

Robustness Analysis with LS-OPT[®]







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Outline

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 - Direct and metamodel-based Monte Carlo Analysis
- Example Robustness Analysis
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About LS-OPT

- LS-OPT is a standalone optimization software
 - \rightarrow can be linked to any simulation code
 - Interface to LS-DYNA, MSC-Nastran, Excel, Matlab
 - User-defined interface
 - Interfaces to preprocessors, e.g. for shape optimization
 - Interface to LS-PrePost, ANSA, Hypermorph, ...
 - User-defined interface to any preprocessor
 - Result extraction
 - Interface to META Post
 - User-defined interface





About LS-OPT

- LS-DYNA Integration
 - Checking of LS-DYNA keyword files (*DATABASE_)
 - Importation of design parameters from LS-DYNA keyword files (*PARAMETER)
 - Support of include files (*INCLUDE)
 - Monitoring of LS-DYNA progress
 - Result extraction of most LS-DYNA response types
 - D3plot compression (node and part selection)

		Stage Case1						
	Setup Parameters Histories	Responses File Operations						
	Response definitions		Add new					
	New response							
Name	Subcase	Multipiler Offset	DBBEMAC					
Displ			DBFSI					
		Not metamodel-linked	DEFORC					
			ELOUT					
Component	Direction		<u>FLD</u>					
 Coordinate 	X Component		FREQUENCY					
 Displacement 	 Y Component 		GLETAT					
 Velocity 	 Z Component 		INTEORC					
 Acceleration 	O Acceleration O Resultant							
 Rotational Displacemer 		MATSLIM						
O Rotational Velocity								
 Rotational Acceleration 		NODOLIT						
 Deformation 			NODEOR					
 Distance 		PETPESS						
IdentifierType ID			REDOUT					
ID \$ 42000128		BCEOBC						
			RWFORC					
Select		SBTOUT						
Maximum Value	SECFORC							
Filtering		SPCFORC						
SAE Filter	SPHOUT							
	SWFORC							
Frequency Time u	init		THICK					
60 Seco	nds 🗘							
		<u>C</u> ancel <u>O</u> K	<u><u></u>K</u>					



About LS-OPT

- Current production version is LS-OPT 5.2
- LS-OPT Support web page
 - → <u>www.lsoptsupport.com</u>
 - Download of Executables
 - Tutorials

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- HowTos / FAQs
- Documents

Welcome to LS-OPT S	LS-OPT Suppo	Search Site	
		HOME EXAMPLES DOWINLOADS DOCUMENTS HOWTOS	
	Navigation	Welcome to LS-OPT Support Site	
	Getting Started Documents	LS-OPT, the graphical optimization tool that interfaces perfectly with LS-DYNA,	
	Examples HowTos Glossary Downloads	allows the user to structure the design process, explore the <u>design space</u> and compute optimal designs according to specified constraints and objectives. The program is also highly suited to the solution of <u>system identification</u> problems and <u>stochastic</u> analysis.	
	FAQs News About us	The graphical tool LS-OPTui interfaces with LS-DYNA and provides an environment to specify optimization input, monitor and control parallel simulations and post-process optimization data, as well as viewing multiple designs using LS-PREPOST.	
	News New Curve Matching Metric	Applications: Design Optimization, Design of Experiments (Sensitivity Analysis), System Identification, Reliability Studies	
	in LS-OPT 4.2 Aug 18, 2011 Full Vehicle MDO -	Optimization	
	Example Jun 03, 2011	Size-/Shape optimization Constraints, mixed continuous/discrete variables, multiple load cases, etc.	
	Release of LS-OPT®	Multi-Objective optimization (Pareto Frontier)	
	Version 4.2 May 13, 2011	remaining based design optimization more	
	LS-TaSC (Topology and Shape Computation)	System-/Parameter Identification	
	available Apr 19, 2011	Material parameter evaluation	
	Beta Release of LS-TaSC (Topology and Shape	Calibration of test results more	
	Computation) available Feb 02, 2011	Design Exploration	
	more	Meta Models: Interrelation design variables vs. system responses Study of design changes more	



Robustness Analysis with LS-OPT



Motivation

- Simulation
 - Design parameters (sheet thicknesses, material properties, ...) fully controllable
- Reality
 - Design parameters are associated with uncertainties
- Sources of uncertainties
 - Manufacturing imperfections
 - Load variations
 - Environment variations

..



Variation of design parameters (uncertainties) should be considered in design process simulation



Estimation of probability quantities of variables and responses

t1

t2 t3 t4 t5

t6 t10 t64

t73

-1

-0.75

-0.5

-0.25

Coefficient of Correlation

- mean
- standard deviation
- distribution function
- Analysis of relationship (sensitivities)
 variables ← → responses
 - correlation analysis
 - stochastic contributions
- Reliability of a system
 - evaluation of probability of failure







0.75

0.5

0.25

- Uncertainties of variables (sheet thicknesses, material properties, ...)
 - Probability density function
 - Uniform distribution
 - Normal distribution
 - ...
 - *PERTURBATION (LS-DYNA keyword)
 - Geometric imperfections
 - Material imperfections
 - → Buckling analysis





sheet thickness variation by a harmonic random field, amplitude: m=0,s=0.005mm in both directions



LS-DYNA Keyword *PERTURBATION

- Scatter of parameters constituted by means of probability distributions
- Approximation of probability distributions using appropriate samples = experiments
- Investigation of the FEA-model = system using experiments
- Distribution of the system responses
 → Approximation to exact distribution
- Permitted area





- Monte Carlo Analysis using direct simulations
 - Random process
 - Large number of simulation runs (100+)
- Monte Carlo Analysis using metamodels
 - Construction of a metamodel (Polynomials, Radial Basis Functions, Feedforward Neural Networks, ...)
 - Number of simulations depends on number of variables
 - Reliability, Robustness Analysis through functional evaluation of sampling points (10⁶) on the metamodel







Example

- Tube impact
- Variables (Noise variables)
 - Thickness
 - Scale factor of stress-strain curve
- Response
 - Intrusion

	Distribution Name t		
Problem global setup			
	Type Normal 🗘		
Parameter Setup Stage Matrix Sampling Matrix Resources Features			
	Mean 1		
Show advanced options	Standard Day		
Noise Variable Subregion Size (in Standard Deviations) 2.0 (default)	Standard Dev 0.05		
Enforce Variable Bounds	Preview Mean = 1; Std Dev = 0.05		
Type Name Starting Minimum Maximum Distribution	8		
	0		
Noise V SIGY SV V f	4		
	2		
Add			
	1		
	<u>Cancel</u> <u>O</u> K		



Live demonstration



Optimization considering uncertainties



Optimization

- Deterministic optimization
 - Minimize Objective Function subject to Constraints
 - Optimum very often lies on the constraint boundary



RBDO/Robust Parameter Design

- Includes uncertainty of variables and responses into optimization
- Requires statistical distribution of variables
- Control Variables (Design Parameters)
 - Nominal value controlled by designer
 - Gauge
 - Shape

Noise Variables (Environment)

- Values not controlled by designer but can vary
 - Load
 - Yield stress
 - Friction

ii		Problem global setup							
Parameter Setup	Sta	age Matrix	Sampling Matrix	Resources	Feature	s			
Show advanc	ed op	tions							
🗆 Enforce Varial	ole Bo	ounds							
Туре		Name		Starting	Mir	iimum	Maximum	Distributior	n Delete
Noise	~	Area						area	✓ ▲ ×
Continuous	~	Base			0.8	0.1	1.6	(none)	✓ ▲ ×
Add									
Auu									



16

RBDO/Robust Parameter Design

- Robust Parameter Design (RDO)
 - Improve/Maximize the robustness of the optimum
- Reliability Based Design Optimization (RBDO)
 - Improve failure probability of optimum









Tolerance Optimization

- RBDO/RDO
 - Variables associated with distribution
 - Mean variable values (distribution means) are optimized
- Tolerance Optimization
 - Variables associated with tolerance values
 - → Optimize nominal design variables and tolerances
 - Maximize tolerance
 - No failure within tolerance
 - → incorporate uncertainties into optimization if variable distributions are not available





Summary

- Monte Carlo Analysis (Robustness Analysis)
 - Direct or metamodel based
 - Estimation of PDF, mean, standard deviation, ... of responses
 - Significance of parameters
 - Correlation coefficients
 - Stochastic contribution (only metamodel based MC Analysis)
 - Reliability of system
 - Confidence intervals
 - Buckling Analysis
 - DYNAStats: fringe of statistics on the FE model



Summary

- Reliability Based Design Optimization (RBDO)
 - Probabilistic bounds on constraints
- Robust Parameter Design
 - Minimize Standard Deviation of response
- Tolerance Optimization
 - Incorporate uncertainties into optimization if no distribution information of the variables is available
 - Maximize tolerance
 - no failure within tolerance



Thank you!

