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Engineered Material Solutions For The Worldwide Automotive Industry

Coupling of Digimat to Radioss Block / Bulk : improved physical property prediction of short fiber reinforced polyamide by utilizing fiber orientation

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Agenda

- The challenge
  - Specificities of short fibers polymers
  - What is Digimat ?
- Material identification process
- A real application
  - 3 points bending
  - Compression
  - Modal analysys
- Conclusions and consequences

The challenge

- Lightweight,
- Cost efficiency,
- Predictive, robust design

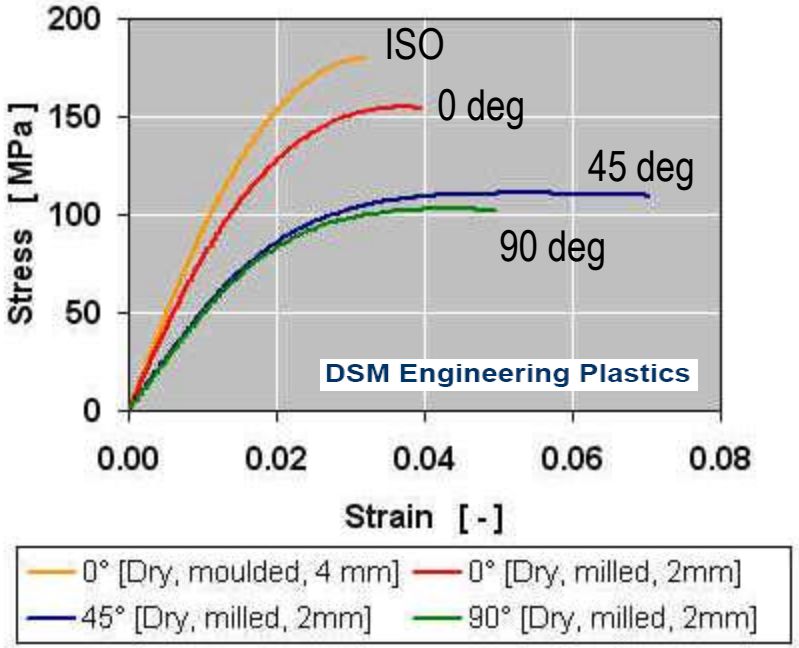
are relevant keywords @ automotive OEM.

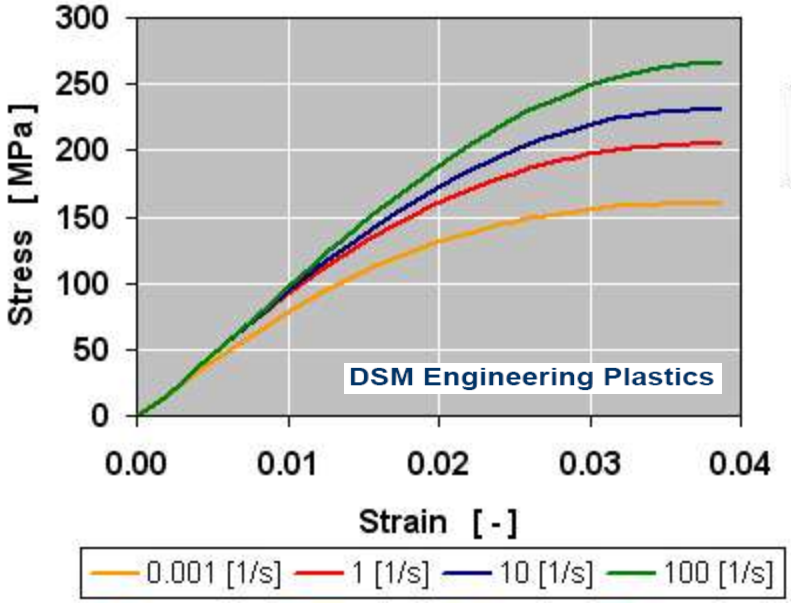
Promoting polymers (when relevant) to a steel thinking industry (car body) is not trivial.

How far can Digimat coupled to CAE software help develop the trust ?

Some material specificities of short fiber reinforced polyamide

The material properties are influenced by fiber orientation ⇨



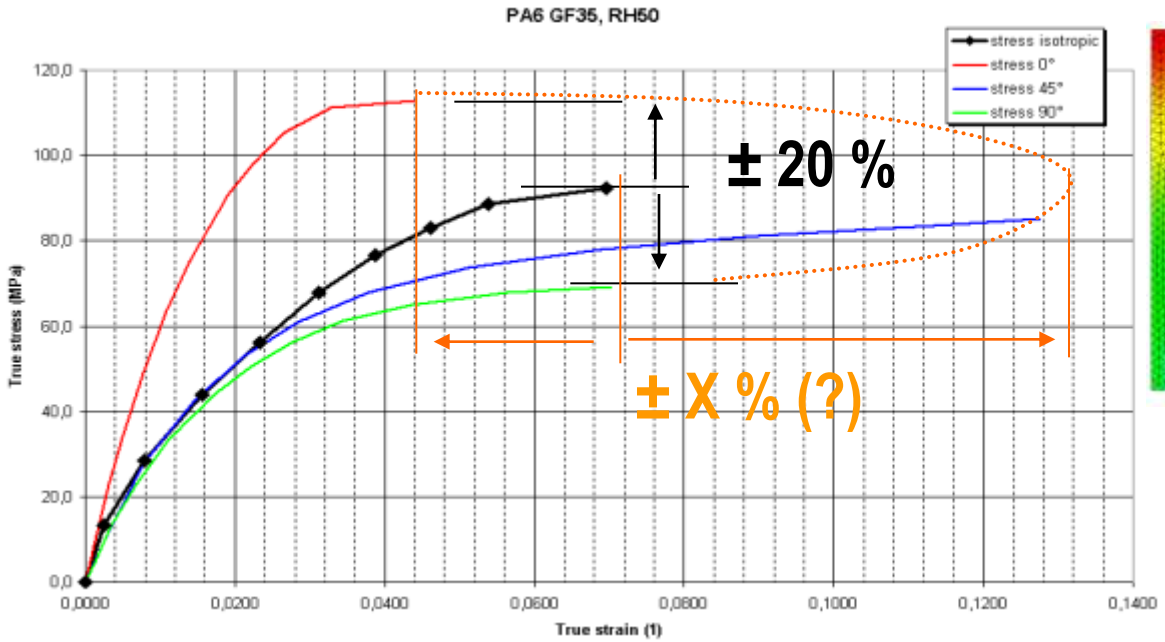


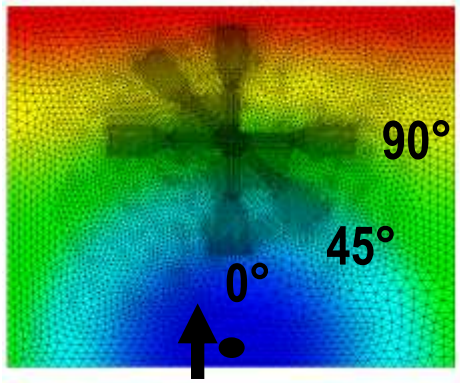
⇦ and influenced by strain rate dependency

Why do we need fiber orientation ? NVH applications

- When fiber orientation are unknown, average/isotropic mechanical properties are used
- For a PA6GF35, dry as molded, typical Young's modulus are :
  - 11000 MPa : fiber in flow (+ 30 %)
  - **8500 MPa :** average orientation
  - 6000 MPa : transverse fiber (-30 %)
- Most of design are conservative
- With still some risks !

Why do we need fiber orientation ? Crash applications





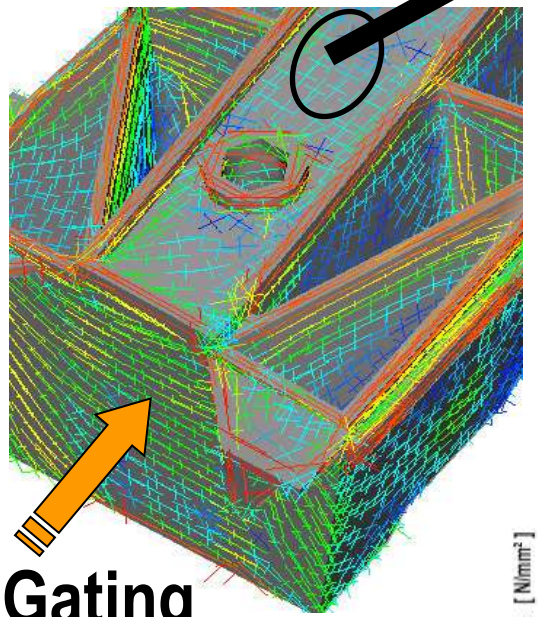
- Isotropic average data as starting point
- Most of our design are conservative
- With still some risks !

Fiber orientation distribution : anisotropic material properties

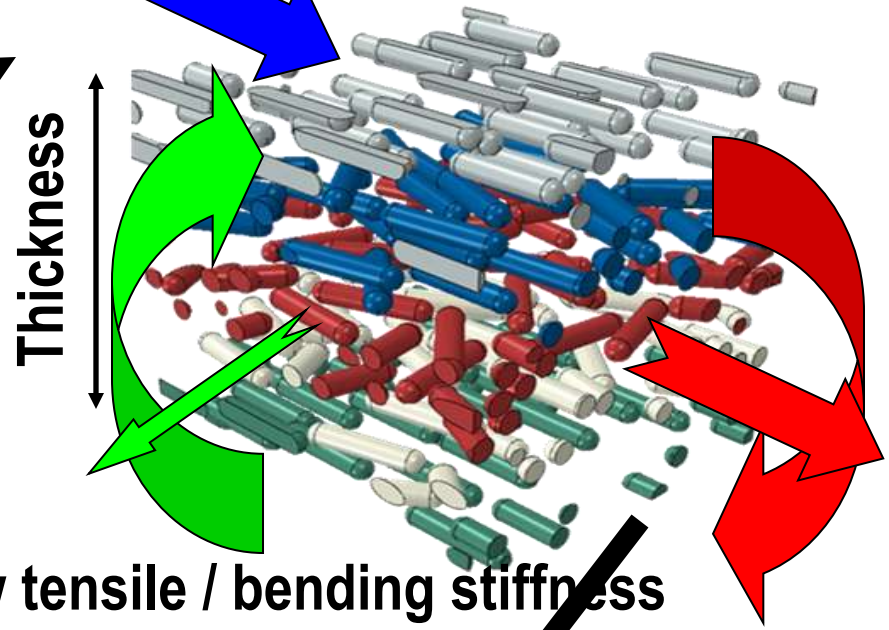
Through the thickness

Flow direction

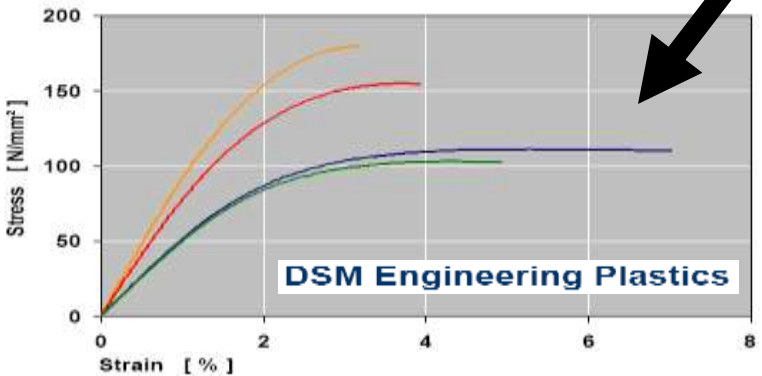
Along the part



Gating



Low tensile / bending stiffness



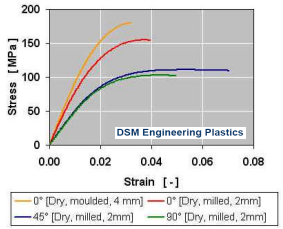
Anisotropic material properties

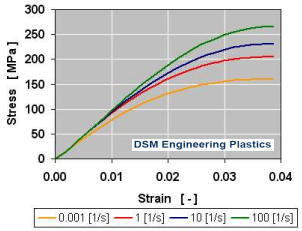
What is Digimat ?

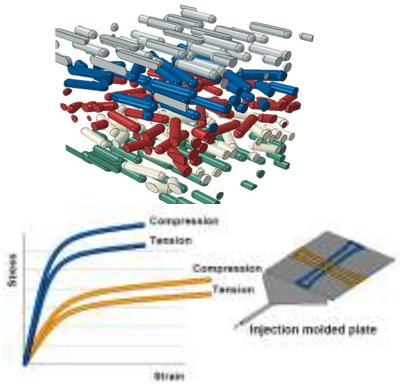
- **Material models library**, based on homogenization methods (Mori-Tanaka)
  - For multi-phase (composite) materials
  - Coupled simulations rheology/mechanics
  - Commercial product, opened and documented (no black box)
- Already linked with major CAE software
  - Abaqus,
  - LS Dyna,
  - Pamcrash,
  - In 2009 Radioss crash (Radioss Block)
  - And now Radioss Bulk (Optistruct, except optimisation)

⇨ Robust design (material/process handling)
⇨ Optimal design (weight, cost vs performance)

Standard isotropic approach vs Digimat simulation







- Fiber orientation sensitivity
  - Isotropic/average approach ✘ (stress level ± 20 %)
  - Advanced material models + coupling with rheology software ⇨ **e-Xdigimat**
- Strain rate dependency
  - Scale factor, interpolation approach ✘
  - Advanced material models ⇨ **e-Xdigimat**
- Other specificities (matrix/fiber microstructure)
  - Failure criterion (uncoupled tension / compression) on each phase ⇨ **e-Xdigimat**
  - Fiber content ⇨ **e-Xdigimat**
  - Asymetric behavior tension/compression ⇨ **e-Xdigimat**
  - …

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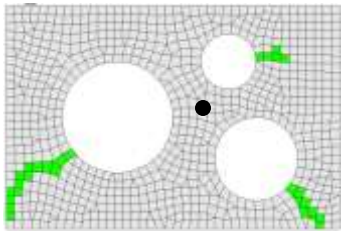
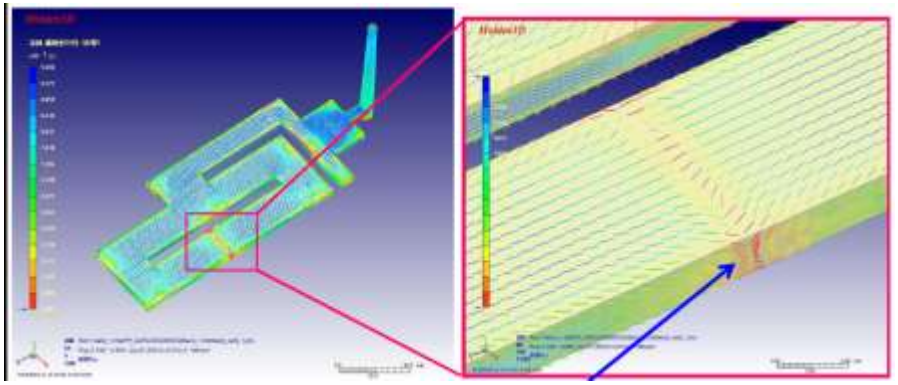
Weldlines handling



- Weldlines could be exported from rheology software to digimat.
- Weldlines are defined by converging fiber flows, and create reduced material properties



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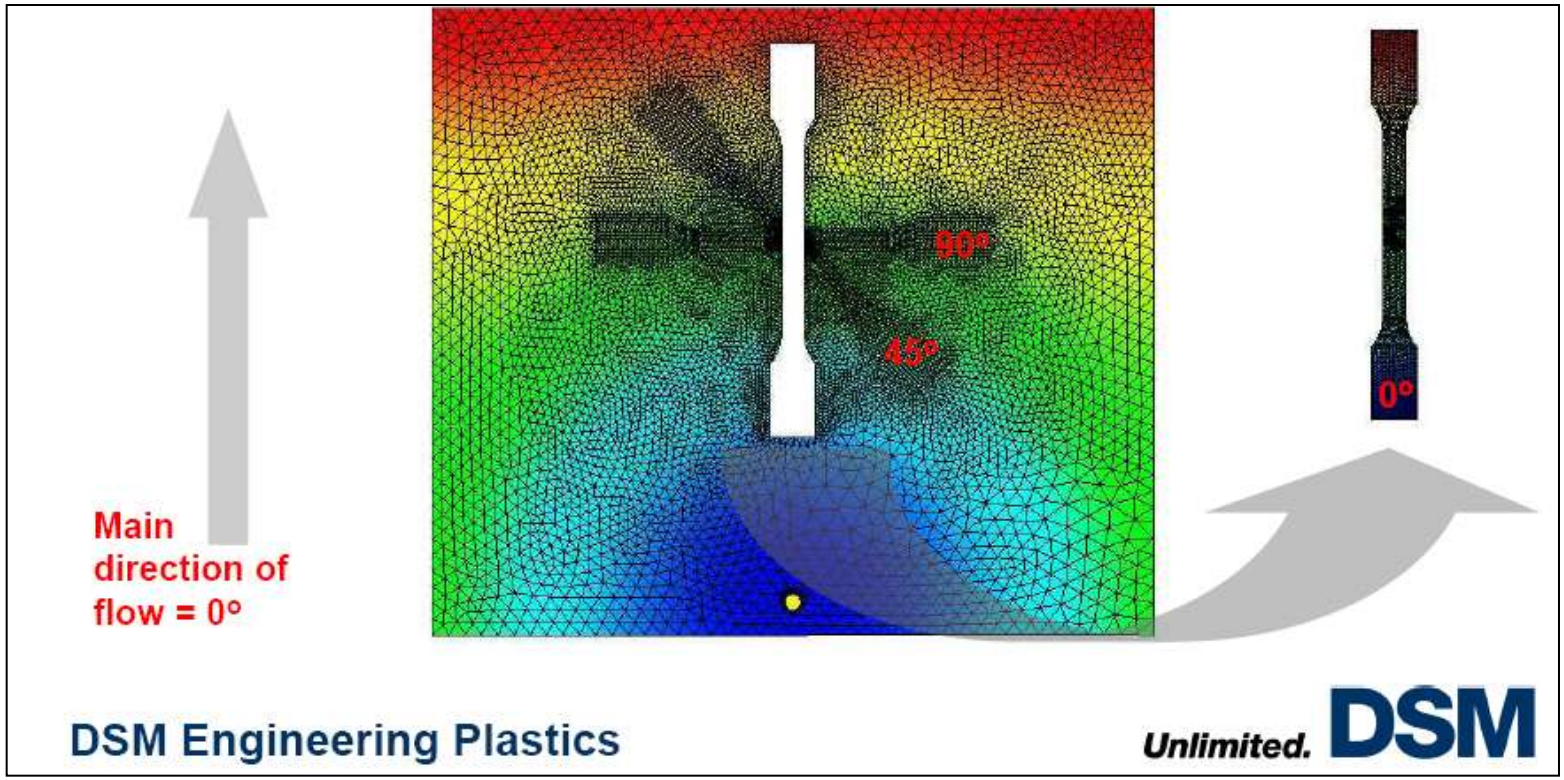
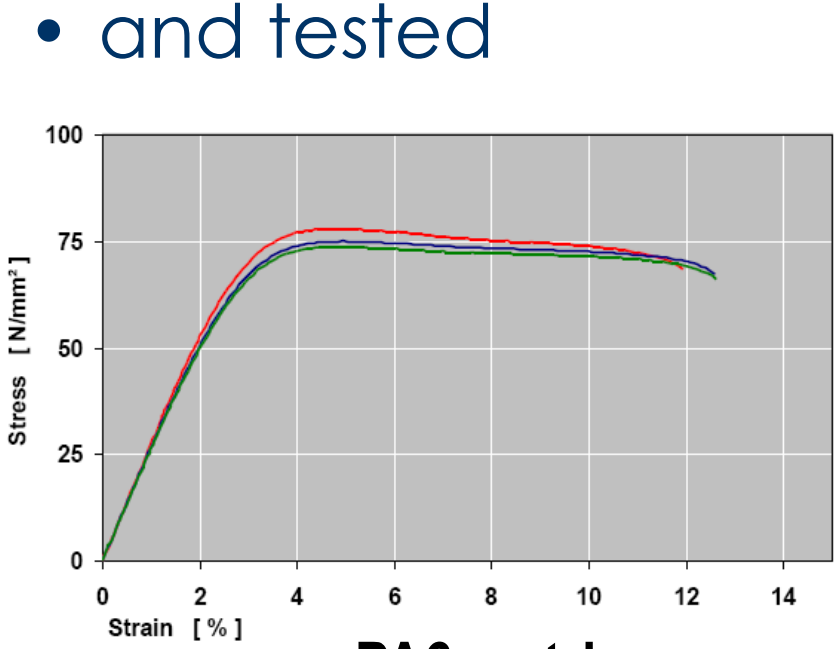
Material identification process

- Tensile specimen are machined from an injected plate

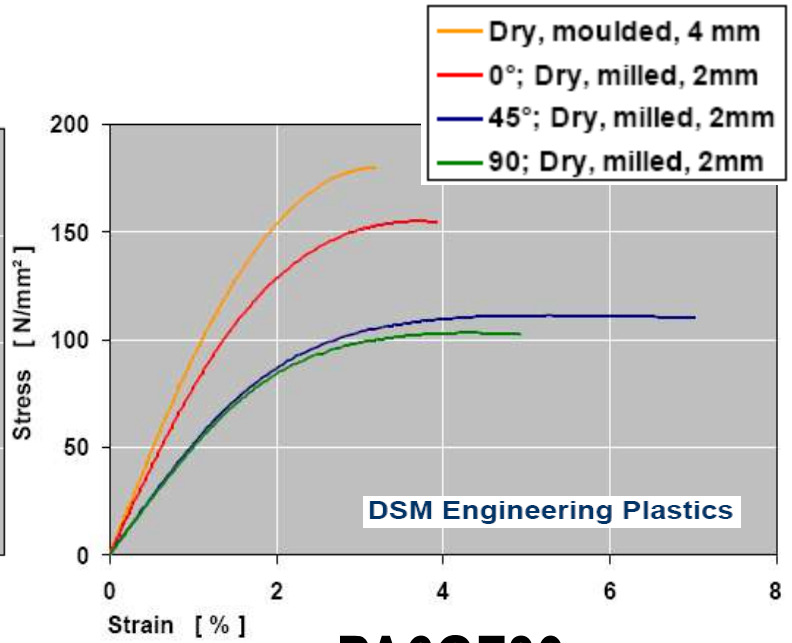


Material identification process

- and tested



PA6 matrix



PA6GF30

- The matrix is isotropic, whereas the composite is anisotropic

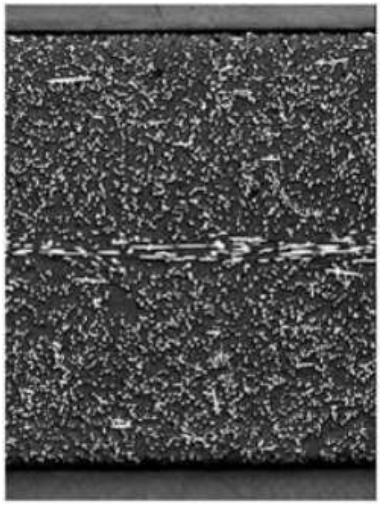
Material identification process

The material model is defined by :

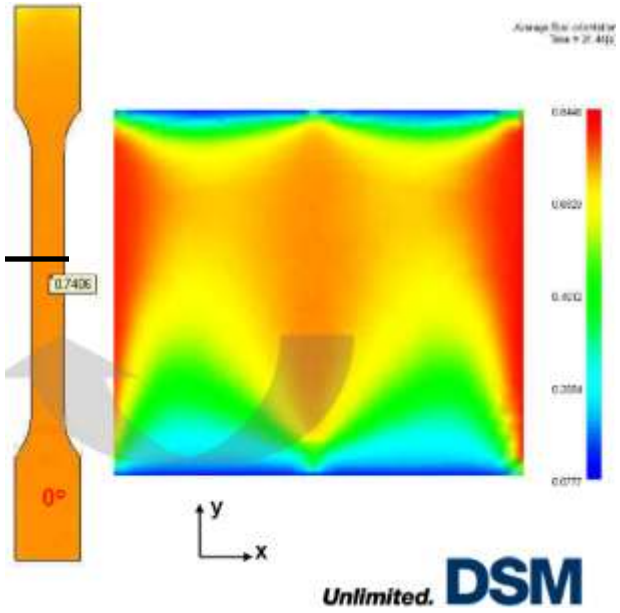
- **Matrix material data**
  - Density
  - Property type (elasto-plastic, viscoplastic, …)
  - Failure criterion
- **Fiber material data** (similar as above)
- **The fiber phase** is defined also by :
  - Fiber content
  - Fiber orientation tensor (from Moldflow or others)
  - Fiber length distribution
  - Fiber aspect ratio (length/diameter)

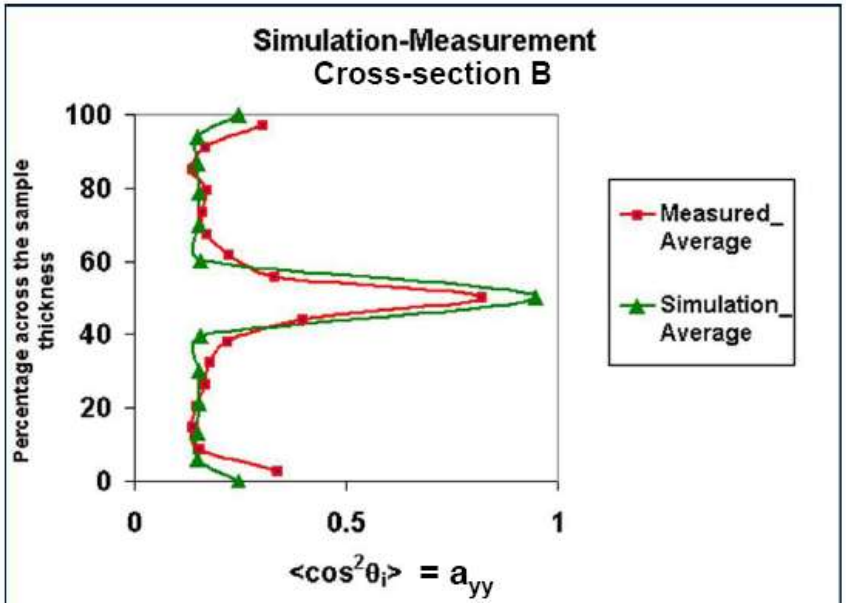
Material identification process

- Run a rheology simulation and export fiber orientation tensor.



Optical reflection microscopy picture

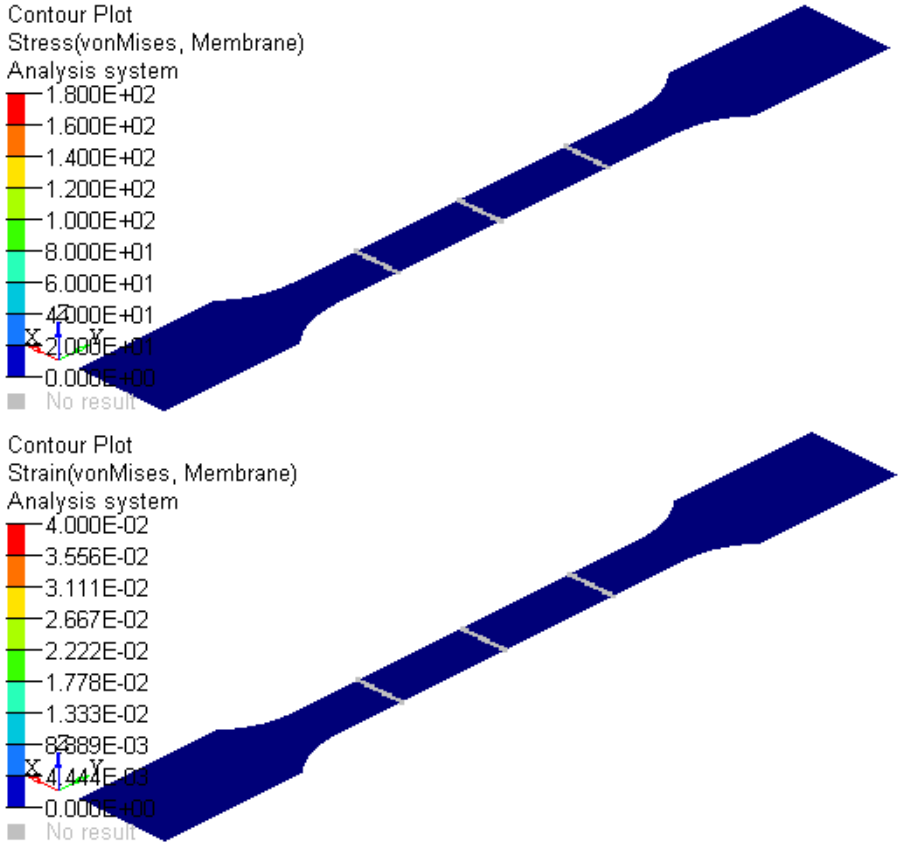


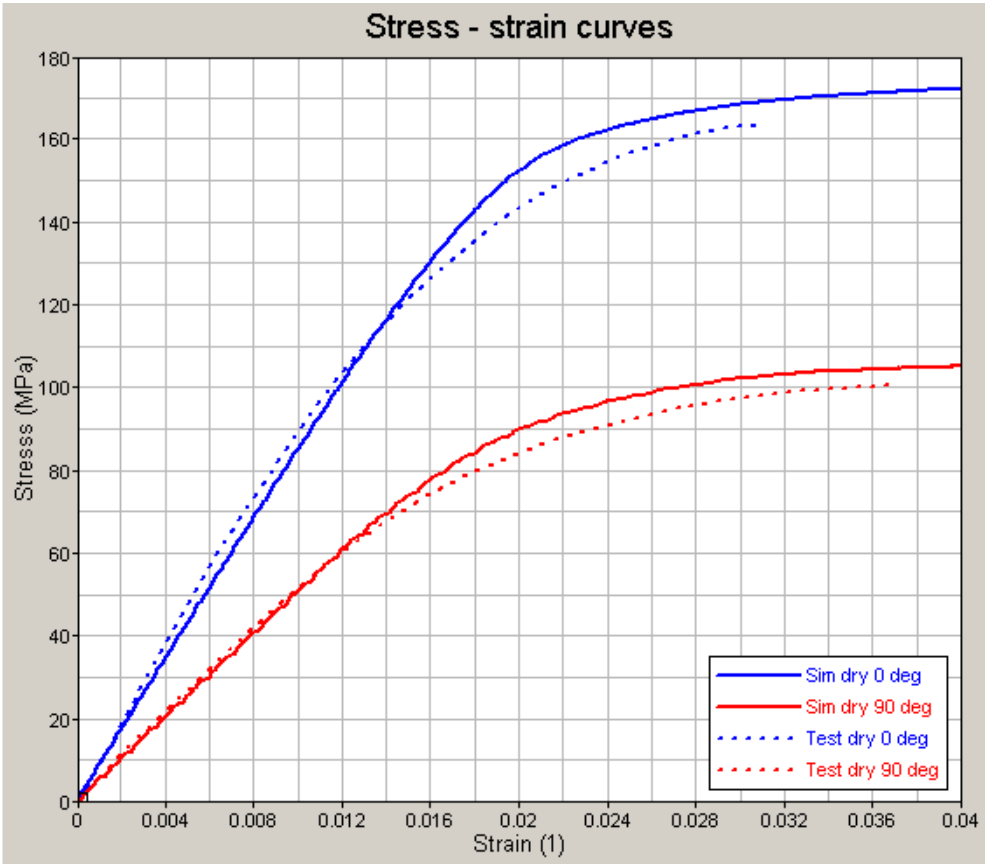


Fiber orientation through the thickness

- This tensor is projected (mapping feature) to CAE model

Results – Tensile test ISO 527 1B





With a unique material dataset, Digimat can capture the orientation effect

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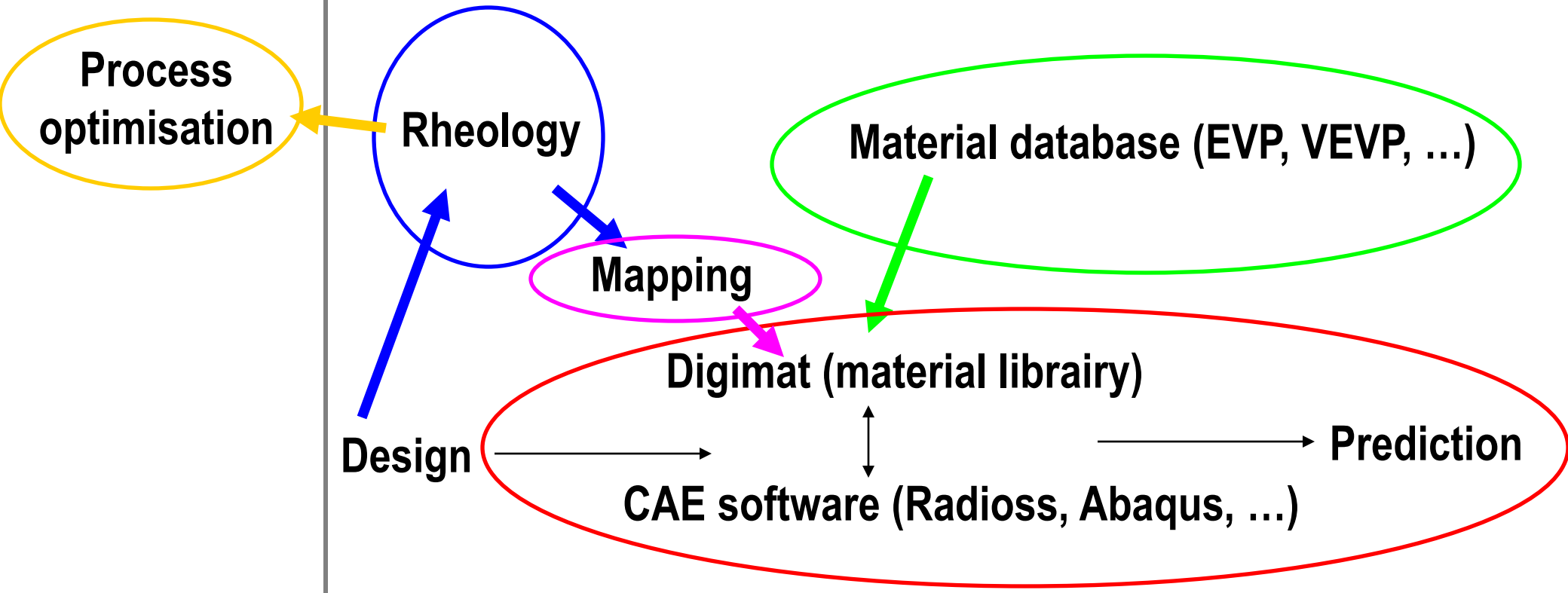
Implementation in Engineering Process



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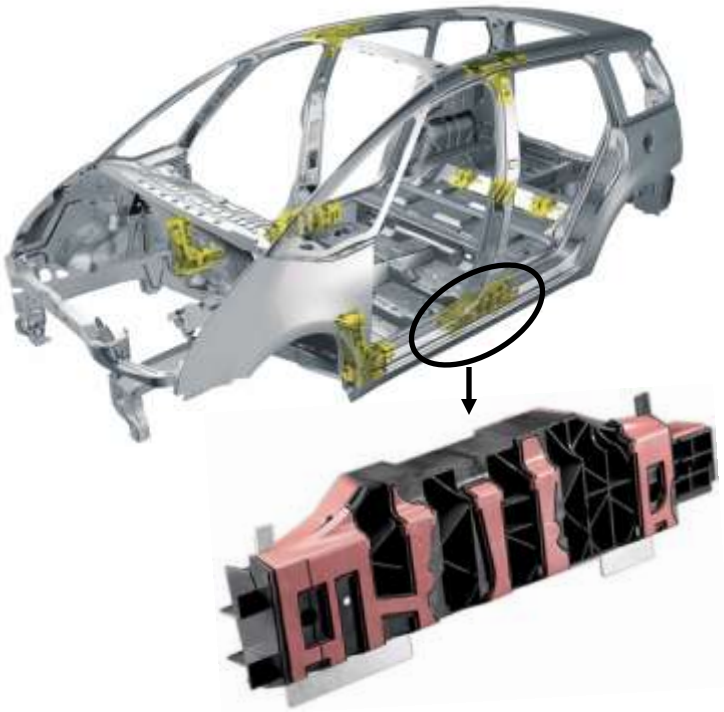
A real application

Structural reinforcement from C4 Picasso lower B pillar (polyamide only)

- Part size : # 600 * 170 * 85 mm
- Thickness : from 2 to 5
- Part weight : 2.4 kg
- Material : PA6GF35



A real application

Compression

Bending

Modal analysys

- As a case study, the part was tested in 2005 in three arbitrary configurations :
  - Compression (50 mm/mn, 3.5 m/s)
  - 3 point bend (50 mm/mn, 1 m/s, 8 m/s)
  - Modal analysis (free-free)
- 2010 Digimat to Radioss will be benchmarked to :
  - 2005 test results (does it match with tests ?)
  - 2005 simulations (does it improve predictivity ?)

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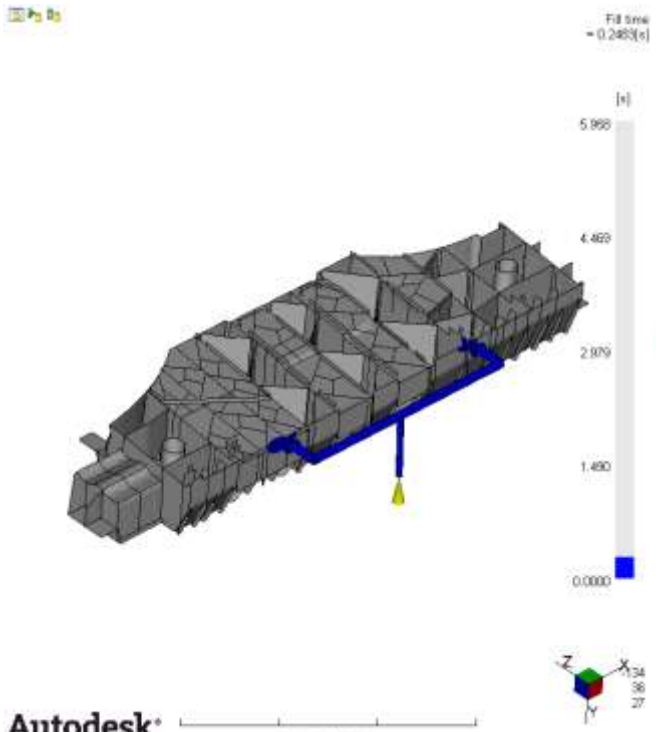
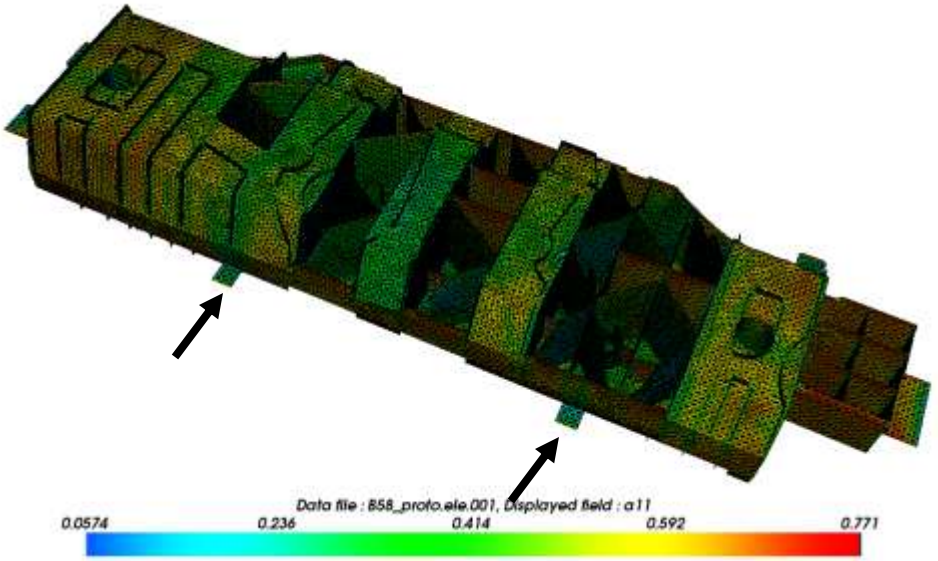
Part input deck

- Previous material data set is used,
- Except the rheology (DSM, 20 layers).

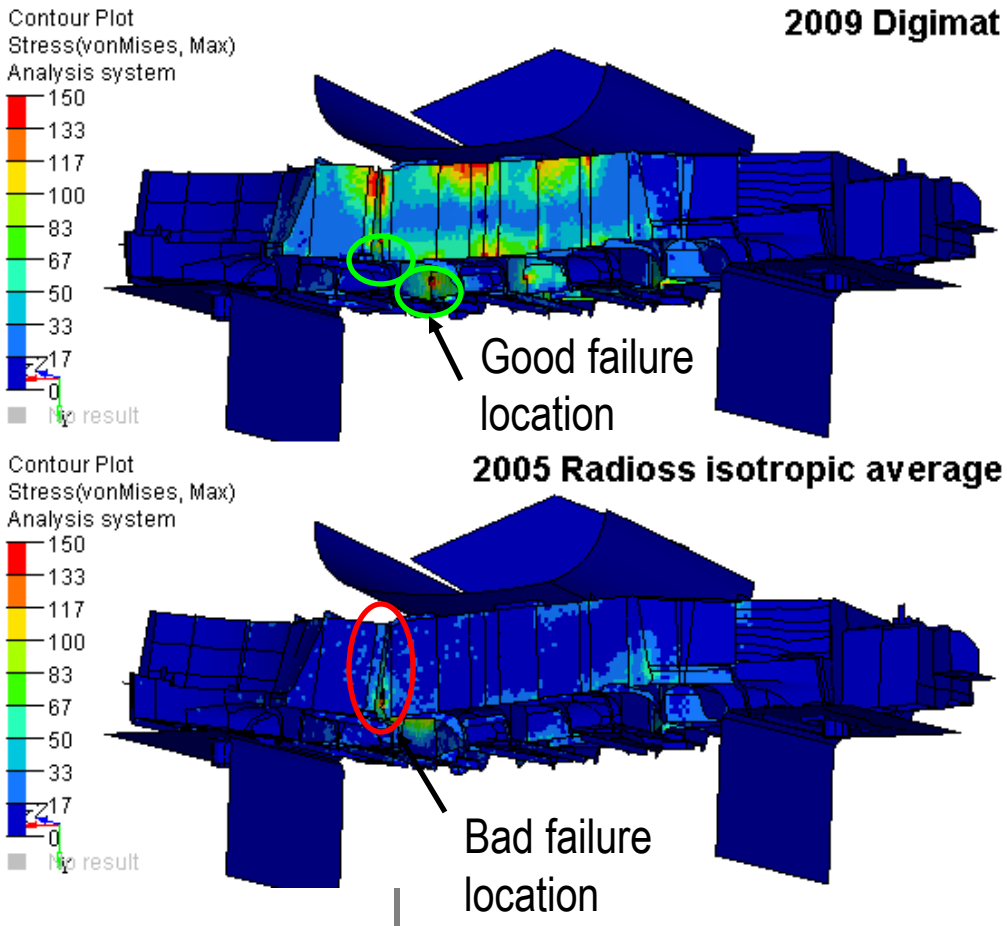
Filling sequence (prototype gating)

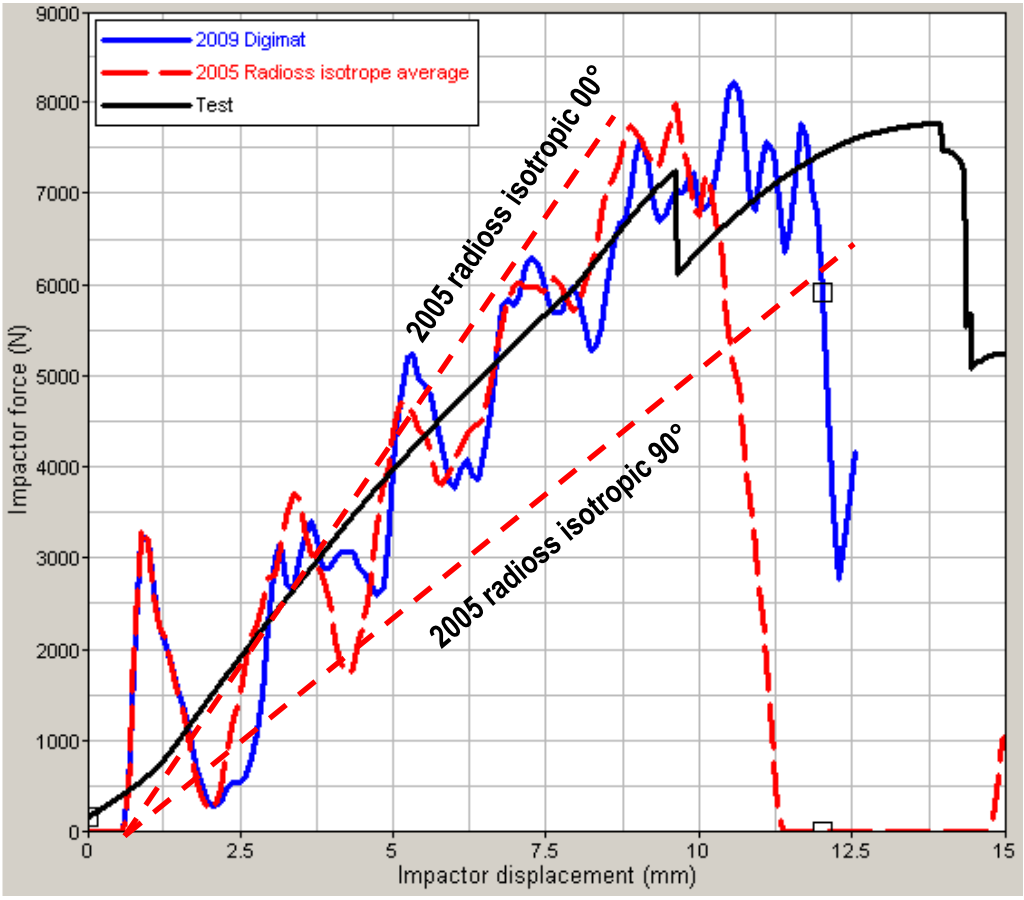


Fiber orientation (prototype gating)



Results – 3 points bending (1 m/s)

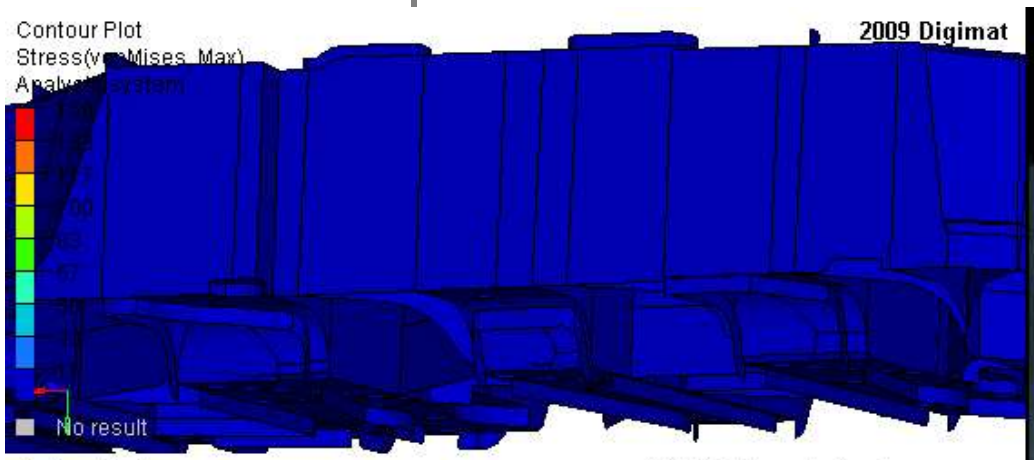


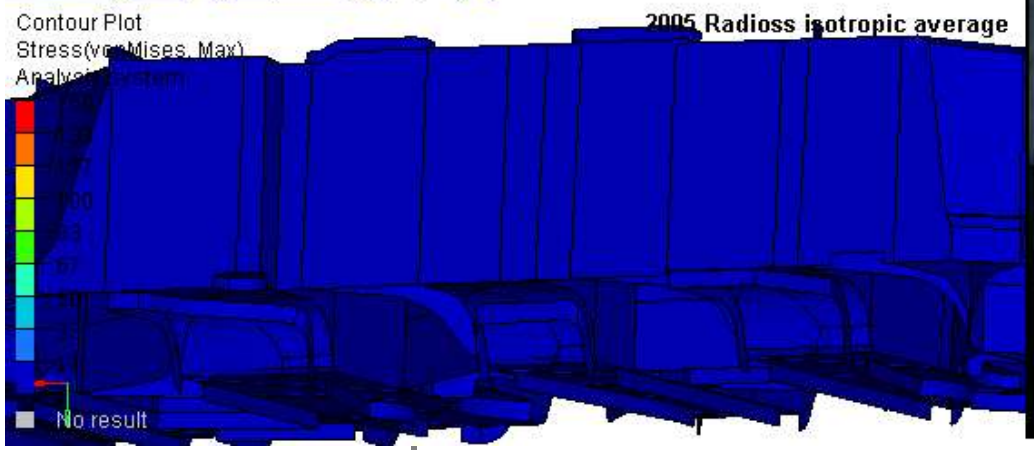


‘2005 Radioss average’ obtained by Reverse Engineering (not predictive)

‘2009 Digimat’ obtained by direct approach (predictive) – Non default mapping

Results – 3 points bending (1 m/s)

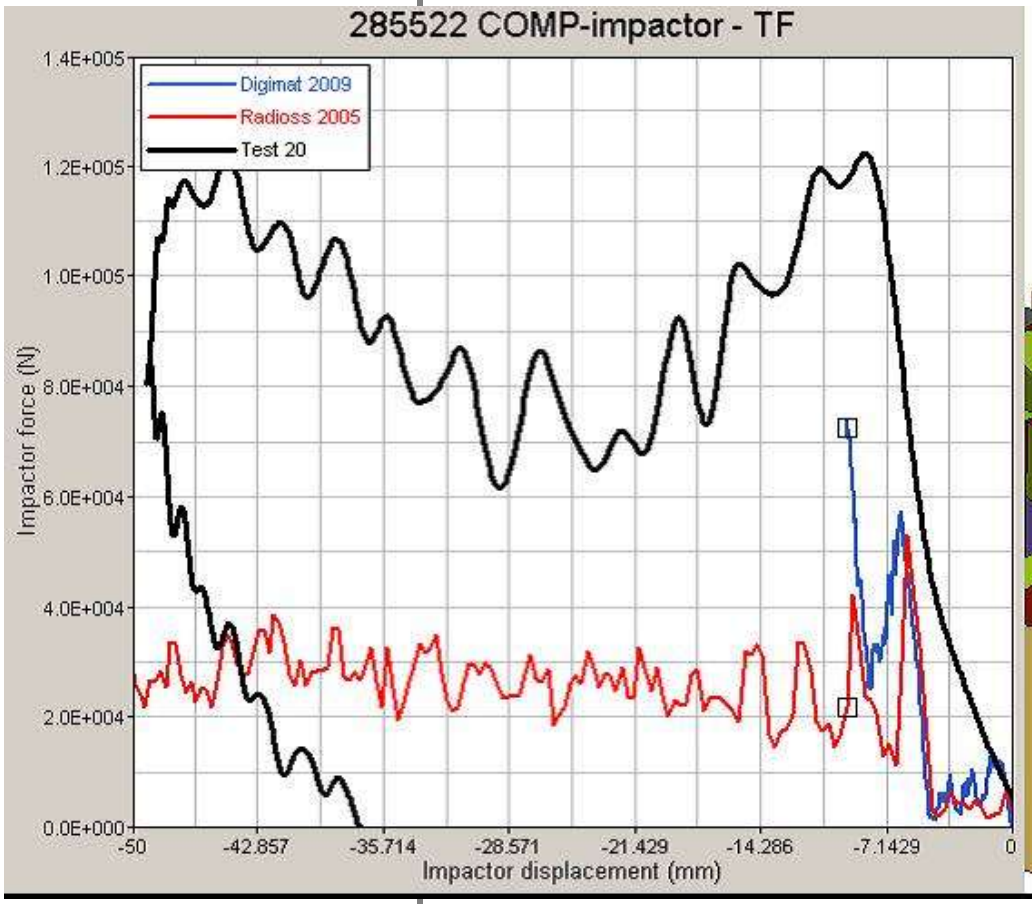


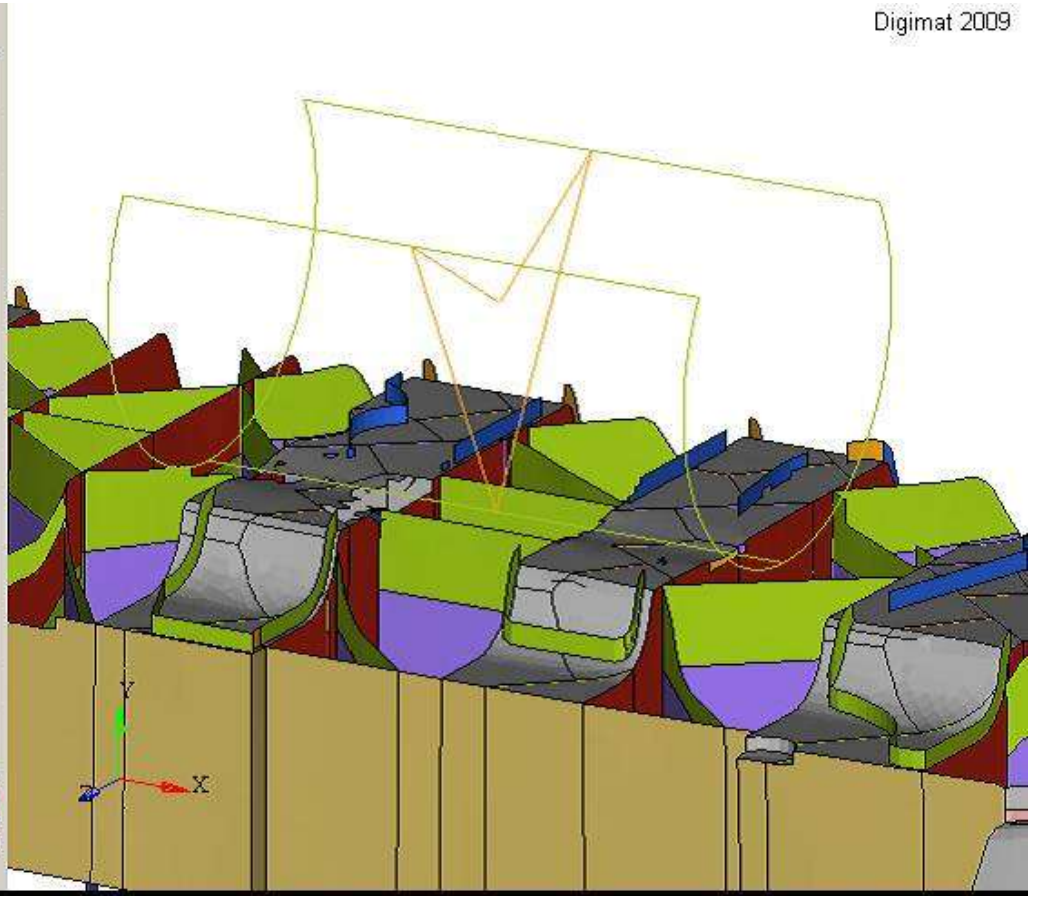


‘2005 Radioss average’ Bad failure location

‘2009 Digimat’ : Good failure location

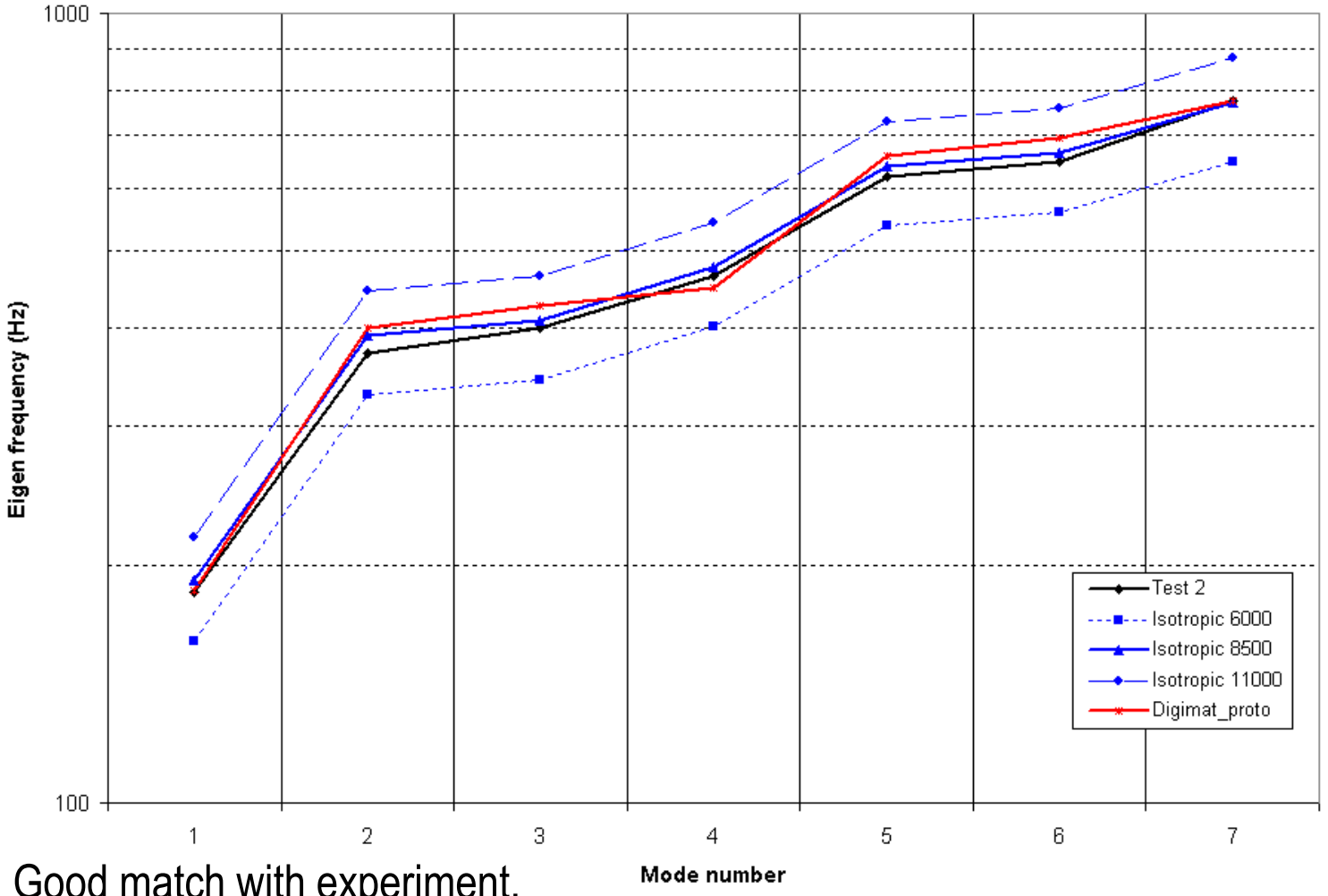
Results – Compression





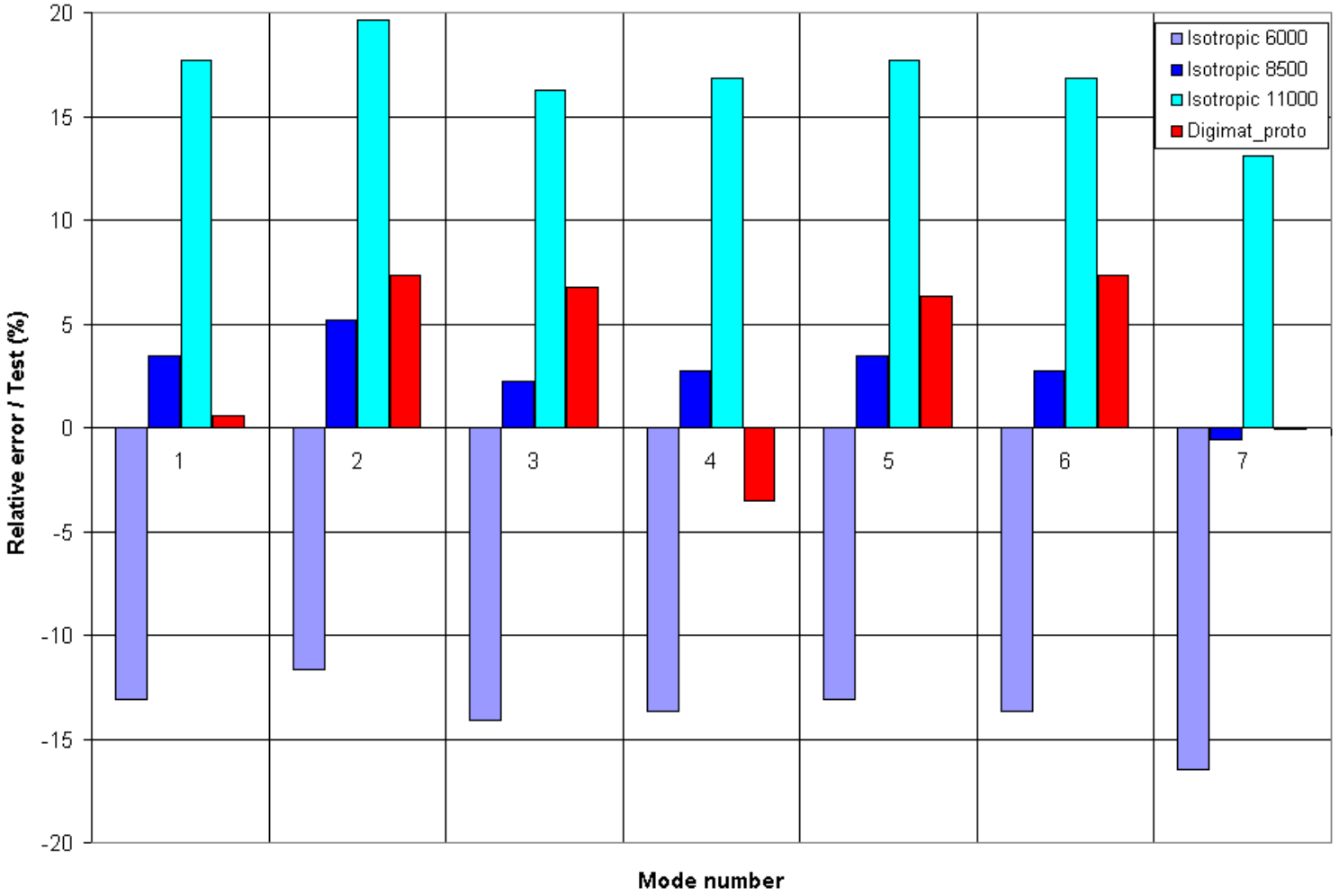
Better than isotropic. Asymetric tension/compression matrix material model will be tested

Results – Modal analysis



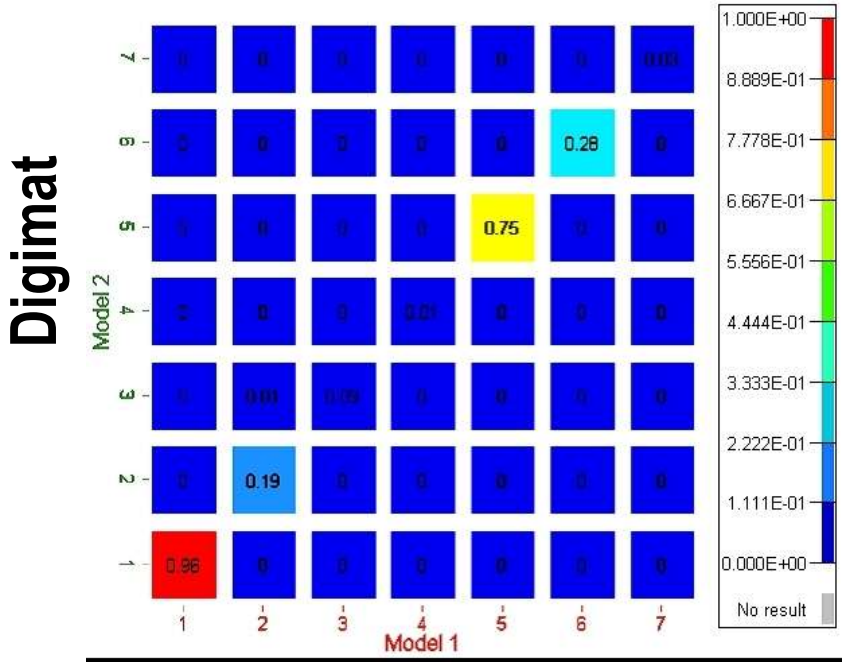
Good match with experiment,
Results closed to average orientation

Results – Modal analysis



First mode predicted with an error of 1 %, other modes < 7 %.

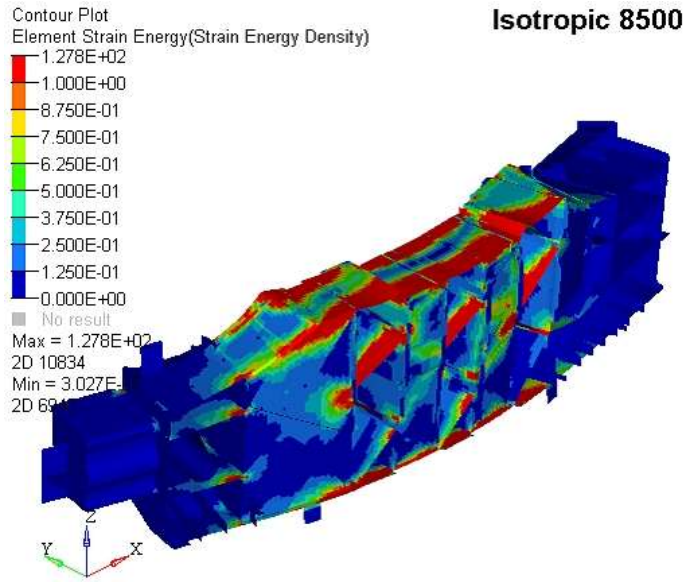
MAC indicator



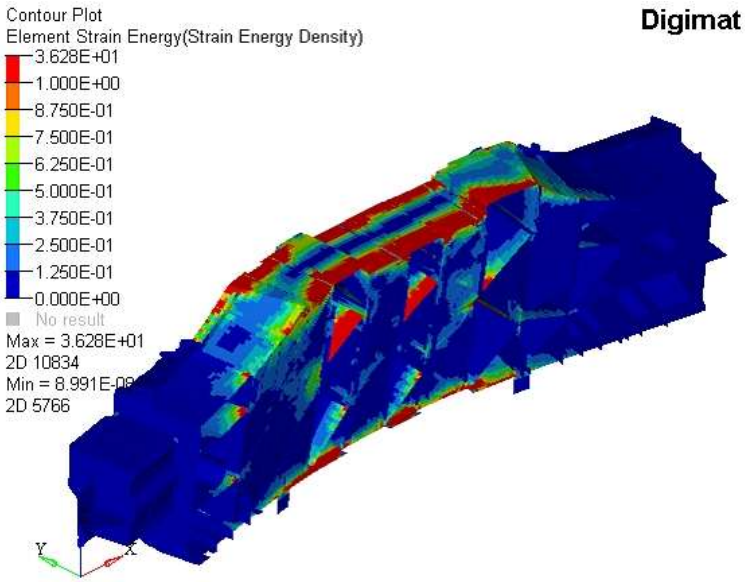
Isotropic 8500 MPa

Some eigen vectors (deformed shapes) seems to be uncorrelated between isotropic and anisotropic results

Strain energy density (1st mode)



Isotropic 8500 MPa

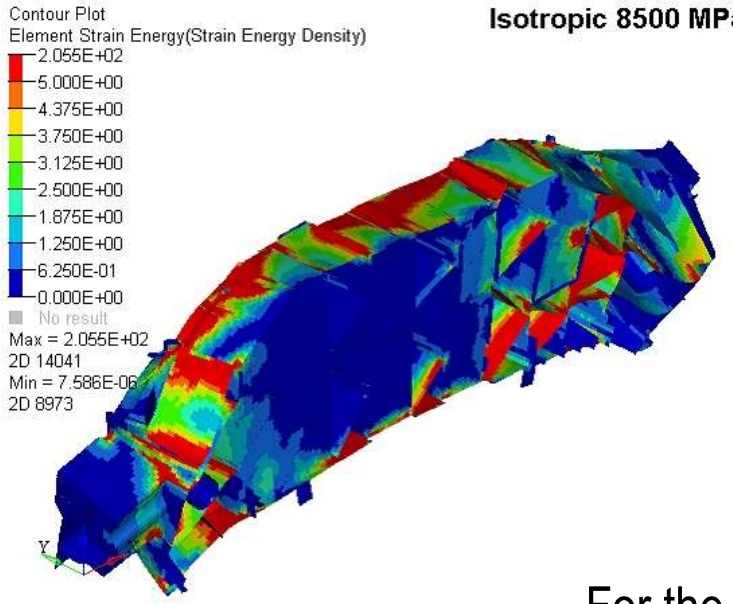


Digimat

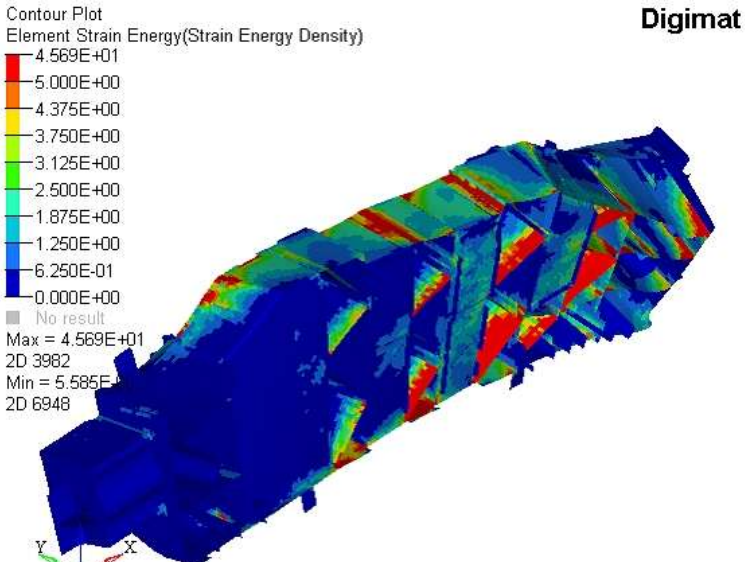
The first mode is correlated.
Digimat and Average orientation approach provide similar results, but modal shapes and strain energy distribution are slightly different.
It will have an impact to optimize the part.

Strain energy density (2nd mode)

View from Y-



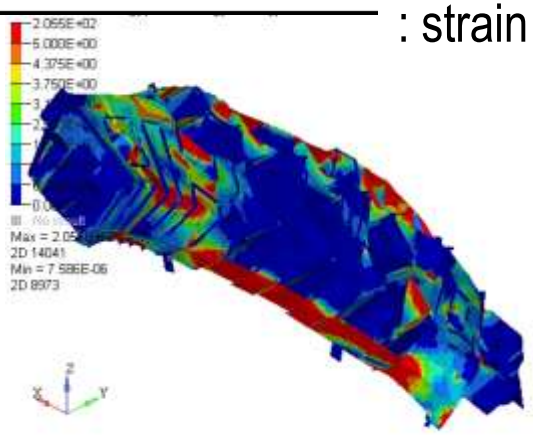
Isotropic 8500 MPa

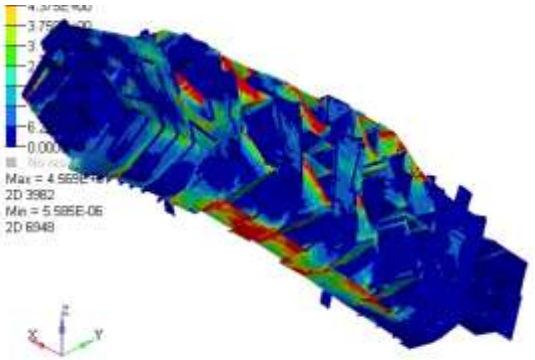


Digimat

For the second mode, differences becomes visibles : strain energy distribution and deformed geometry.

View from Y+





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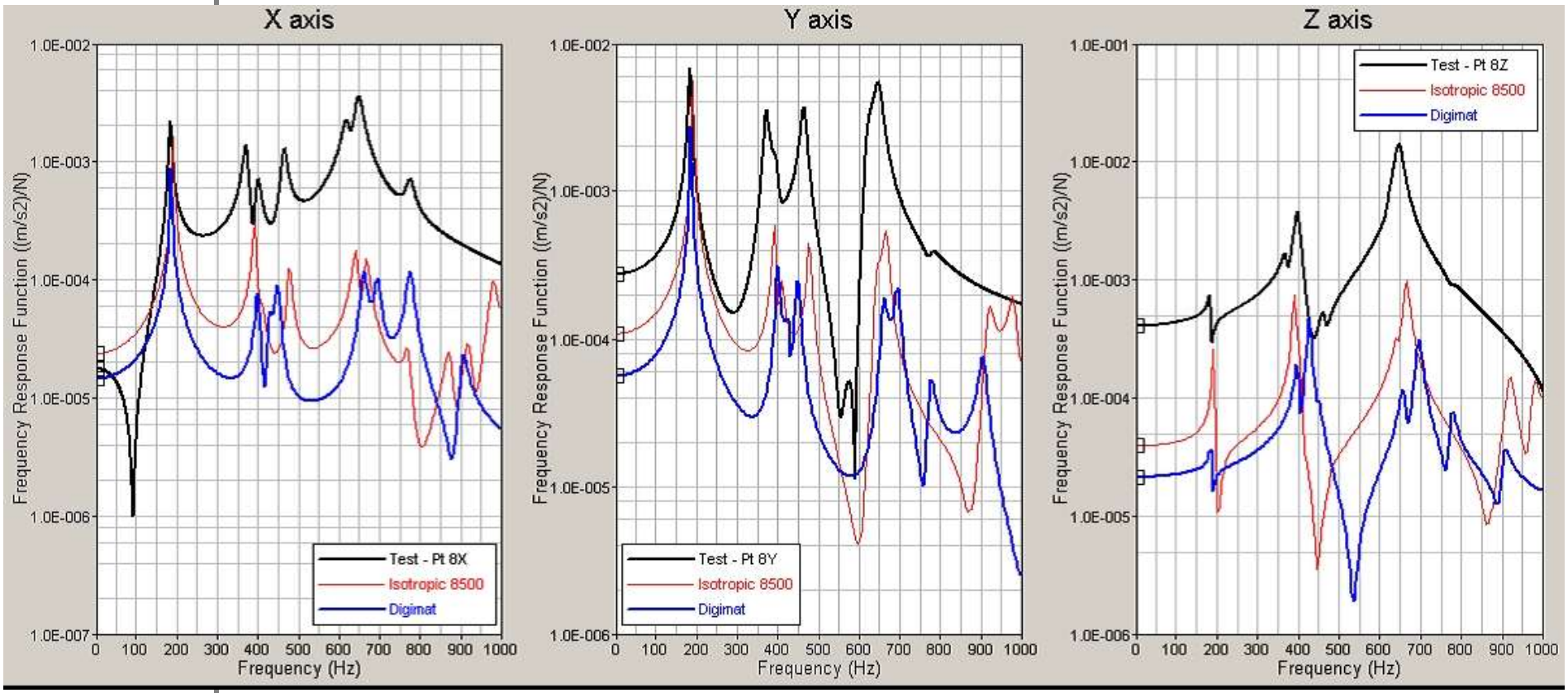
Frequency response function



A prediction closer to the experiment was expected. To be investigated.

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Conclusions Digimat / Radioss Block

Altair and e-Xstream Product managers : Stay on track.

- Interface through user material (potentially full digimat features, easy pre-processing) ☺
- Currently limited to 10 layers, constant thickness (20 variables layers on going) ☺☹
- Good/better match with tests ☺☺☺
- Untypical convergence parameters usage ☹☹
- Unstability using 10 layers formulation ☹☹
- Huge computation time (4h ⇨ 200 h, x50) ☹☹☹
- Could be optimized to x10. This the price of the predictivity. ☺☹
- Interface with Hypercrash not yet available ☹
- Specifics outputs readable in Hyperview. ☺
- Radioss Block implicit in development ☺

Conclusions Digimat / Radioss Bulk

Altair and e-Xstream Product managers : Stay on track.

- Availability ☺
- Interface without user material (MAT8 anisotropic material, extra pre-processing 1 h) ☹
- Huge data files (10 MB ⇨ 460 MB) ☹
- 20 layers available (composite property) ☺
- Fast calculation time. ☺ ☺ ☺
- Good match with tests. ☺ ☺ ☺

Conclusions

- High values features available ☺☺☺
  - To develop the **trust**
  - To guarantee a **robust** and **predictive** design.
  - **Optimal cost/weight design** can be foreseen.

- 20 % material saving already achieved for an NVH application using fiber orientation implementation into CAE. ☺☺

Thank you for your attention

Questions ?

Special thanks to e-Xstream and Altair teams for the support to this study …

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