CASES SUMMARY

                        NUMBER OF USER FREQUENCY LOAD CASES:           0
                        NUMBER OF INTERNAL FREQUENCY LOAD CASES:       1
                        NUMBER OF MODAL  DYNAMIC LOAD CASES:           1
                        TOTAL NUMBER OF LOAD CASES:                    2

1GENESIS   VERSION 10.1                  DATE 12-04-2008  TIME 10:05  PAGE    2
 RANDOM RESPONSE OF A CANTILEVERED PLATE


                                LANCZOS EIGENSOLUTION STATISTICS

  SHIFT        SHIFT          FREQUENCY     EVALUES     NEW      TERM.     CPU
  COUNT        VALUE         (CYC./TIME)    BELOW      FOUND     CODE      TIME
  -----    -------------   -------------   -------   -------   -----   --------
      1     6.316547E+06    4.000000E+02       10          0      10       0.00
      2    -1.000000E+01   -5.032921E-01        0         10       2       0.01
1GENESIS   VERSION 10.1                  DATE 12-04-2008  TIME 10:05  PAGE    3
 RANDOM RESPONSE OF A CANTILEVERED PLATE


                    ****************************************************
                    *  D E S I G N  C Y C L E     0 (ANALYSIS SUMMARY)*
                    ****************************************************
1GENESIS   VERSION 10.1                  DATE 12-04-2008  TIME 10:05  PAGE    4
 RANDOM RESPONSE OF A CANTILEVERED PLATE


                              M A S S / V O L U M E   S U M M A R Y

                          SYSTEM MASS                4.488750E-02
                          SYSTEM VOLUME              1.575000E+04
                          SYSTEM MASS/VOLUME         2.850000E-06
1GENESIS   VERSION 10.1                  DATE 12-04-2008  TIME 10:05  PAGE    5
 RANDOM RESPONSE OF A CANTILEVERED PLATE
```

```
                    E N C L O S I N G   B O X   S U M M A R Y

    LENGTH X   LENGTH Y   LENGTH Z    AREA XY    AREA YZ    AREA XZ VOLUME XYZ
   1.500E+02  1.500E+01  0.000E+00  2.250E+03  0.000E+00  0.000E+00  0.000E+00

1GENESIS   VERSION 10.1                  DATE 12-04-2008  TIME 10:05  PAGE    6
 RANDOM RESPONSE OF A CANTILEVERED PLATE

 MODES FOR METHOD OF LOADCASE 1                             LOADCASE        2

                           E I G E N V A L U E S

                                                         GENERALIZED   GENERALIZED
   MODE       CYCLES      EIGENVALUE     RADIANS            MASS       STIFFNESS

       1  7.848049E+00  2.431550E+03  4.931075E+01  1.000000E+00  2.431550E+03
       2  1.672115E+01  1.103805E+04  1.050621E+02  1.000000E+00  1.103805E+04
       3  4.936079E+01  9.618868E+04  3.101430E+02  1.000000E+00  9.618868E+04
       4  1.026158E+02  4.157080E+05  6.447542E+02  1.000000E+00  4.157080E+05
       5  1.216394E+02  5.841281E+05  7.642827E+02  1.000000E+00  5.841281E+05
       6  1.400379E+02  7.741959E+05  8.798840E+02  1.000000E+00  7.741959E+05
       7  2.601806E+02  2.672451E+06  1.634763E+03  1.000000E+00  2.672451E+06
       8  2.803592E+02  3.103055E+06  1.761549E+03  1.000000E+00  3.103055E+06
       9  2.812544E+02  3.122901E+06  1.767173E+03  1.000000E+00  3.122901E+06
      10  3.676873E+02  5.337244E+06  2.310248E+03  1.000000E+00  5.337244E+06
      11  5.682706E+02  1.274882E+07  3.570549E+03  1.000000E+00  1.274882E+07
1GENESIS   VERSION 10.1                  DATE 12-04-2008  TIME 10:05  PAGE    7
 RANDOM RESPONSE OF A CANTILEVERED PLATE


             ********************************************
             *  D E S I G N  C Y C L E     0 (ANALYSIS)*
             ********************************************
1GENESIS   VERSION 10.1                  DATE 12-04-2008  TIME 10:05  PAGE    8
 RANDOM RESPONSE OF A CANTILEVERED PLATE

 DYNAMIC LOADING AT THE FREE END OF THE PLATE               LOADCASE        1

-------------------------------------------------------------------
Dynamic responses have been deleted to save space
-------------------------------------------------------------------

------------Porsions of this file has been removed to save space-------------


1GENESIS   VERSION 10.1                  DATE 12-04-2008  TIME 10:05  PAGE  408
 RANDOM RESPONSE OF A CANTILEVERED PLATE
                                                        RANDOM             30
 +00
 ***** THERE WERE        1 WARNING MESSAGES *****
1                             ***** END OF OUTPUT *****
```

2.39 Rigid Body Modes of Doubly Curved Shells

Example ID:

A039

Analysis Data:

GRID, CQUAD4, CWELD, EIGR

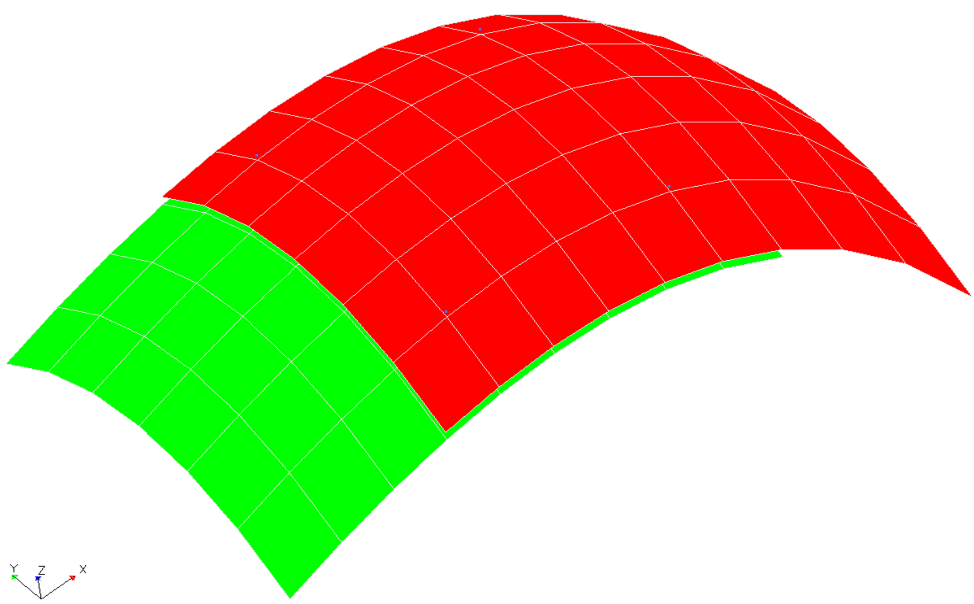
Special Features Used:

CWELD connector elements

Problem Statement:

Verify the six rigid body modes of two doubly curved shells connected by WELD elements of type PARTPAT, ELPAT, ELEMID, GRIDID and ALIGN.

Structural Analysis Model:



Analysis Model Description:

1. Two doubly curved shells with 48 quadilateral elements each connected by 4 welds.

Special Modeling Techniques:

None.

Reference Solution:

None.

Calculated Solution:

1. Rigid and elastic modes of structure

The above results are printed in the A039.out file.

2.39.1 Input Data

```
$-----------------------------------------------------------------------$
$ Data written by Design Studio for Genesis 10.1 (r521)
$ Exported on 2009-03-31 17:42
$-----------------------------------------------------------------------$
$
$ Executive Control
$
POST = PUNCH
SOL COMPAT1
CEND
$
$ Solution Control
$
LINE = 64,80
ECHO = UNSORT(PARAM,DOPT)
$
$ Loadcase definitions
$
SUBCASE 10
   LABEL = Loadcase 10
   METHOD = 1
   MODTRK=NO
   DISP = POST,ALL
   ESE = POST,ALL
BEGIN BULK
$
$ Parameters
$
$
$ Property definitions
$
$HMCOLOR COMP        1       1
PSHELL         1       11.000000       1               1
$HMCOLOR COMP        2       2
PSHELL         2       11.000000       1               1
$HMCOLOR COMP        6       3
PWELD          6       12.000000                               SPOT
$HMCOLOR COMP        7       5
PSHELL         7       21.000000       2               2
$HMCOLOR COMP        8       6
PSHELL         8       21.000000       2               2
$HMCOLOR COMP       12       7
PWELD         12       22.000000                               SPOT
$HMCOLOR COMP       13       1
PSHELL        13       31.000000       3               3
$HMCOLOR COMP       14       2
PSHELL        14       31.000000       3               3
$HMCOLOR COMP       18       3
PWELD         18       32.000000
SWLDPRM    PRTSW       0  NREDIA       2  GSMOVE       2   GMCHK       1
+          GSTOL     0.0 PROJTOL     0.2  GSPROJ    20.0
$
```

```
$ Material definitions
$
$HMNAME MAT        1 "MAT1"
MAT1           1207000.0        .30000007.8000-9
$HMNAME MAT        2 "MAT1"
MAT1           2207000.0        .30000007.8000-9
$HMNAME MAT        3 "MAT1"
MAT1           3207000.0        .30000007.8000-9
$
$ Load definitions
$
$HMNAME LOADCOL        1 "Method 1"
EIGR           1     SMS        10000.00              36
$
$ Boundary Condition definitions
$
$
$ Grid points
$
GRID           5        90.00000     0.070.08133
GRID           7             0.060.0000070.01790
GRID           9        90.0000060.0000070.09919
GRID          10             0.0     0.070.00000
GRID          77        10.00000     0.075.07760
GRID          78        20.00000     0.079.20670
GRID          79        30.00000     0.082.34758
GRID          80        40.00000     0.084.34912
GRID          81        50.00000     0.085.06771
GRID          82        60.00000     0.084.30118
GRID          83        70.00000     0.081.79037
GRID          84        80.00000     0.077.20472
GRID          85             0.010.0000078.36184
GRID          86        10.0000010.0000083.38850
GRID          87        20.0000010.0000087.51803
GRID          88        30.0000010.0000090.65744
GRID          89        40.0000010.0000092.65994
GRID          90        50.0000010.0000093.37844
GRID          91        60.0000010.0000092.61201
GRID          92        70.0000010.0000090.10146
GRID          93        80.0000010.0000085.51624
GRID          94        90.0000010.0000078.40251
GRID          95             0.020.0000083.34978
GRID          96        10.0000020.0000088.37678
GRID          97        20.0000020.0000092.50993
GRID          98        30.0000020.0000095.64416
GRID          99        40.0000020.0000097.64646
.
.
.
GRID        1000        120.000040.00000-98.2621
GRID        1001        30.0000050.00000-47.3552
GRID        1002        40.0000050.00000-45.3511
GRID        1003        50.0000050.00000-44.6355
GRID        1004        60.0000050.00000-45.4034
GRID        1005        70.0000050.00000-47.9115
```

```
GRID        1006        80.0000050.00000-52.4981
GRID        1007        90.0000050.00000-59.6061
GRID        1008        100.000050.00000-69.8869
GRID        1009        110.000050.00000-83.9798
GRID        1010        120.000050.00000-103.243
GRID        1011        40.0000060.00000-53.6619
GRID        1012        50.0000060.00000-52.9464
GRID        1013        60.0000060.00000-53.7143
GRID        1014        70.0000060.00000-56.2221
GRID        1015        80.0000060.00000-60.8082
GRID        1016        90.0000060.00000-67.9156
GRID        1017        100.000060.00000-78.1953
GRID        1018        110.000060.00000-92.2868
$
$ Element definitions
$
CQUAD4       109       1     146     147     156     155     0.0
CQUAD4       110       1     147     148     157     156     0.0
CQUAD4       111       1     148     149     158     157     0.0
CQUAD4       112       1     149     150     159     158     0.0
CQUAD4       113       1     150     151     160     159     0.0
CQUAD4       114       1     151     152     161     160     0.0
CQUAD4       115       1     152     153     162     161     0.0
CQUAD4       116       1     153     154     163     162     0.0
CQUAD4       117       1     154     143     164     163     0.0
CQUAD4       118       1     155     156     166     165     0.0
CQUAD4       119       1     156     157     167     166     0.0
CQUAD4       120       1     157     158     168     167     0.0
.
.
.
CQUAD4       100       2     125     126     135       7     0.0
CQUAD4       101       2     126     127     136     135     0.0
CQUAD4       102       2     127     128     137     136     0.0
CQUAD4       103       2     128     129     138     137     0.0
CQUAD4       104       2     129     130     139     138     0.0
CQUAD4       105       2     130     131     140     139     0.0
CQUAD4       106       2     131     132     141     140     0.0
CQUAD4       107       2     132     133     142     141     0.0
CQUAD4       108       2     133     134       9     142     0.0
CWELD        209       6     300PARTPAT
+              1       2
CWELD        210       6     301ELPAT
+            146      95
CWELD        211       6     302ELPAT
+            122      71
CWELD        212       6     303PARTPAT
+              1       2
CQUAD4       321       7     449     450     459     458     0.0
CQUAD4       322       7     450     451     460     459     0.0
CQUAD4       323       7     451     452     461     460     0.0
CQUAD4       324       7     452     453     462     461     0.0
CQUAD4       325       7     453     454     463     462     0.0
CQUAD4       326       7     454     455     464     463     0.0
CQUAD4       327       7     455     456     465     464     0.0
```

```
CQUAD4      328      7     456     457     466     465     0.0
CQUAD4      329      7     457     446     467     466     0.0
CQUAD4      330      7     458     459     469     468     0.0
.
.
.
CQUAD4      315      8     431     432     441     440     0.0
CQUAD4      316      8     432     433     442     441     0.0
CQUAD4      317      8     433     434     443     442     0.0
CQUAD4      318      8     434     435     444     443     0.0
CQUAD4      319      8     435     436     445     444     0.0
CQUAD4      320      8     436     437     312     445     0.0
CWELD       421     12     803GRIDID                  QQ
+           449    450     459     458
+           382    383     392     391
CWELD       422     12     804GRIDID                  QQ
+           498    499     508     447
+           431    432     441     440
CWELD       423     12     805ELEMID
+           326    275
CWELD       424     12     806ELEMID
+           371    320
CQUAD4      533     13     952     953     962     961     0.0
CQUAD4      534     13     953     954     963     962     0.0
CQUAD4      535     13     954     955     964     963     0.0
CQUAD4      536     13     955     956     965     964     0.0
CQUAD4      537     13     956     957     966     965     0.0
CQUAD4      538     13     957     958     967     966     0.0
CQUAD4      539     13     958     959     968     967     0.0
CQUAD4      540     13     959     960     969     968     0.0
.
.
.
CQUAD4      520     14     926     927     937     936     0.0
CQUAD4      521     14     927     928     938     937     0.0
CQUAD4      522     14     928     929     939     938     0.0
CQUAD4      523     14     929     930     940     939     0.0
CQUAD4      524     14     931     932     941     813     0.0
CQUAD4      525     14     932     933     942     941     0.0
CQUAD4      526     14     933     934     943     942     0.0
CQUAD4      527     14     934     935     944     943     0.0
CQUAD4      528     14     935     936     945     944     0.0
CQUAD4      529     14     936     937     946     945     0.0
CQUAD4      530     14     937     938     947     946     0.0
CQUAD4      531     14     938     939     948     947     0.0
CQUAD4      532     14     939     940     815     948     0.0
CWELD       633     18        ALIGN      962     895
CWELD       634     18        ALIGN     1002     935
CWELD       635     18        ALIGN      966     899
CWELD       636     18        ALIGN     1006     939
ENDDATA
```

2.39.2 Output Data

```
1







                  GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
                 G        E       NN  N   E       S          I     S
                 G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
                 G    G   E       N  NN   E            S     I          S
                  GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                      STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE



                                   COPYRIGHT, 1991-2008

                           VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                                ALL RIGHTS RESERVED, WORLDWIDE

                                         VERSION 10.2

                                   BUILD CODE 200904030915 BETA




     PROJECT NAME: A039
     RUN STARTED:  Apr  3, 2009 09:16
     SYSTEM TYPE:  Linux 2.6.25.5-1.1-default x86_64 4-CPU (LP64)
     LENVEC:             250000000
     IOBUFF:               256,64K
    THREADS:              1

                                   ANALYSIS PROBLEM SUMMARY

                   NUMBER OF GRID POINTS:                       428
                   NUMBER OF CQUAD4->PSHELL ELEMENTS:           324
                   NUMBER OF CWELD ELEMENTS:                     12
                   TOTAL NUMBER OF NON RIGID ELEMENTS:          336
                   NUMBER OF ELEMENT PROPERTIES:                  9
                   NUMBER OF MATERIALS:                           3
                   NUMBER OF DEGREES OF FREEDOM:               2520
```

```
                           LOAD CASES SUMMARY

               NUMBER OF USER FREQUENCY LOAD CASES:          1
               TOTAL NUMBER OF LOAD CASES:                   1

1GENESIS   VERSION 10.2                  DATE 04-03-2009  TIME  9:16  PAGE    4


             ****************************************************
             *  D E S I G N  C Y C L E      0 (ANALYSIS SUMMARY)*
             ****************************************************
1GENESIS   VERSION 10.2                  DATE 04-03-2009  TIME  9:16  PAGE    5


                       M A S S / V O L U M E   S U M M A R Y

                SYSTEM MASS              3.328003E-04
                SYSTEM VOLUME            4.266671E+04
                SYSTEM MASS/VOLUME       7.800000E-09
1GENESIS   VERSION 10.2                  DATE 04-03-2009  TIME  9:16  PAGE    6


                E N C L O S I N G   B O X   S U M M A R Y

    LENGTH X   LENGTH Y   LENGTH Z    AREA XY    AREA YZ    AREA XZ VOLUME XYZ
   1.200E+02  6.000E+01  2.136E+02  7.200E+03  1.282E+04  2.563E+04  1.538E+06

1GENESIS   VERSION 10.2                  DATE 04-03-2009  TIME  9:16  PAGE    7


 LOADCASE 10                                                LOADCASE        10

                           E I G E N V A L U E S

                                                        GENERALIZED   GENERALIZED
   MODE       CYCLES      EIGENVALUE      RADIANS          MASS        STIFFNESS

        1  5.878905E-03 -1.364434E-03  3.693825E-02  1.000000E+00 -1.364434E-03
        2  3.312458E-03 -4.331721E-04  2.081279E-02  1.000000E+00 -4.331721E-04
        3  3.075418E-03 -3.733945E-04  1.932342E-02  1.000000E+00 -3.733945E-04
        4  2.245860E-03 -1.991248E-04  1.411116E-02  1.000000E+00 -1.991248E-04
        5  1.751814E-03 -1.211534E-04  1.100697E-02  1.000000E+00 -1.211534E-04
        6  1.602762E-03 -1.014140E-04  1.007045E-02  1.000000E+00 -1.014140E-04
        7  1.498613E-03 -8.866227E-05  9.416065E-03  1.000000E+00 -8.866227E-05
        8  5.285808E-04  1.103018E-05  3.321171E-03  1.000000E+00  1.103018E-05
        9  1.034052E-03  4.221281E-05  6.497138E-03  1.000000E+00  4.221281E-05
       10  1.911360E-03  1.442264E-04  1.200943E-02  1.000000E+00  1.442264E-04
       11  2.463215E-03  2.395324E-04  1.547684E-02  1.000000E+00  2.395324E-04
       12  2.978914E-03  3.503287E-04  1.871707E-02  1.000000E+00  3.503287E-04
       13  4.522433E-03  8.074282E-04  2.841528E-02  1.000000E+00  8.074282E-04
       14  4.609521E-03  8.388250E-04  2.896248E-02  1.000000E+00  8.388250E-04
```

```
       15  6.304370E-03  1.569073E-03  3.961153E-02  1.000000E+00  1.569073E-03
       16  3.979237E-02  6.251141E-02  2.500228E-01  1.000000E+00  6.251141E-02
       17  1.902518E-01  1.428950E+00  1.195387E+00  1.000000E+00  1.428950E+00
       18  2.896874E-01  3.312982E+00  1.820160E+00  1.000000E+00  3.312982E+00
       19  4.608776E+02  8.385539E+06  2.895779E+03  1.000000E+00  8.385539E+06
       20  4.933177E+02  9.607560E+06  3.099606E+03  1.000000E+00  9.607560E+06
       21  5.033549E+02  1.000249E+07  3.162672E+03  1.000000E+00  1.000249E+07
       22  5.097313E+02  1.025752E+07  3.202736E+03  1.000000E+00  1.025752E+07
       23  5.164023E+02  1.052776E+07  3.244651E+03  1.000000E+00  1.052776E+07
       24  5.206990E+02  1.070368E+07  3.271648E+03  1.000000E+00  1.070368E+07
       25  8.404569E+02  2.788629E+07  5.280747E+03  1.000000E+00  2.788629E+07
       26  8.711762E+02  2.996206E+07  5.473761E+03  1.000000E+00  2.996206E+07
       27  8.824563E+02  3.074300E+07  5.544637E+03  1.000000E+00  3.074300E+07
       28  1.070319E+03  4.522577E+07  6.725011E+03  1.000000E+00  4.522577E+07
       29  1.103356E+03  4.806084E+07  6.932593E+03  1.000000E+00  4.806084E+07
       30  1.126401E+03  5.008941E+07  7.077387E+03  1.000000E+00  5.008941E+07
       31  1.461045E+03  8.427268E+07  9.180015E+03  1.000000E+00  8.427268E+07
       32  1.506711E+03  8.962309E+07  9.466947E+03  1.000000E+00  8.962309E+07
       33  1.514124E+03  9.050704E+07  9.513519E+03  1.000000E+00  9.050704E+07
       34  1.525955E+03  9.192702E+07  9.587858E+03  1.000000E+00  9.192702E+07
       35  1.534064E+03  9.290661E+07  9.638808E+03  1.000000E+00  9.290661E+07
       36  1.593267E+03  1.002159E+08  1.001079E+04  1.000000E+00  1.002159E+08
1GENESIS   VERSION 10.2                DATE 04-03-2009  TIME  9:16  PAGE    8


                 ********************************************
                 *  D E S I G N  C Y C L E      0 (ANALYSIS)*
                 ********************************************
1                                ***** END OF OUTPUT *****
```

2.40 Rigid Body Modes of Double Hat Structure

Example ID:

A040

Analysis Data:

GRID, CQUAD4, CWELD, EIGR

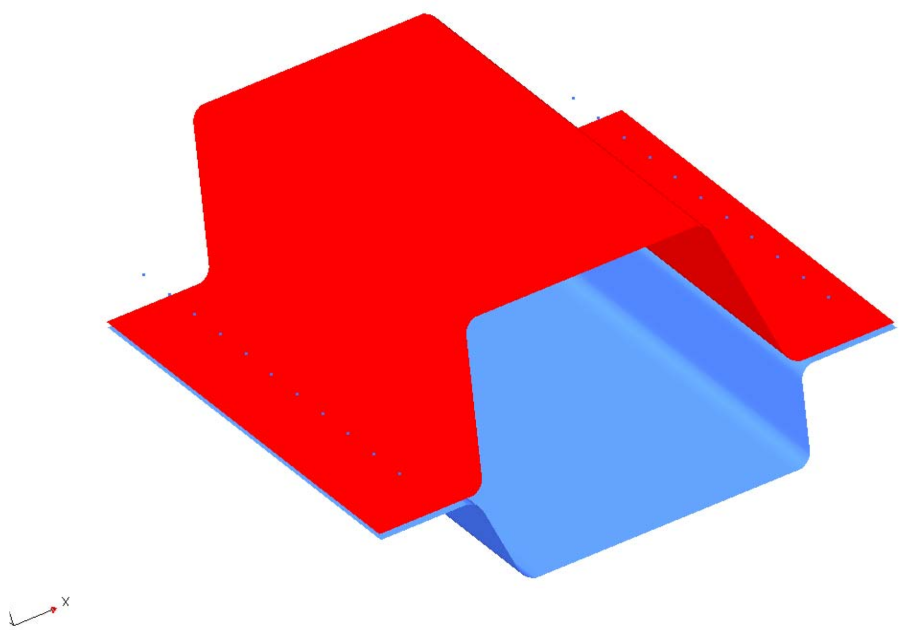
Special Features Used:

CWELD connector elements

Problem Statement:

Verify the six rigid body modes of a double hat structure connected by WELD elements of type PARTPAT.

Structural Analysis Model:



Analysis Model Description:

1. Double hat structure with 25088 quadilateral elements connected by 22 welds.

Special Modeling Techniques:

None.

Reference Solution:

None.

Calculated Solution:

1. Rigid and elastic modes of structure

The above results are printed in the A040.out file.

2.40.1 Input Data

```
$---------------------------------------------------------------------
      --$
$ Data written by Design Studio for Genesis 10.1 (r521)
$ Exported on 2009-03-31 15:02
$---------------------------------------------------------------------
      --$
$
$ Executive Control
$
POST = PUNCH
DIAG = 85
SOL COMPAT1
CEND
$
$ Solution Control
$
LINE = 64,80
ECHO = UNSORT(PARAM,DOPT)
PERTURBATION = POST
SHAPE = POST
$
$ Loadcase definitions
$
SUBCASE 2
   LABEL = Loadcase 2
   METHOD = 1
   MODTRK=NO
   DISP = POST,ALL
   ESE = POST,ALL
BEGIN BULK
$
$ Parameters
$
$
$ Property definitions
$
$HMNAME COMP        1 "Top"
$HMCOLOR COMP        1       1
PSHELL         1       11.000000       1               1
$HMNAME COMP        3 "Bottom"
$HMCOLOR COMP        3       3
PSHELL         3       11.000000       1               1
$HMCOLOR COMP        6       3
PWELD          6       15.000000                               SPOT
SWLDPRM    PRTSW       0  NREDIA       2  GSMOVE       2   GMCHK       1
+          GSTOL     0.0 PROJTOL     0.2  GSPROJ    20.0
$
$ Material definitions
```

```
$
$HMNAME MAT        1 "MAT1 1 (fix me)"
MAT1           1207000.0       .30000007.8000-9
$
$ Load definitions
$
$HMNAME LOADCOL        1 "Method 1"
EIGR           1     SMS       30000.00              12
$
$ Boundary Condition definitions
$
$
$ Grid points
$
GRID           1       23.00000     0.0     0.0
GRID           2            0.0     0.0     0.0
GRID           3       26.00000     0.03.000000
GRID           4       33.00000     0.039.00000
GRID           5       36.00000     0.042.00000
GRID           6       63.00000     0.042.00000
GRID          16            0.05.000000     0.0
GRID          17       23.000005.000000     0.0
GRID          18       26.000005.0000003.000000
GRID          19       33.000005.00000039.00000
GRID          20       36.000005.00000042.00000
GRID          21       63.000005.00000042.00000
GRID          22            0.03.750000     0.0
GRID          23            0.02.500000     0.0
GRID          24            0.01.250000     0.0
GRID          25       1.9166675.000000     0.0
GRID          26       1.9166673.750000     0.0
GRID          27       1.9166672.500000     0.0
GRID          28       1.9166671.250000     0.0
GRID          29       1.916667     0.0     0.0
GRID          30       3.8333335.000000     0.0
GRID          31       3.8333333.750000     0.0
GRID          32       3.8333332.500000     0.0
GRID          33       3.8333331.250000     0.0
GRID          34       3.833333     0.0     0.0
GRID          35       5.7500005.000000     0.0
.
.
.
GRID       29600       65.52564156.2500-25.5000
GRID       29601       68.05128156.2500-25.5000
GRID       29602       70.57692156.2500-25.5000
GRID       29605       63.00000155.0000-25.5000
GRID       29607       68.05128155.0000-25.5000
GRID       29608       115.00005.00000010.00000
GRID       29609       115.000020.0000010.00000
GRID       29610       115.000035.0000010.00000
```

```
GRID       29611      115.000050.0000010.00000
GRID       29612      115.000065.0000010.00000
GRID       29613      115.000080.0000010.00000
GRID       29614      115.000095.0000010.00000
GRID       29615      115.0000110.000010.00000
GRID       29616      115.0000125.000010.00000
GRID       29617      115.0000140.000010.00000
GRID       29618      115.0000155.000010.00000
GRID       29619      10.0000020.0000010.00000
GRID       29620      10.0000035.0000010.00000
GRID       29621      10.0000050.0000010.00000
GRID       29622      10.0000065.0000010.00000
GRID       29623      10.0000080.0000010.00000
GRID       29624      10.0000095.0000010.00000
GRID       29625      10.00000110.000010.00000
GRID       29626      10.00000125.000010.00000
GRID       29627      10.00000140.000010.00000
GRID       29628      10.00000155.000010.00000
GRID       29631      10.000005.00000010.00000
$
$ Element definitions
$
CQUAD4         1       1      16      22      26      25     0.0
CQUAD4         2       1      22      23      27      26     0.0
CQUAD4         3       1      23      24      28      27     0.0
CQUAD4         4       1      24       2      29      28     0.0
CQUAD4         5       1      25      26      31      30     0.0
CQUAD4         6       1      26      27      32      31     0.0
CQUAD4         7       1      27      28      33      32     0.0
CQUAD4         8       1      28      29      34      33     0.0
CQUAD4         9       1      30      31      36      35     0.0
CQUAD4        10       1      31      32      37      36     0.0
.
.
.
CQUAD4     25190       3   29339   29591   29597   29351     0.0
CQUAD4     25191       3   29591   29592   29598   29597     0.0
CQUAD4     25192       3   29592   29593   29599   29598     0.0
CQUAD4     25193       3   29593   29594   29600   29599     0.0
CQUAD4     25194       3   29594   29595   29601   29600     0.0
CQUAD4     25195       3   29595   29529   29602   29601     0.0
CQUAD4     25196       3   29351   29597   29114   28850     0.0
CQUAD4     25197       3   29597   29598   29115   29114     0.0
CQUAD4     25198       3   29598   29599   29605   29115     0.0
CQUAD4     25199       3   29599   29600   29117   29605     0.0
CQUAD4     25200       3   29600   29601   29607   29117     0.0
CQUAD4     25201       3   29601   29602   29088   29607     0.0
CWELD      30001       6   29608PARTPAT
+              1       3
CWELD      30002       6   29609PARTPAT
+              1       3
```

```
CWELD      30003      6   29610PARTPAT
+              1      3
CWELD      30004      6   29611PARTPAT
+              1      3
CWELD      30005      6   29612PARTPAT
+              1      3
CWELD      30006      6   29613PARTPAT
+              1      3
CWELD      30007      6   29614PARTPAT
+              1      3
CWELD      30008      6   29615PARTPAT
+              1      3
CWELD      30009      6   29616PARTPAT
+              1      3
CWELD      30010      6   29617PARTPAT
+              1      3
CWELD      30011      6   29618PARTPAT
+              1      3
CWELD      30012      6   29619PARTPAT
+              1      3
CWELD      30013      6   29620PARTPAT
+              1      3
CWELD      30014      6   29621PARTPAT
+              1      3
CWELD      30015      6   29622PARTPAT
+              1      3
CWELD      30016      6   29623PARTPAT
+              1      3
CWELD      30017      6   29624PARTPAT
+              1      3
CWELD      30018      6   29625PARTPAT
+              1      3
CWELD      30019      6   29626PARTPAT
+              1      3
CWELD      30020      6   29627PARTPAT
+              1      3
CWELD      30021      6   29628PARTPAT
+              1      3
CWELD      30022      6   29631PARTPAT
+              1      3
ENDDATA
```

2.40.2 Output Data

```
1

              GGGG    EEEEE   N   N   EEEEE    SSSSS   IIIII    SSSSS
             G        E       NN  N   E       S          I     S
             G   GG   EEEE    N N N   EEEE     SSSS      I      SSSS
             G    G   E       N  NN   E            S     I          S
              GGGG    EEEEE   N   N   EEEEE   SSSSS    IIIII   SSSSS


                  STRUCTURAL ANALYSIS AND OPTIMIZATION SOFTWARE


                               COPYRIGHT, 1991-2008

                     VANDERPLAATS RESEARCH & DEVELOPMENT, INC.

                          ALL RIGHTS RESERVED, WORLDWIDE

                                  VERSION 10.2

                             BUILD CODE 200904030915 BETA



     PROJECT NAME: DH2
     RUN STARTED:  Apr  3, 2009 09:17
     SYSTEM TYPE:  Linux 2.6.25.5-1.1-default x86_64 4-CPU (LP64)
     LENVEC:             250000000
     IOBUFF:               256,64K
     THREADS:                    1

     FOR DEVELOPMENT TESTING ONLY
     *** NOT FOR DISTRIBUTION ***


1GENESIS   VERSION 10.2                  DATE 04-03-2009  TIME  9:17
      PAGE    1
```

```
                    ***   I N P U T   D A T A   E C H O   ***

                  ---  EXECUTIVE & SOLUTION CONTROL SECTION  ---


 $--------------------------------------------------------------------
      ---$
 $ Data written by Design Studio for Genesis 10.1 (r521)
 $ Exported on 2009-03-31 15:02
 $--------------------------------------------------------------------
      ---$
 $
 $ Executive Control
 $
 POST = PUNCH
 DIAG = 85
 SOL COMPAT1
 CEND
 $
 $ Solution Control
 $
 LINE = 64,80
 ECHO = UNSORT(PARAM,DOPT)
 PERTURBATION = POST
 SHAPE = POST
 $
 $ Loadcase definitions
 $
 SUBCASE 2
    LABEL = Loadcase 2
    METHOD = 1
    MODTRK=NO
    DISP = POST,ALL
    ESE = POST,ALL
1GENESIS   VERSION 10.2                  DATE 04-03-2009  TIME  9:17
      PAGE    2



                             ---  BULKDATA SECTION  ---


 BEGIN BULK
 ENDDATA

1GENESIS   VERSION 10.2                  DATE 04-03-2009  TIME  9:17
      PAGE    3
```

```
                    ANALYSIS PROBLEM SUMMARY

          NUMBER OF GRID POINTS:                    26010
          NUMBER OF CQUAD4->PSHELL ELEMENTS:        25088
          NUMBER OF CWELD ELEMENTS:                    22
          TOTAL NUMBER OF NON RIGID ELEMENTS:       25110
          NUMBER OF ELEMENT PROPERTIES:                 3
          NUMBER OF MATERIALS:                          1
          NUMBER OF DEGREES OF FREEDOM:            155928


                      LOAD CASES SUMMARY

         NUMBER OF USER FREQUENCY LOAD CASES:           1
         TOTAL NUMBER OF LOAD CASES:                    1

1GENESIS   VERSION 10.2                  DATE 04-03-2009  TIME  9:17
      PAGE    4



        ****************************************************
        *  D E S I G N  C Y C L E      0 (ANALYSIS SUMMARY)*
        ****************************************************
1GENESIS   VERSION 10.2                  DATE 04-03-2009  TIME  9:17
      PAGE    5



                M A S S / V O L U M E   S U M M A R Y

              SYSTEM MASS              4.447218E-04
              SYSTEM VOLUME            5.701561E+04
              SYSTEM MASS/VOLUME       7.800000E-09
1GENESIS   VERSION 10.2                  DATE 04-03-2009  TIME  9:17
      PAGE    6



              E N C L O S I N G   B O X   S U M M A R Y

   LENGTH X   LENGTH Y   LENGTH Z   AREA XY    AREA YZ    AREA XZ VOLUME XYZ
   1.262E+02  1.600E+02  6.750E+01  2.019E+04  1.080E+04  8.516E+03
      1.363E+06

1GENESIS   VERSION 10.2                  DATE 04-03-2009  TIME  9:17
      PAGE    7
```

```
 LOADCASE 2                                                    LOADCASE        2

                               E I G E N V A L U E S

                                                        GENERALIZED   GENERALIZED
   MODE      CYCLES      EIGENVALUE     RADIANS           MASS         STIFFNESS

       1  4.556492E-02 -8.196358E-02  2.862928E-01  1.000000E+00 -
     8.196358E-02
       2  3.236136E-02 -4.134408E-02  2.033324E-01  1.000000E+00 -
     4.134408E-02
       3  2.095993E-02 -1.734361E-02  1.316951E-01  1.000000E+00 -
     1.734361E-02
       4  9.380188E-03 -3.473624E-03  5.893746E-02  1.000000E+00 -
     3.473624E-03
       5  2.443385E-02  2.356914E-02  1.535224E-01  1.000000E+00
     2.356914E-02
       6  8.059826E-02  2.564549E-01  5.064138E-01  1.000000E+00
     2.564549E-01
       7  2.840831E+02  3.186035E+06  1.784947E+03  1.000000E+00
     3.186035E+06
       8  3.260877E+02  4.197866E+06  2.048869E+03  1.000000E+00
     4.197866E+06
       9  3.350886E+02  4.432808E+06  2.105424E+03  1.000000E+00
     4.432808E+06
      10  3.725899E+02  5.480522E+06  2.341052E+03  1.000000E+00
     5.480522E+06
      11  6.589418E+02  1.714170E+07  4.140254E+03  1.000000E+00
     1.714170E+07
      12  7.062279E+02  1.969017E+07  4.437361E+03  1.000000E+00
     1.969017E+07
1GENESIS   VERSION 10.2                  DATE 04-03-2009  TIME  9:17
     PAGE    8


               ********************************************
               *  D E S I G N  C Y C L E     0 (ANALYSIS)*
               ********************************************
1                             ***** END OF OUTPUT *****
```

A

- Analysis Examples
. . . . Anisotropic Plate with Thermal Load - A 148
. . . . Anisotropic Plate with Thermal Load - B 158
. . . . Beam Supported by Springs 112
. . . . Beam with Temperature Load 95
. . . . Buckling Analysis of a Tripod 338
. . . . Circular Ring 38
. . . . Classical Three Rod Truss 11
. . . . Conduction on an Elliptical Bar Heated by a Distant Source 180
. . . . Convection-Conduction Heat Transfer in the Straight Cantilever Problem 200
. . . . Deformed Beam 55
. . . . Dynamic Response of a CELAS1/CDAMP1/CMASS1 Structure 242
. . . . Dynamic Response of the Cantilevered Beam 208
. . . . Dynamic Response of the Cantilevered Beam With and Without Modal Damping 231
. . . . Dynamic Response of the Cantilevered Beam With Element Structural Damping 220
. . . . Enforced Dynamic Displacement with the Lagrange Multiplier Method 376
. . . . Enforced Dynamic Displacement with the Large Mass Method 352
. . . . Heat Conduction In An Anisotropic Plate 185
. . . . Heat Conduction in an Anisotropic Solid 192
. . . . Planar Grillage with Internal Pin 119
. . . . Portal Frame 28
. . . . Portal Frame with Flexible Nodes 102
. . . . Rod Modeled with Penta Elements 139
. . . . Rod Modeled with Tetra Elements 127
. . . . Square Plate With Volume Heat Generation and Enforced Temperature 173
. . . . Straight Uniform Fin Analysis 167
. . . . Ten Rod Truss 20
. . . . Thin Axisymmetric Annulus 259
. . . . Three Independant beams 308
. . . . Three Rod Truss - Analysis Using Multidisciplinary Load Cases 248
. . . . Three Story Facade with a Panel - A 68
. . . . Three Story Facade with a Panel - B 77
. . . . Two Bar Symmetric Frame 61
. . . . Two Independant Beams, with and without Offset 326
. . . . Two pairs of Beams with and without Warping Coefficients 318
. . . . Vibration of a Skewed Beam 86
. . . . Wide Column/Wide Beam Frame 47
- Axisymmetric elements 259

B

- Bar library cross sections 338, 352, 376

C

- CBAR 28, 38
- CBAR element
. . . . Offset 47
. . . . Pin flags 119
. . . . Pressure loading 102
- CBEAM 308, 318
- CBEAM element
. . . . Offset 326
. . . . Shear center axis offset from neutral axis 326
- CDAMP1 242
- CELAS1 102, 112
- Centrifugal loading 259
- CHBDY 167, 180, 200
- CMASS1 242
- Concentrated mass 11
- CONM2 11
- Convection 167
- Coordinate systems
. . . . Cylindrical 38
. . . . Multiple 86
- CPENTA 139
- CTETRA 127
- CTRIAX6 259

D

- Damping
. . . . Modal 231
. . . . Scalar damping element 242
. . . . Structural 220
- DAREA 208
- DELAY 208
- Direct dynamic analysis 208, 248
- DLOAD 208

E

- Eigenvalue analysis 11, 86, 248
- Enforced displacements 55
- Enforced temperature 173

F

- FREQ 208

- Frequency response analysis 208, 220, 231, 242, 248

G

- Gravity loading 338

H

- Heat transfer analysis 167, 173, 180, 185, 192, 200, 248

M

- Mass element

. . . . CMASS1 242

. . . . CONM2 11

- MAT2 158
- MAT5 185, 192
- MAT8 148
- Modal damping 231
- Modal dynamic analysis 208, 248
- MPC 61
- Multiple load case types 248
- Multipoint constraint 61, 102

N

- Non-symmetric beam 308

P

- PBARL 338, 352, 376
- PBEAM 308

. . . . Warping coefficients 318

- PLOADA 102
- Portal frame 28

Q

- QHBDY 185, 192
- QVOL 173

R

- RBE2 68
- RFORCE 259
- Rigid body element 68

- RLOAD1 208

S

- Scalar point 242
- SDAMPING 231
- Single point constraint 95
- Solid elements

. . . . CPENTA 139

. . . . CTETRA 127
- SPC 95
- SPCD 55
- SPOINT 242
- Static analysis 11, 20, 28, 38, 47, 55, 61, 68, 77, 95, 102, 112, 119, 127, 139, 148, 158, 248, 259, 308, 318, 326
- STATSUB 338, 352, 376, 400, 431, 440, 449
- Structural damping 220
- Symmetry 62

T

- TABDMP1 231
- TABLED1 208
- Tapered beam 308
- TEMP 95
- Ten rod truss 20
- Thermal loading 95
- Three rod truss 11, 248