Multi-Scale Modeling of Crash and Failure of Reinforced Plastics Parts with DIGIMAT to LS-DYNA Interface

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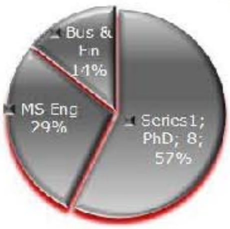
Agenda

- e-Xstream engineering
  - ✓ The company
  - ✓ DIGIMAT technology
    - The Nonlinear Multiscale Modeling Platform
  - ✓ DIGIMAT applications
- Integration of injection molding simulation in LS-DYNA calculations
  - ✓ Material models
    - Available Models
    - Reverse Engineering
  - ✓ Failure indicators
  - ✓ Computational time
- Summary

e-Xstream engineering

- The company
  - ✓ Founded in 2003
- The Business:
  - ✓ Simulation Software & Services
  - ✓ 100% focused on material modeling
- The team
  - ✓ Strong & highly motivated
  - ✓ High level of education
- The product

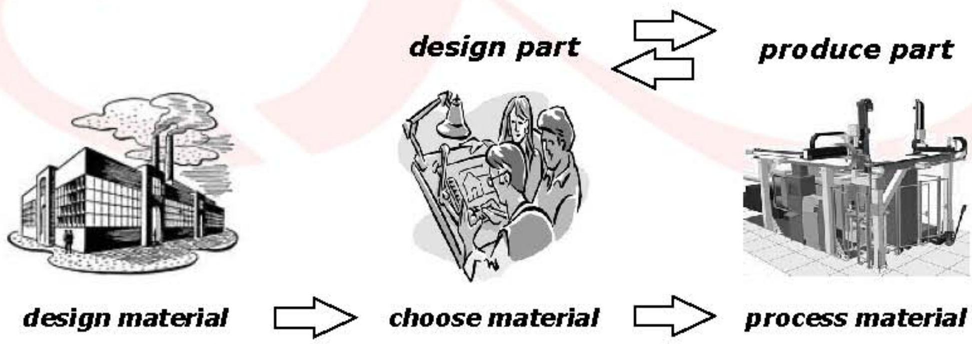
digimat



Belgium
Luxembourg
Germany

The Idea

- How can we design the optimal material ?
  - ✓ Relation between the material microstructure (e.g. Fiber content, length, orientation) and properties (e.g. Mechanical, Thermal,…)
- How can we select the optimal material?
  - ✓ Link between material and structure performance
- How can we optimally process the material?
  - ✓ Relation between the process and product performance



The Customers

- Material suppliers
  - ✓ Plastics
  - ✓ Rubber
  - ✓ Ceramics, hard metals
  - ✓ Other: nano…
- Objectives
  - ✓ To reduce material testing (time & cost)
  - ✓ To improve material understanding
  - ✓ To promote material usage

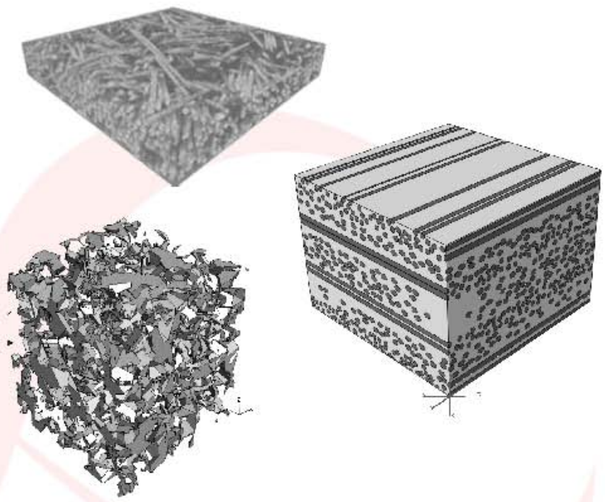
The Customers

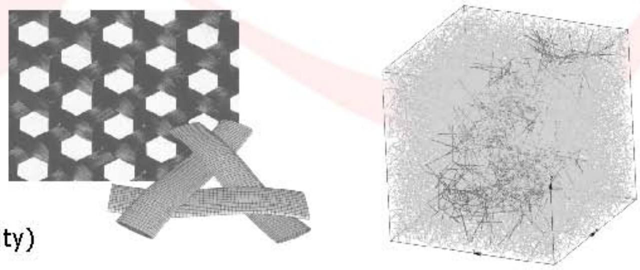
- Material users
  - ✓ Automotive
  - ✓ Airospace
  - ✓ Consumer / industrial products
  - ✓ Electronics
- Objectives
  - ✓ To improve FEA accuracy & prediction
  - ✓ To bridge the gap between processing & part design
  - ✓ To reduce prototyping & testing (time & cost)

The Material

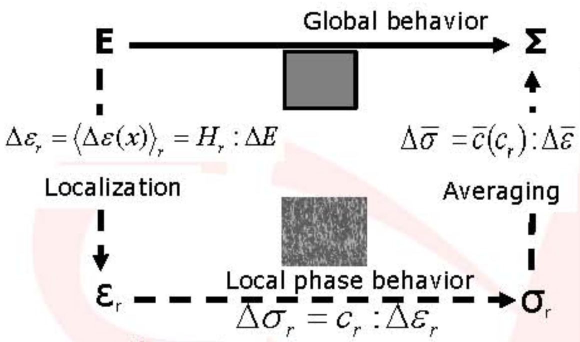
Composites

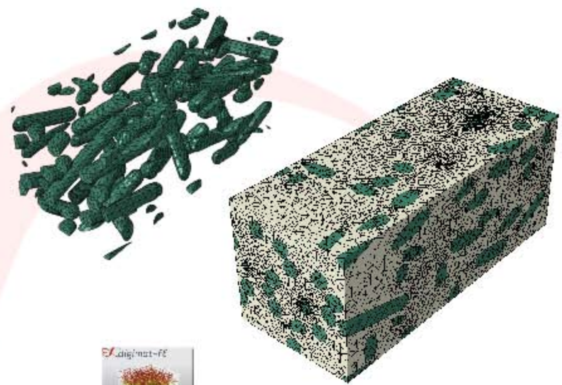
- ✓ Fiber reinforced polymers
  - Short fiber
  - Long fiber
  - Endless fiber
- ✓ Rubber
  - Particle reinforced
- ✓ Hard metals
  - Crystallites
- ✓ Woven composites
  - Endless fiber
- ✓ Nano
  - CNT (electrical conductivity)

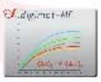




The Technology





Method 

Define separate phases (material law)
Define microstructure (ellipsoids)
Calculate average (macro/micro) results

Pros

Fast model preparation/solution
Nonlinear material properties
Fully coupled multi-scale analyses

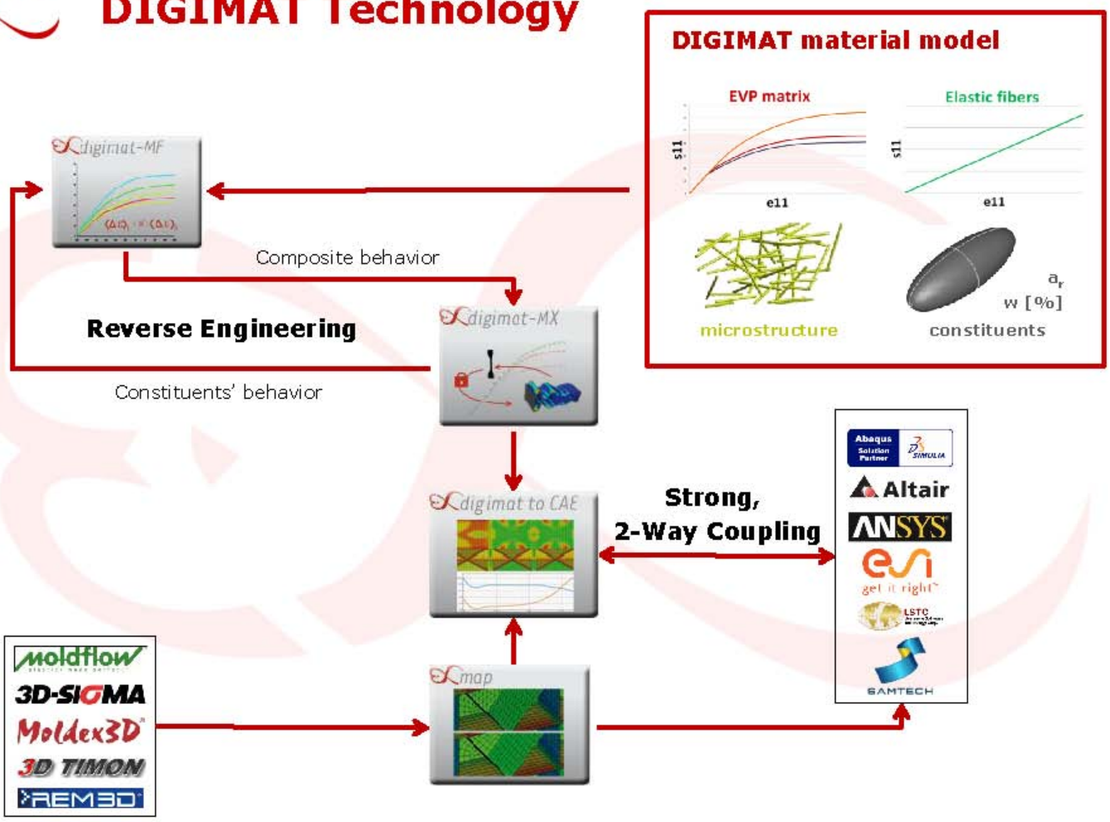
Method

Generate the microstructure itself
Build FE model (mesh optimization, CPU…)
Perform uncoupled multi-scale analyses

Pros

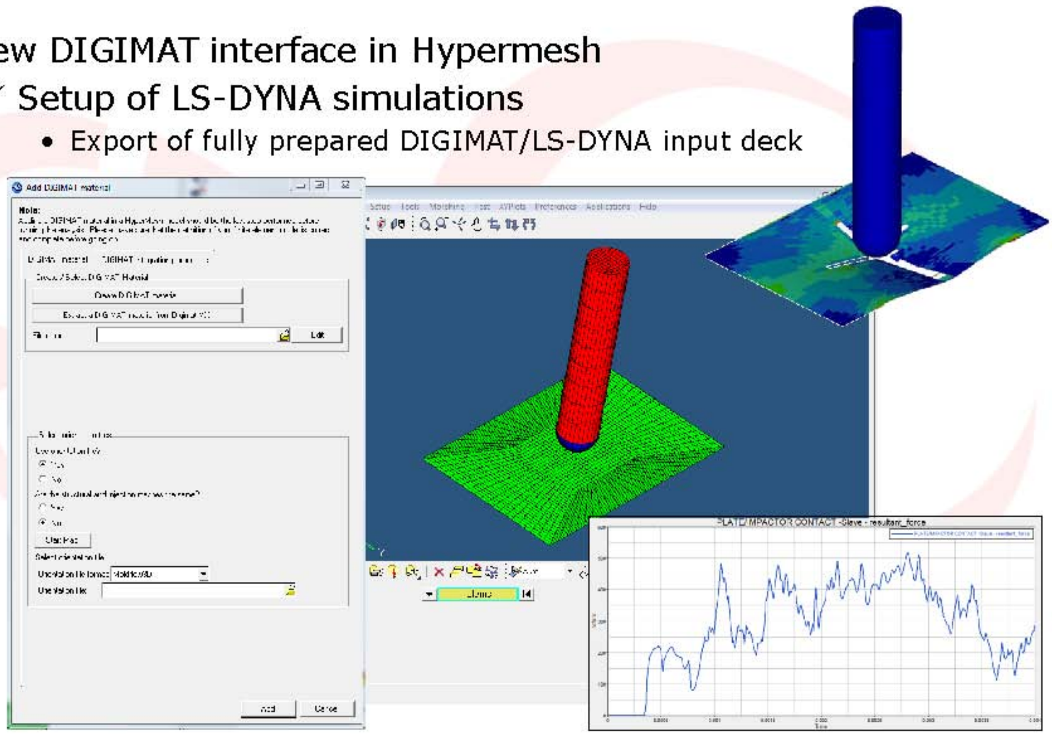
Accurate predictions at the micro scale
Complex inclusion shapes (non ellipsoidal)
Explicit modelling of clustering & percolation

DIGIMAT Technology



DIGIMAT Technology

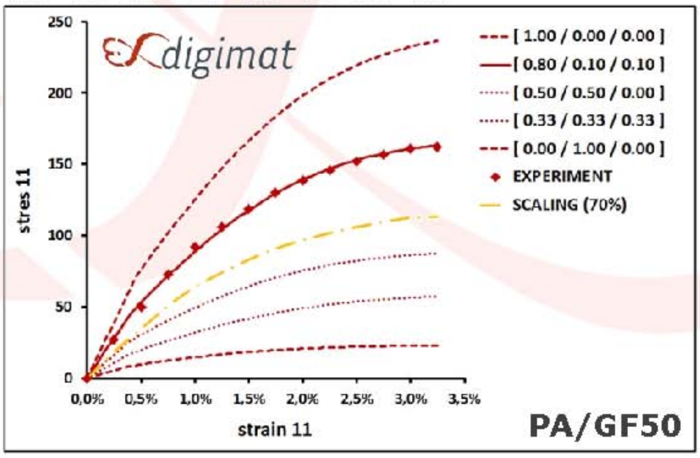
- New DIGIMAT interface in Hypermesh
  - ✓ Setup of LS-DYNA simulations
    - Export of fully prepared DIGIMAT/LS-DYNA input deck



DIGIMAT Material Models

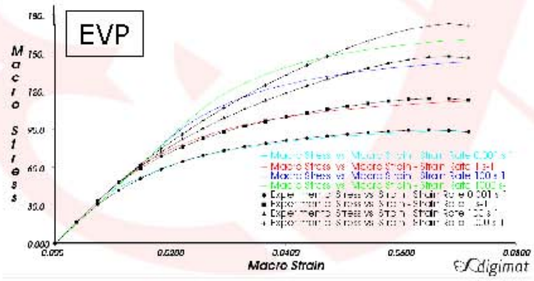
- The material behavior depends on the fiber orientation
  - ✓ What is the effect if we apply such a behavior to our simulations?

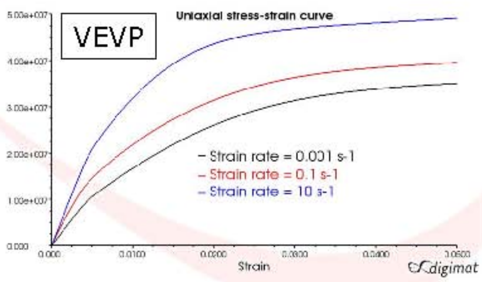
along		tensile bar		2D		3D		perpendicular	
ε11	σ11	ε11	σ11	ε11	σ11	ε11	σ11	ε11	σ11
0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
0,0002	2,5678	0,0002	1,8409	0,0002	1,0853	0,0002	0,7166	0,0002	0,3527
0,0003	5,1356								
0,0005	7,7034								
0,0007	10,2710								
0,0008	12,8390								
0,0010	15,4070								
0,0011	17,9750								
0,0013	20,5420								
0,0015	23,1100								
0,0016	25,6780								
0,0018	28,2460								
0,0020	30,8130								
0,0021	33,3810								
0,0023	35,9490								
0,0024	38,5170								
0,0026	41,0850								
0,0028	43,6520								
0,0029	46,2200								
0,0031	48,7880								
0,0033	51,3560								
0,0034	53,9240								
0,0036	56,4910								
0,0037	59,0590								
0,0039	61,6270								
0,0041	64,1950								



DIGIMAT Material Models

- Overview
  - ✓ Elastoplastic (EP)
  - ✓ Elasto-visco-plastic (EVP)
  - ✓ Visco-elastic (VE)
  - ✓ Visco-elastic-visco-plastic (VEVP)





- New models (soon) available
  - ✓ Thermo-elasto-plastic (TEP)
  - ✓ Thermo-elasto-visco-plastic (TEVP)

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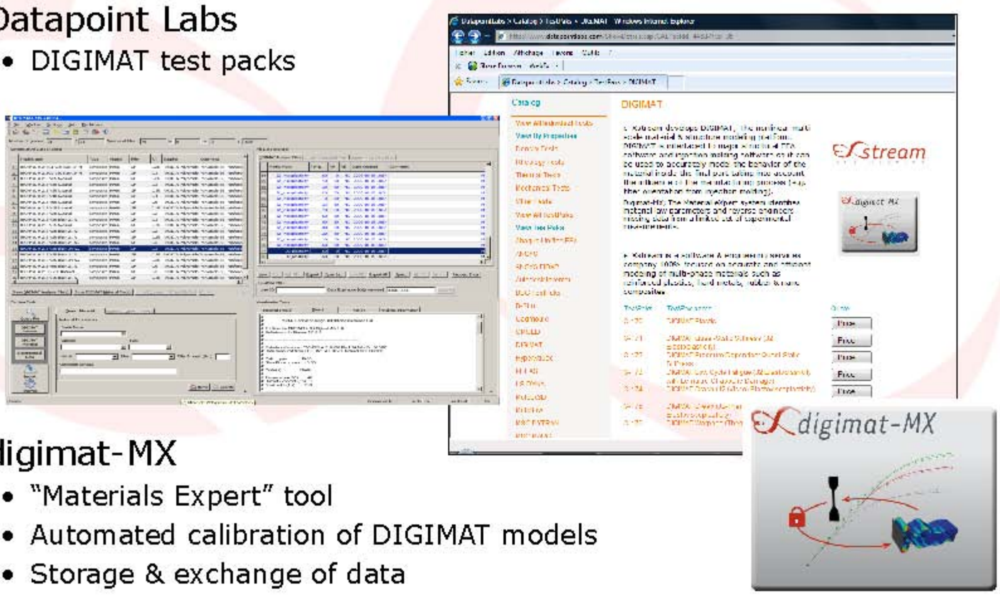
DIGIMAT Material Models

- Measurement & Reverse Engineering
  - ✓ Datapoint Labs
    - DIGIMAT test packs
  - ✓ digimat-MX
    - "Materials Expert" tool
    - Automated calibration of DIGIMAT models
    - Storage & exchange of data

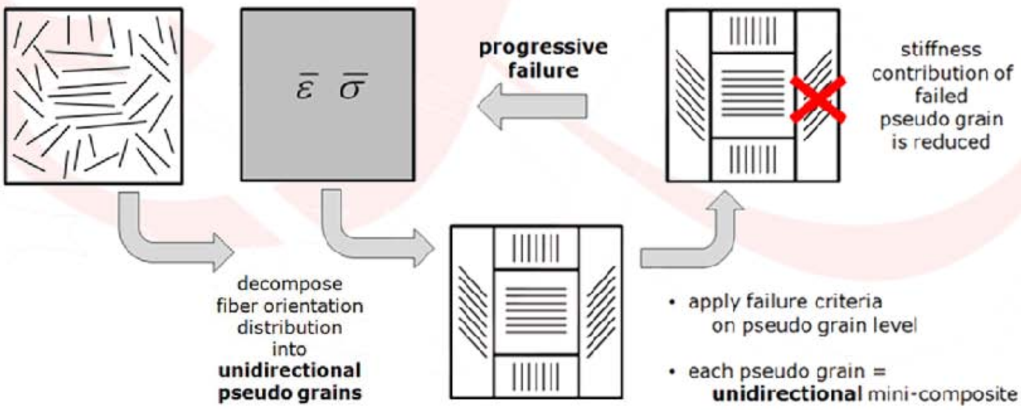
DatapointLabs expert material testing



DIGIMAT Material Models

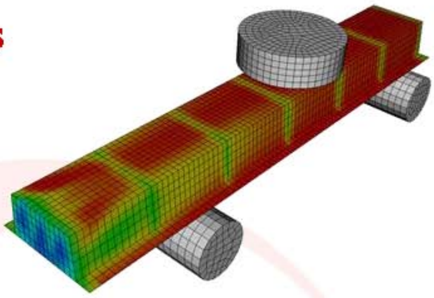
- Failure indicators
  - ✓ Available
    - Maximum strain/stress, Tsai-Wu, Tsai Hill…
  - ✓ FPGF model
    - "First-Pseudo-Grain-Failure"

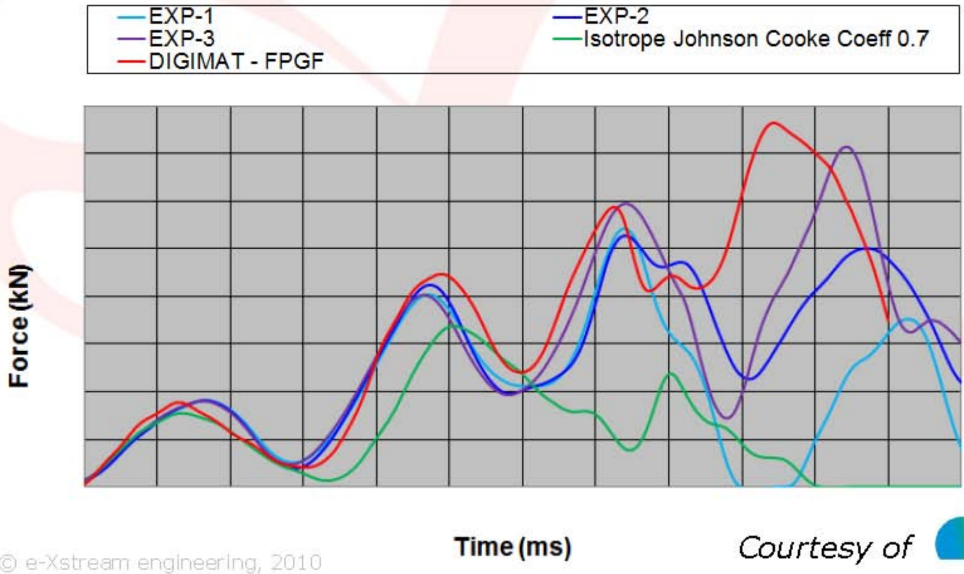
→ direct use of experimental data from ± unidirectional dumbbells



DIGIMAT Material Models

- Failure indicators
  - ✓ FPGF model
    - Test vs. experiment





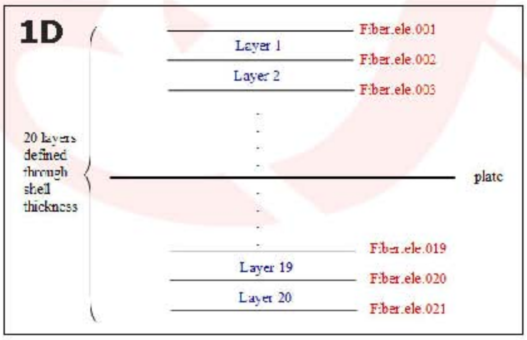
Courtesy of Rhodia

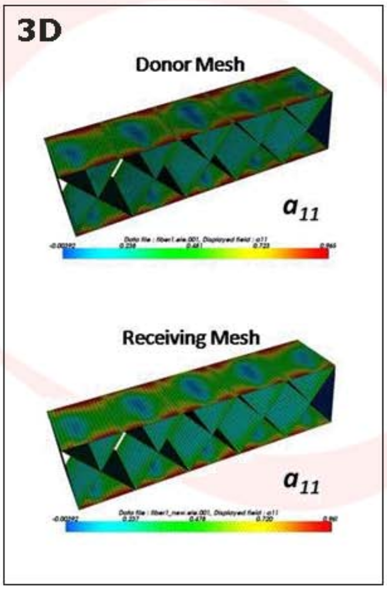
DIGIMAT Computational Time

- DIGIMAT can become costly in explicit simulations
  - ✓ Factor of 10 – 100 can occur
    - Why is that…?
  - ✓ The stability of explicit integration schemes requires small time steps, Δt is estimated based on
    - Element size
    - (Local) stiffness
  - ✓ Measures to reduce computational time
    - Changes in the model
    - Changes in the material
    - Changes in the method
    - Changes in the software

DIGIMAT Computational Time

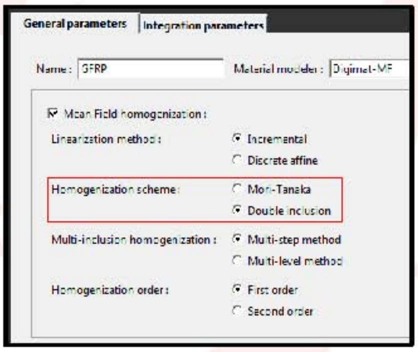
- Changes in the model
  - ✓ 1D Mapping
    - Reduce number of layers (from 20 to 8 - 10)
  - ✓ 3D Mapping
    - Reduce number of elements

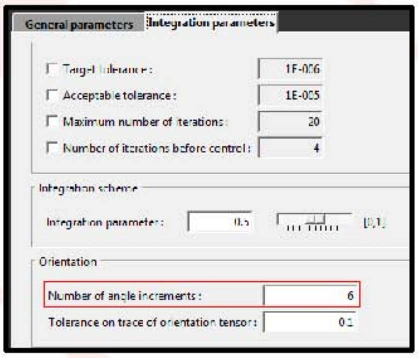




DIGIMAT Computational Time

- Changes in the material
  - ✓ Homogenization method

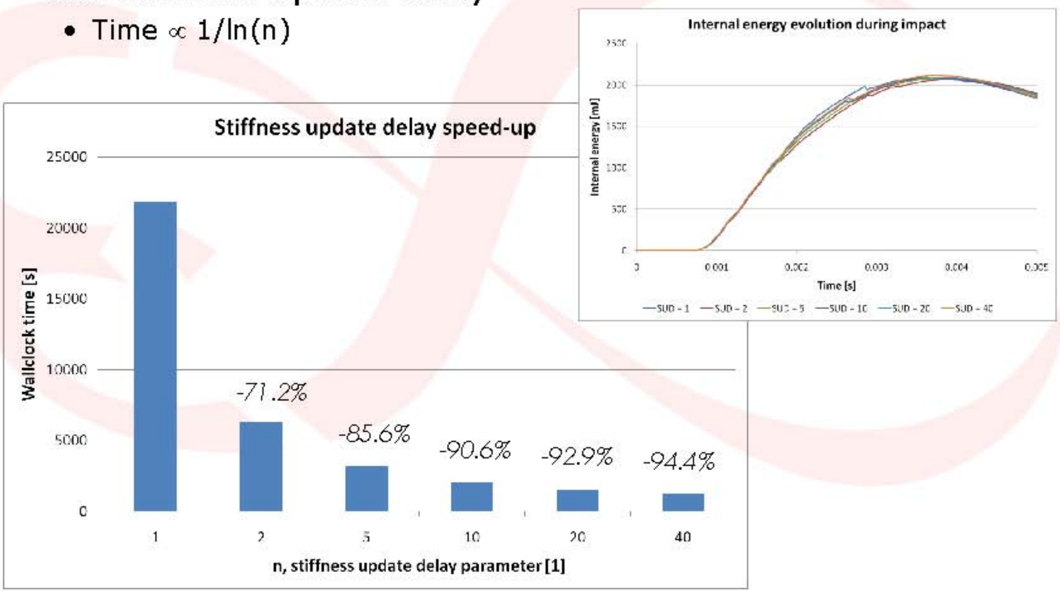




	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6
Homogenization	M-T	DI	M-T	DI	M-T	DI
# of angle increments	6	6	20	20	36	36
CPU Time (s)	478	676	1790	2398	3445	3988
Cost difference (%)	/	+29.3	+274	+402	+621	+734

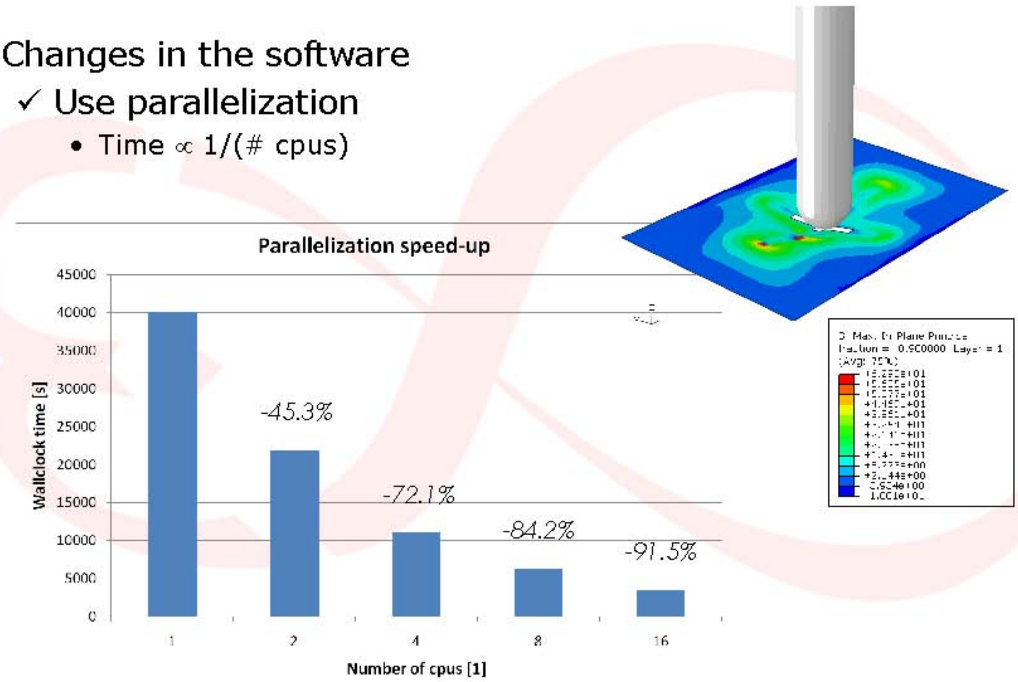
DIGIMAT Computational Time

- Changes in the method
  - ✓ Use stiffness update delay
    - Time ∝ 1/ln(n)



DIGIMAT Computational Time

- Changes in the software
  - ✓ Use parallelization
    - Time ∝ 1/(# cpus)



Summary

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- DIGIMAT technology
  - ✓ Bridges the gap between processing conditions, material description and the behavior of injection molded parts in simulation
  - ✓ Offers a broad range of material descriptions for the use in explicit simulations
  - ✓ Offers the FPGF failure model which has successfully be tested for fiber reinforced polymer materials
  - ✓ Includes a several strategies to reduce computational cost in coupled simulation

Thank you for your attention!

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