Moldex3D
MOLDING INNOVATION

eStream
ENGINEERING
MSC Software Company

2014 Molding Innovation Day

Moldex3D eDesign

Simulazione ed analisi strutturale meccanica

Moldex3D / DIGIMAT - MSC

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10 Luglio 2014
POINT Polo per Innovazione Tecnologica
Dalmine Bergamo

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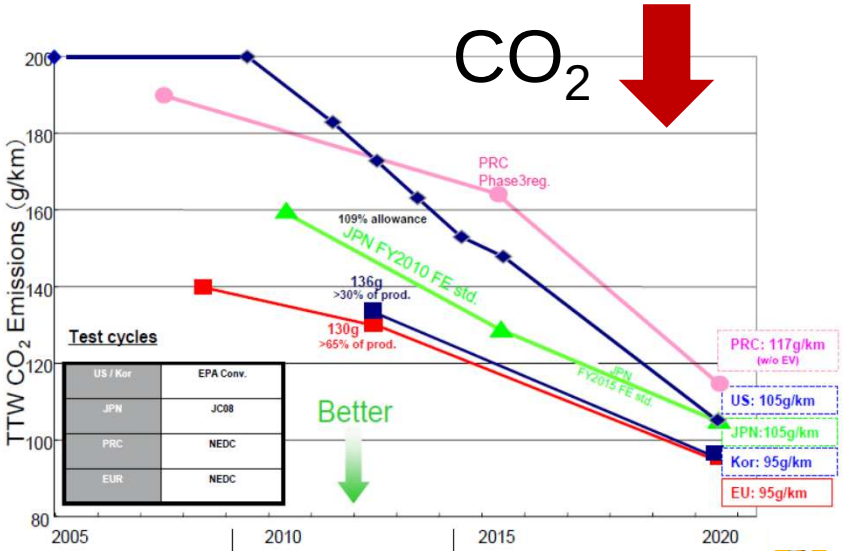
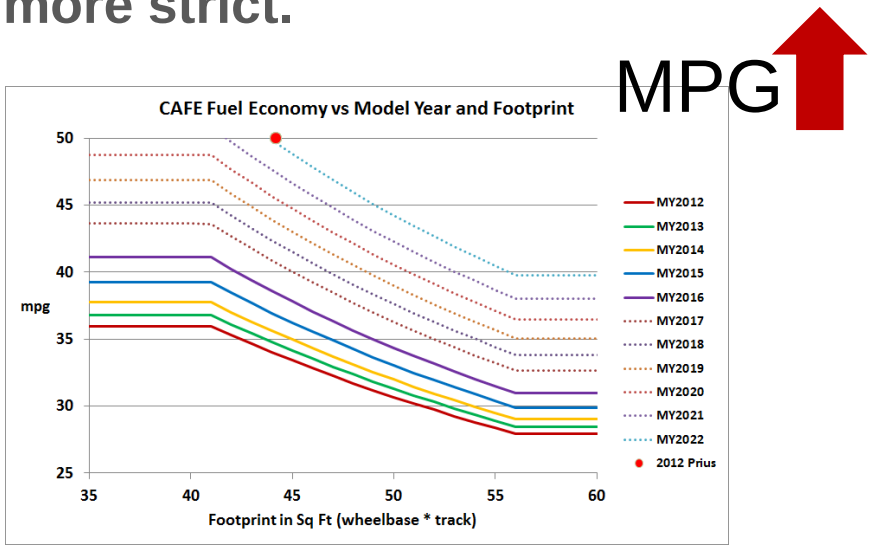
Contents

- Challenge in automotive field
- Chopped fiber reinforced plastic and processing
- Challenge in mechanical performance prediction of part made of chopped fiber reinforced plastic
- Bridge the gap between the manufacturing process and the structural analysis

Challenge in automotive field

> Worldwide regulation in CO_2 emission and fuel consumption are more and more strict.





> Reach the new targets passes by a reduction of vehicle weight

– decrease the weight by 100 kg leads to a reduction of 8g CO2/km

Composite to reduce vehicle weight

> **Replacing metal parts with "plastic" parts in vehicles offers several advantages:**

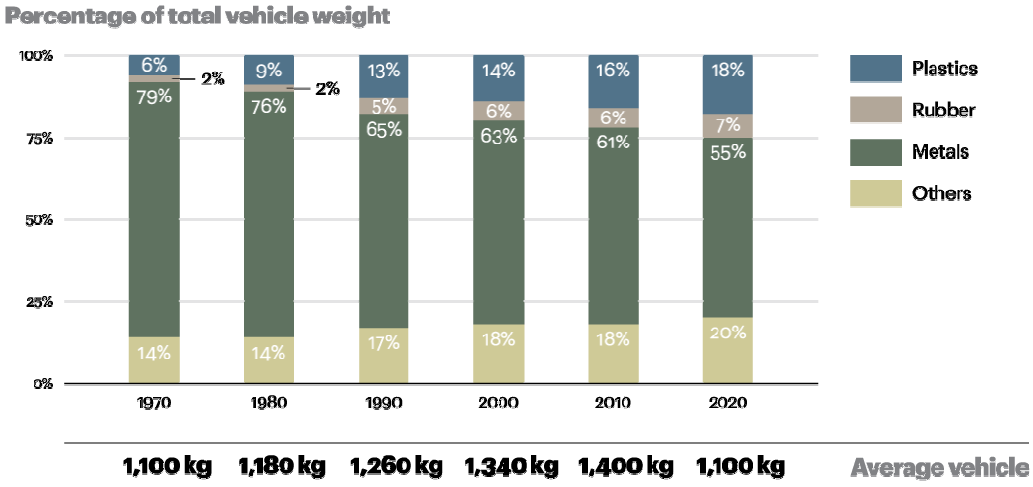
- **Mass reduction** ➡
  - ✓ *Lower emissions of pollutants*
  - ✓ *Higher mileage*
  - ✓ *Freedom to redistribute masses to improve handling*
- **Shortens the assembly line** ➡
  - ✓ *Cost reduction for manufacturing and maintenance*
  - ✓ *Energy savings*
- **Material cost reduction (actual amount depends on geographical region)**

> **Composite materials present a suitable balance between mass reduction (low density) and strength (high Young's modulus).**

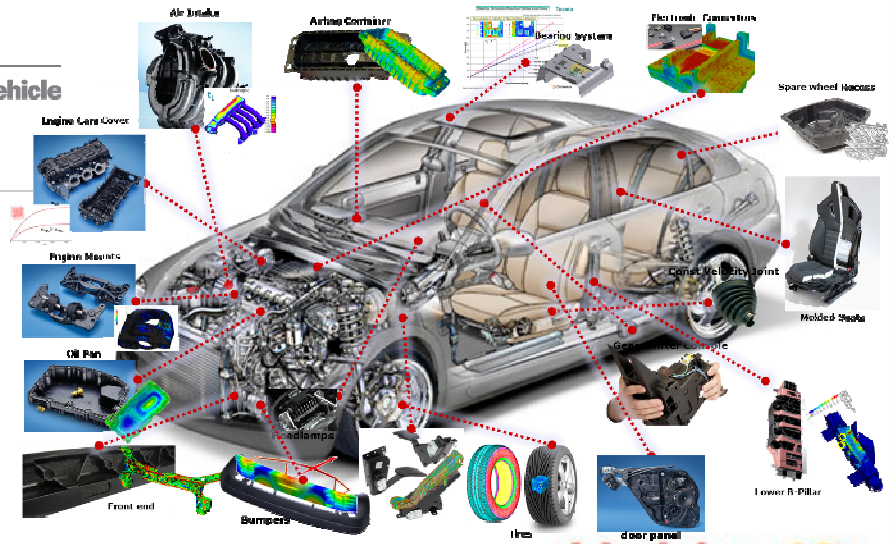
“Plastics” : Chopped Fiber Reinforced Plastic

Figure 1

Plastics will account for 18 percent of average vehicle weight by 2020, up from 14 percent in 2000



Notes: kg = kilogram. Due to rounding, some percentages may not add up to 100.
Source: A.T. Kearney analysis



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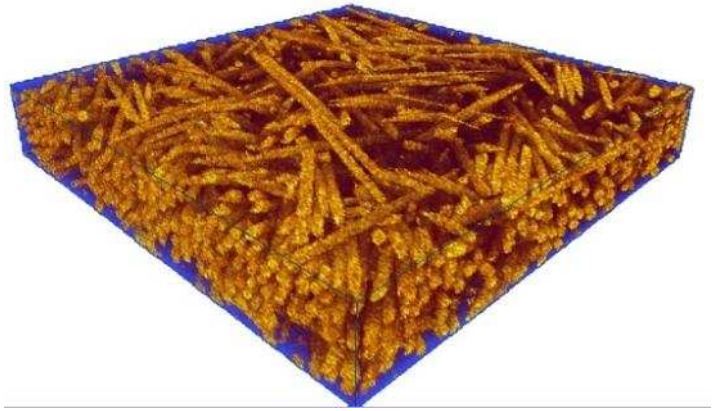
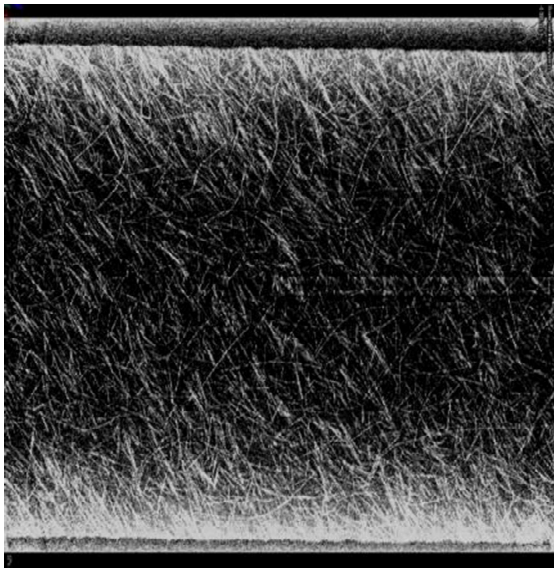
Chopped Fiber Reinforced Plastic

- Resin:
  - Polyamide (PA)
  - Polypropylene (PP)
  - Polyoxymethylene (POM)
  - Polethylenimine (PEI)
  - …

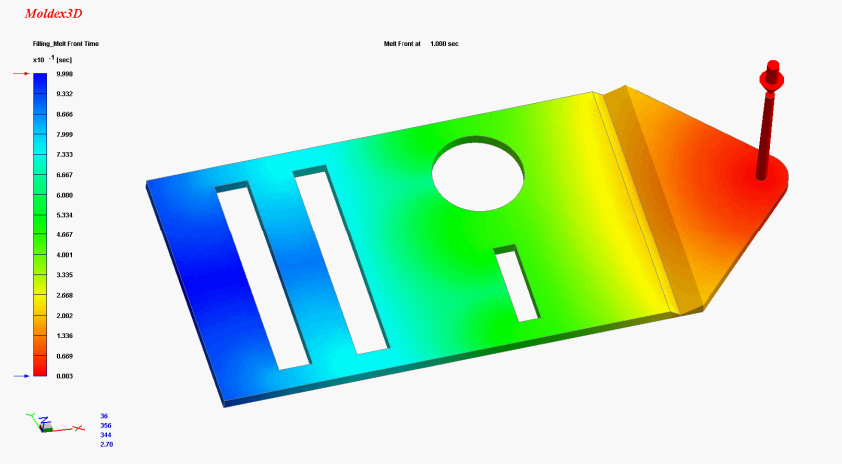


- Fiber Material
  - Carbon
  - Glass



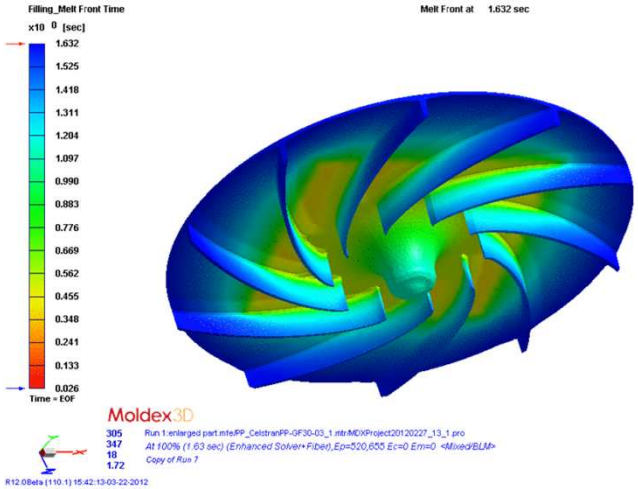
- Fiber with limited length

Processing: injection and compression



Injection process

Moldex3D®



Compression process

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Challenge in mechanical performance prediction of part made of chopped fiber reinforced plastic

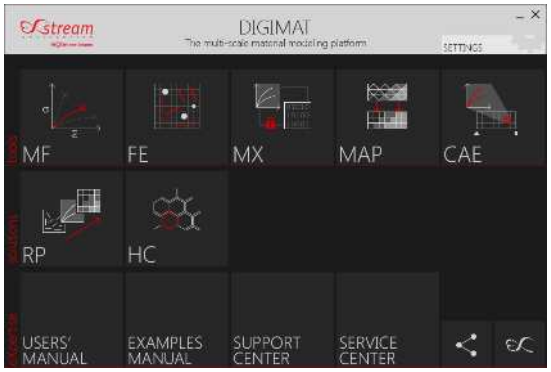
> *Fiber orientation* in the part is governed by the injection and compression process.

> The *mechanical performance of the material* depends on

- **the orientation of the fibers relative to the loading type and direction.**
- **the non-linear, strain rate dependent thermo-mechanical behavior of the resin**

> **Accurate prediction requires a solution allowing to capture the effect of the fiber orientation on the performance of the resin.**

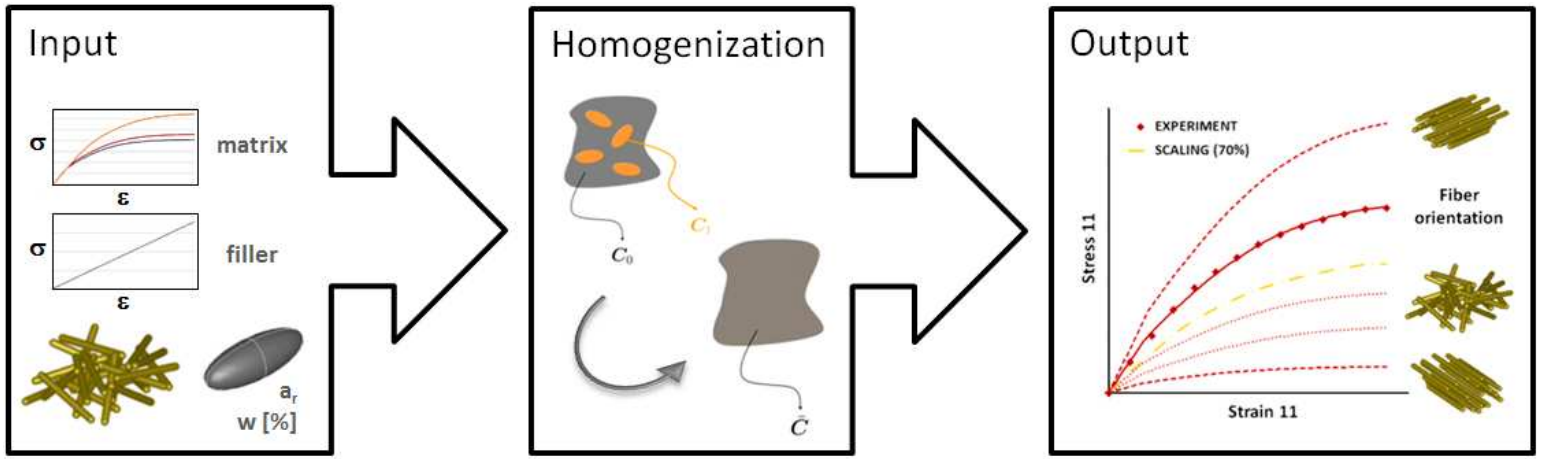
DIGIMAT



DIGIMAT - Micromechanical modeling solution

> **Multiscale approach**

– **Influence of fillers: amount, shape, orientation, ...**



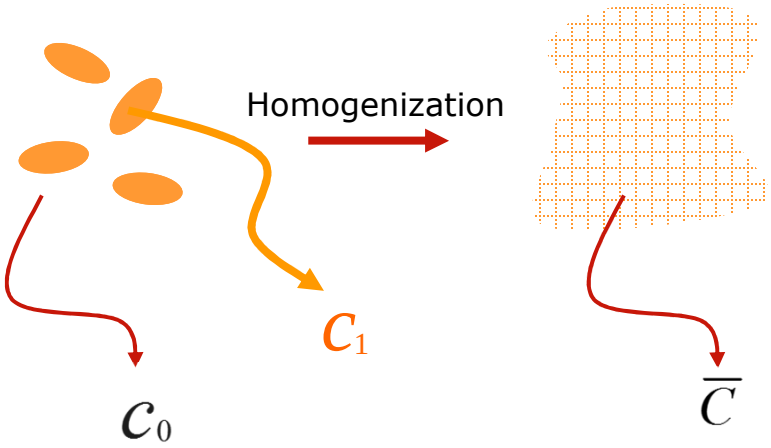
Per-phase material properties + microstructure information

State-of-the-art homogenization methods

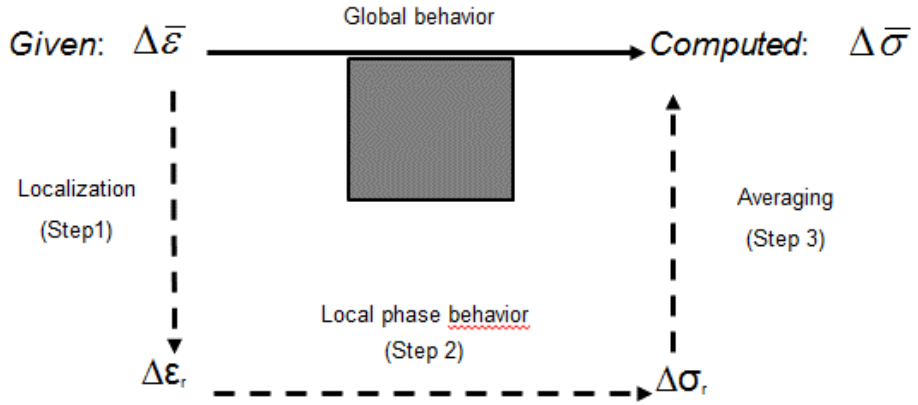
DIGIMAT material model sensitive to composite microstructure

DIGIMAT Technology - Homogenization theory

> **Homogenization**
  - Based on Mori-Tanaka theory and Eshelby's solution
  - Worked at the level of the Grain → Pseudo-grain

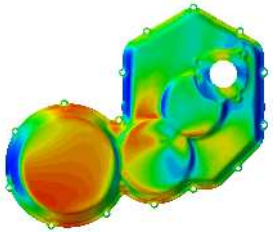


> **Strength**
  - Fast model preparation/solution
  - Accurate results
  - Enables fully coupled nonlinear analyses.

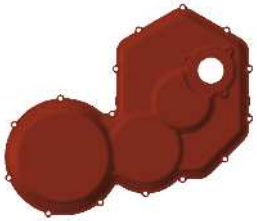


How to apply Digimat in an FEA analysis ?

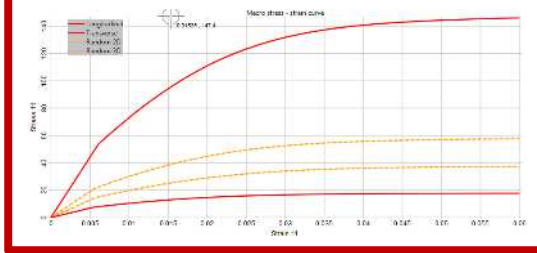
Fiber orientation
(*.xml or *.dof)



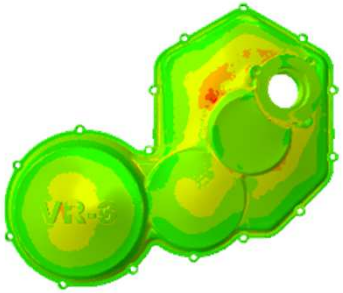
FEA Model



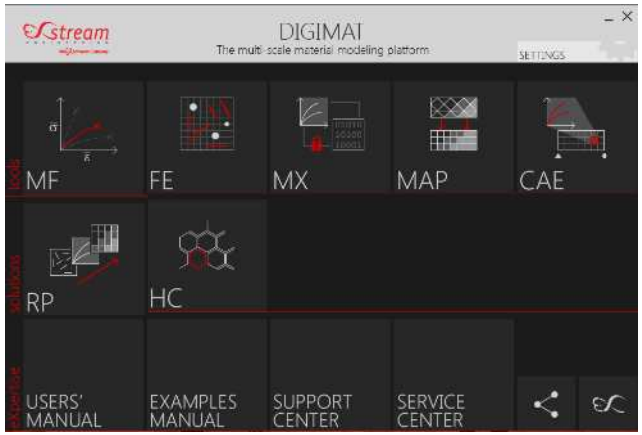
Digimat material
(*.daf)



Digimat to FEA

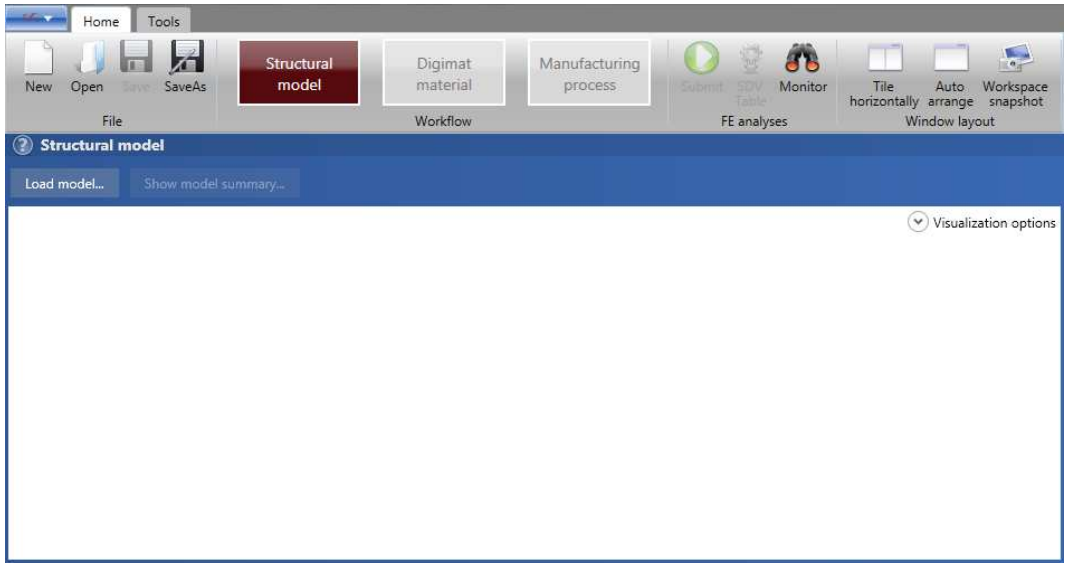


Study of the mechanical performance of engine cover block under a given pressure



Digimat-RP, preprocessing tool dedicated to the preparation of the Digimat to FEA analysis.

- Short fiber **R**einforced **P**lastics analysis
- Injection Molded part
- FEA Analysis
- User friendly



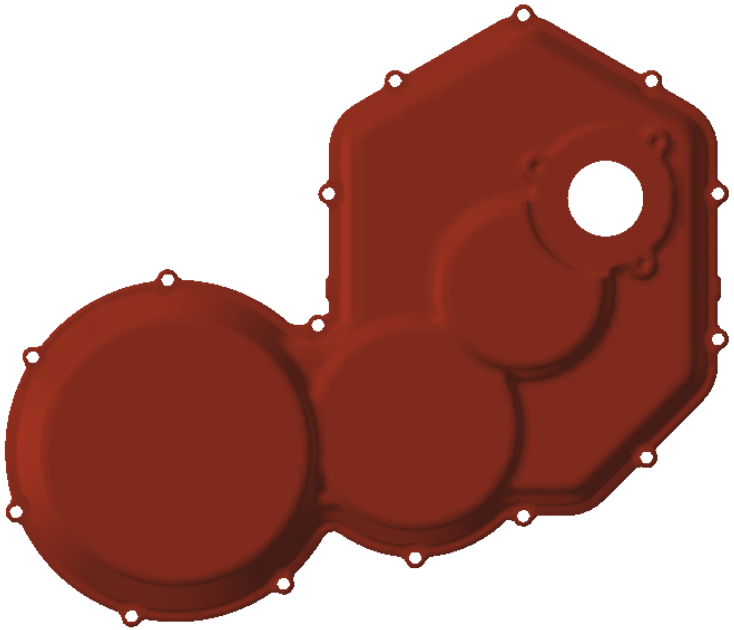
Digimat-RP

Step 1 : load FEA model

Step 2 : load Digimat material

Step 3 : create the link with the manufacturing processing

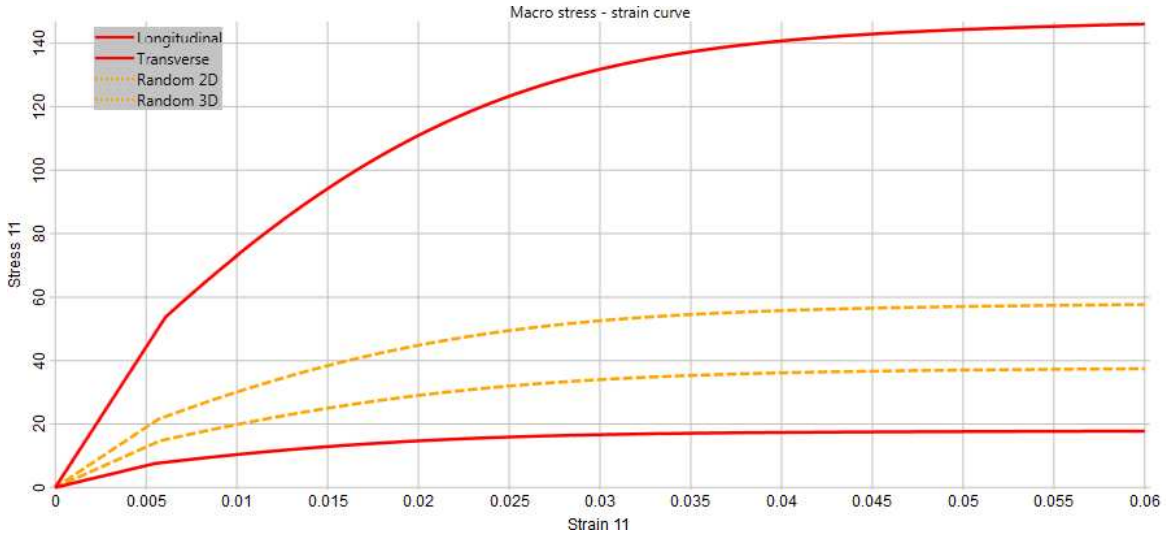
Digimat-RP – Structural Model



Structural model – MSC Marc

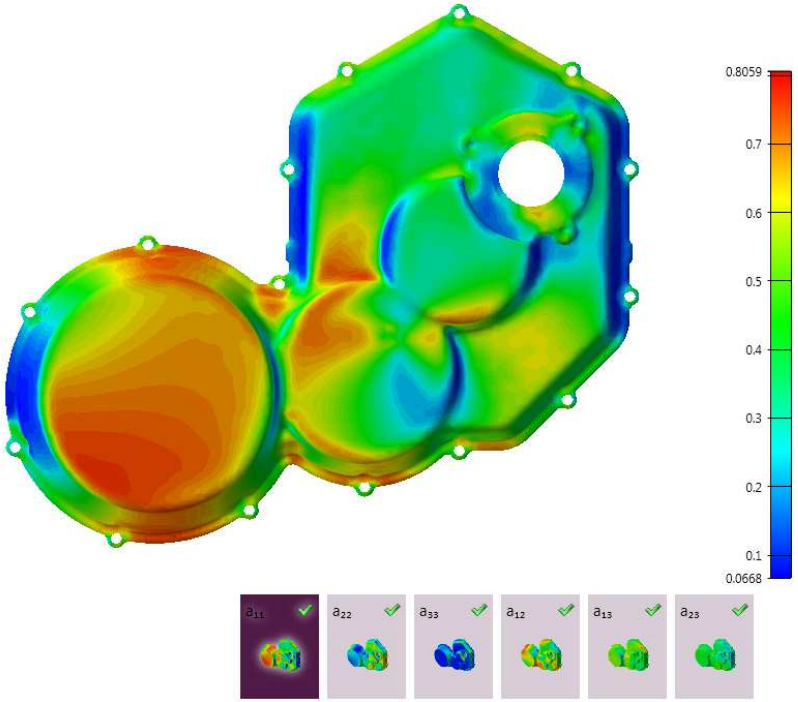
- 137.000 quadratic tetrahedral elements

Digimat-RP - Material model



Behavior of the material depends on the fiber orientation

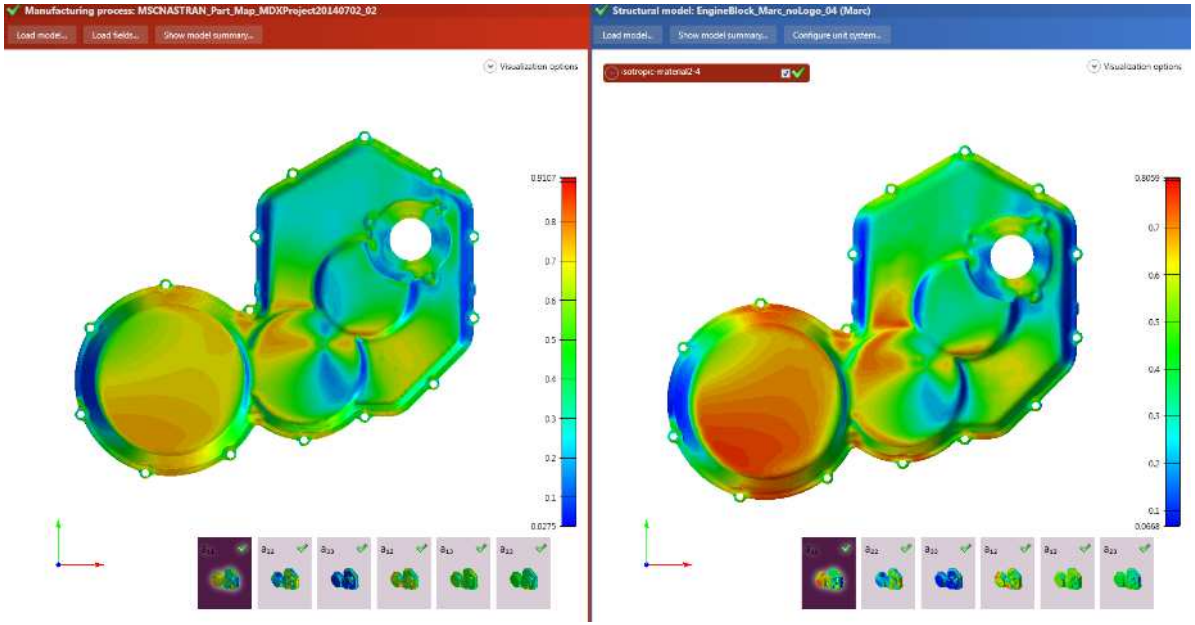
Digimat-RP – Link with manufacturing process



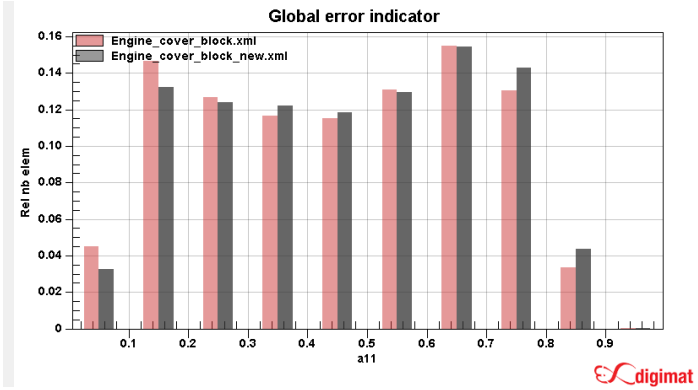
Fiber orientation computed in Moldex

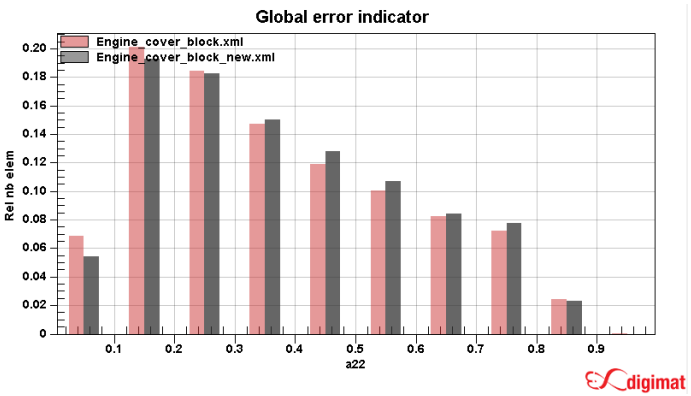
- 337.657 linear tetrahedral elements

Injection and structural mesh are different, mapping is required



- Difference in mesh density
- Fully automatic process
- Fiber orientation data are not degradated





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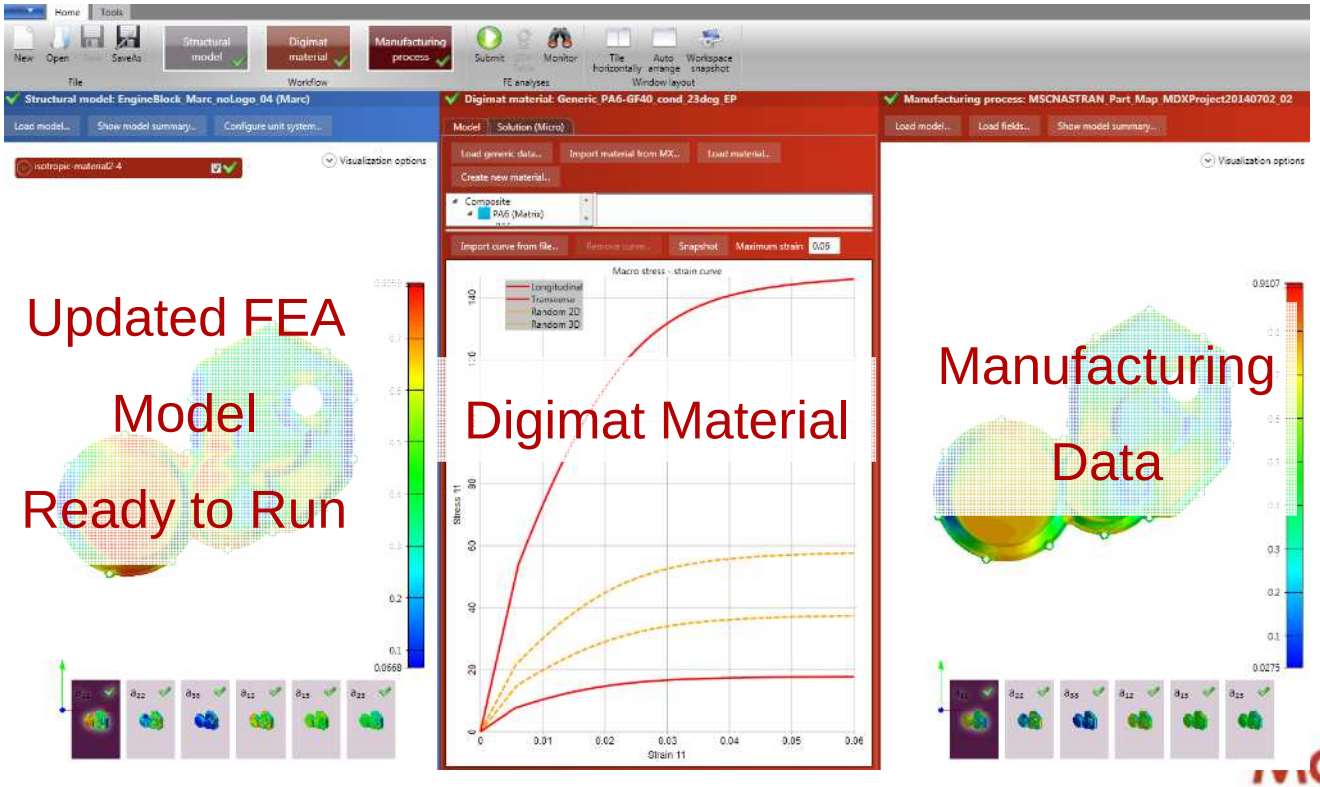
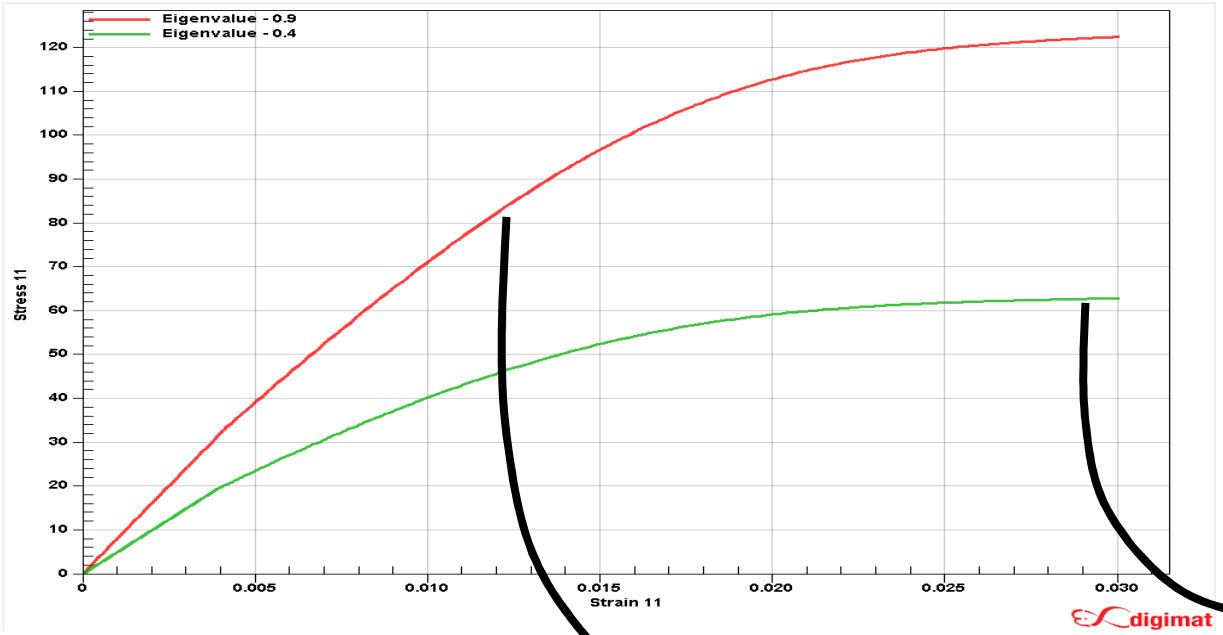
Digimat-RP


Home
Tools
New
Open
SaveAs
Structural model
Digimat material
Manufacturing process
Monitor
Tile horizontally
Auto arrange
Workspace snapshot
File
Workflow
FE analyses
Window layout

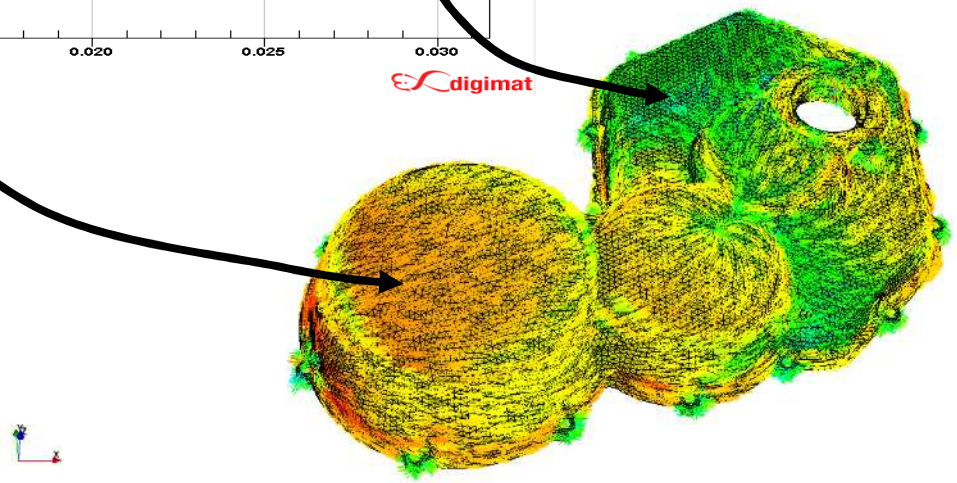

Updated FEA Model Ready to Run
Digimat Material
Manufacturing Data

Effect of the fiber orientation on the material performance



digimat

Response to an uniaxial loading in the x-axis



Displayed value : First eigenvalue

0.365 0.490 0.615 0.740 0.865

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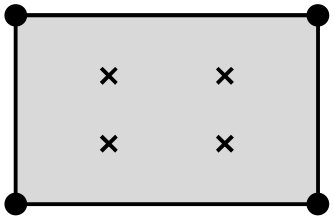
DIGIMAT Technology - Coupling with CAE codes

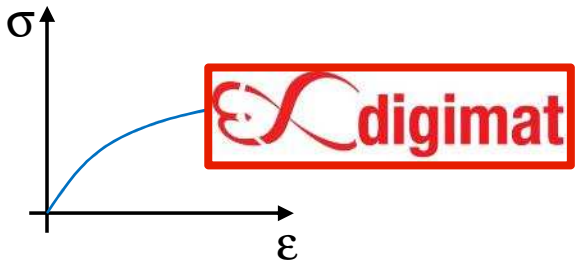
Element level



Strain increments, material state, etc

Internal forces and element stiffnesses

Material level



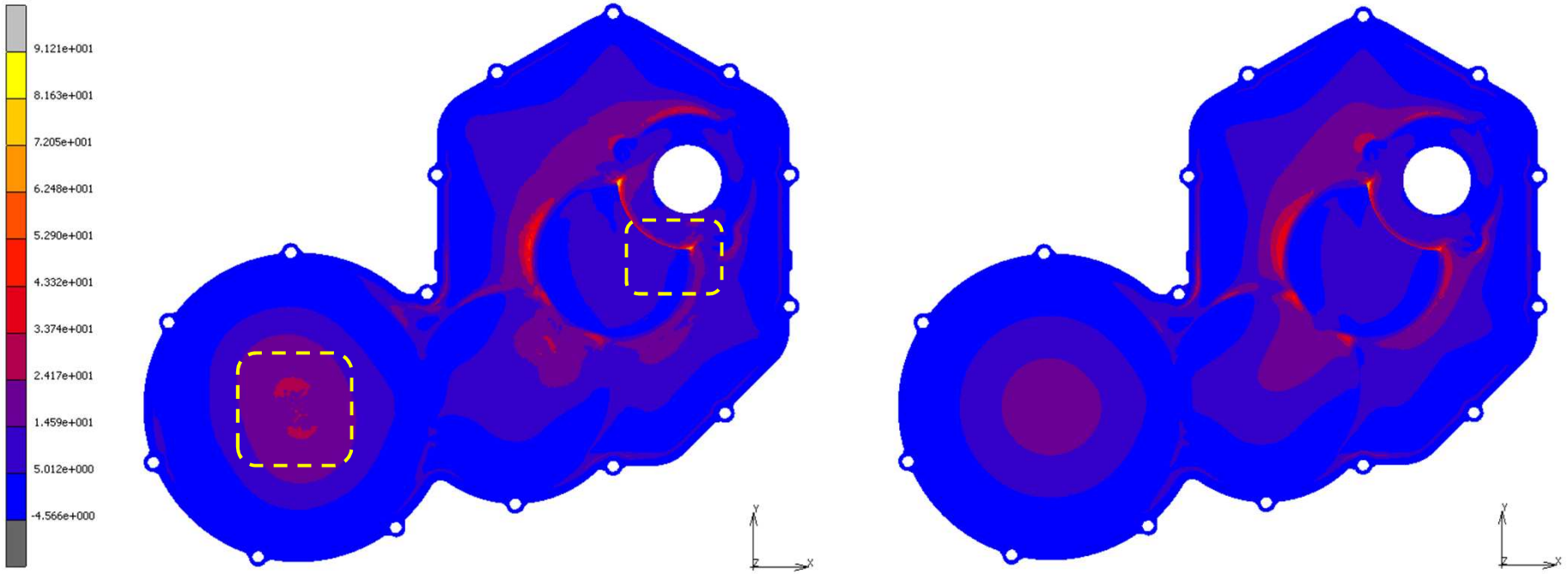
In-code model

Stresses and material stiffness

Fibers orientation

Performance of the part – Isotropic solution vs. Digimat to FEA solution

> Max. principal stress



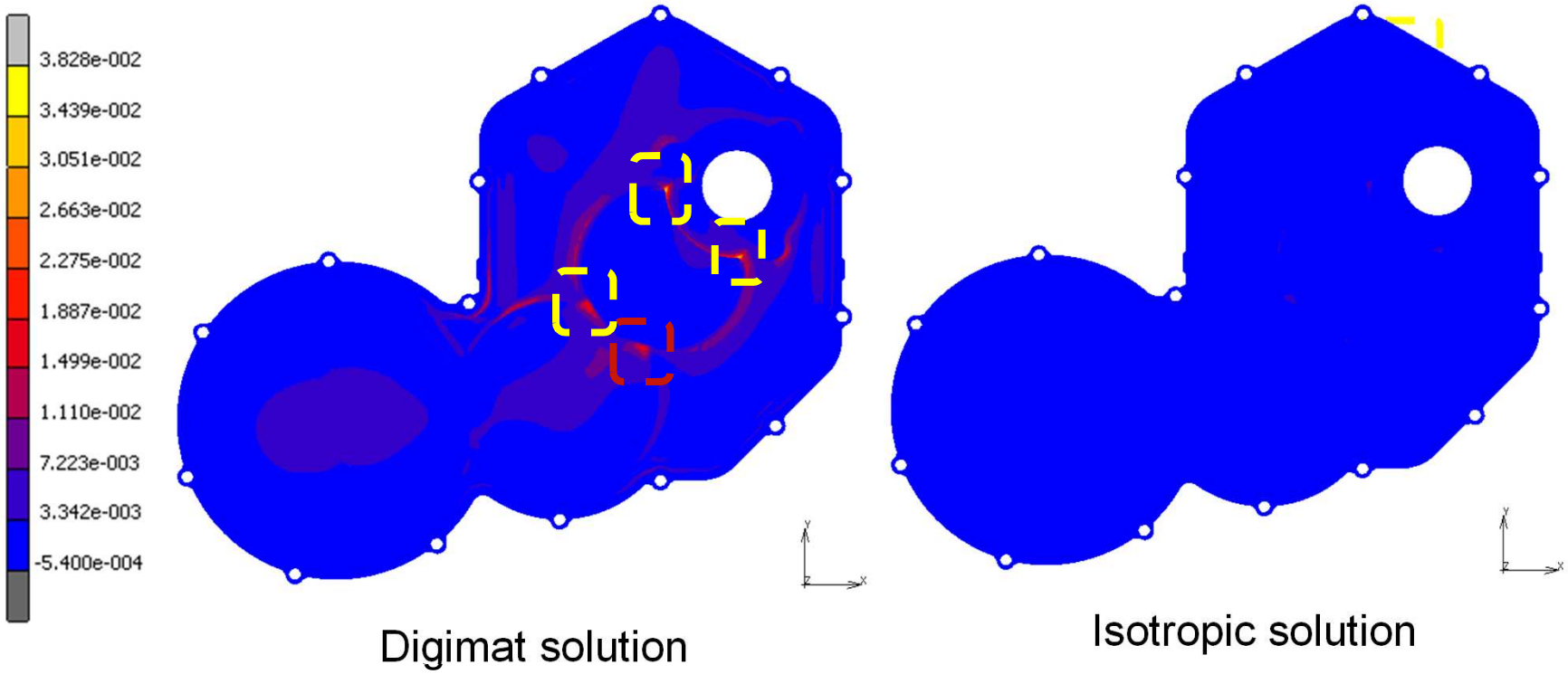
Digimat solution

Isotropic solution

Isotropic solution has been run with an homogeneous elastoplastic material, coming from a law based on a datasheet, test ISO 527

Performance of the part – Isotropic solution vs. Digimat to FEA solution

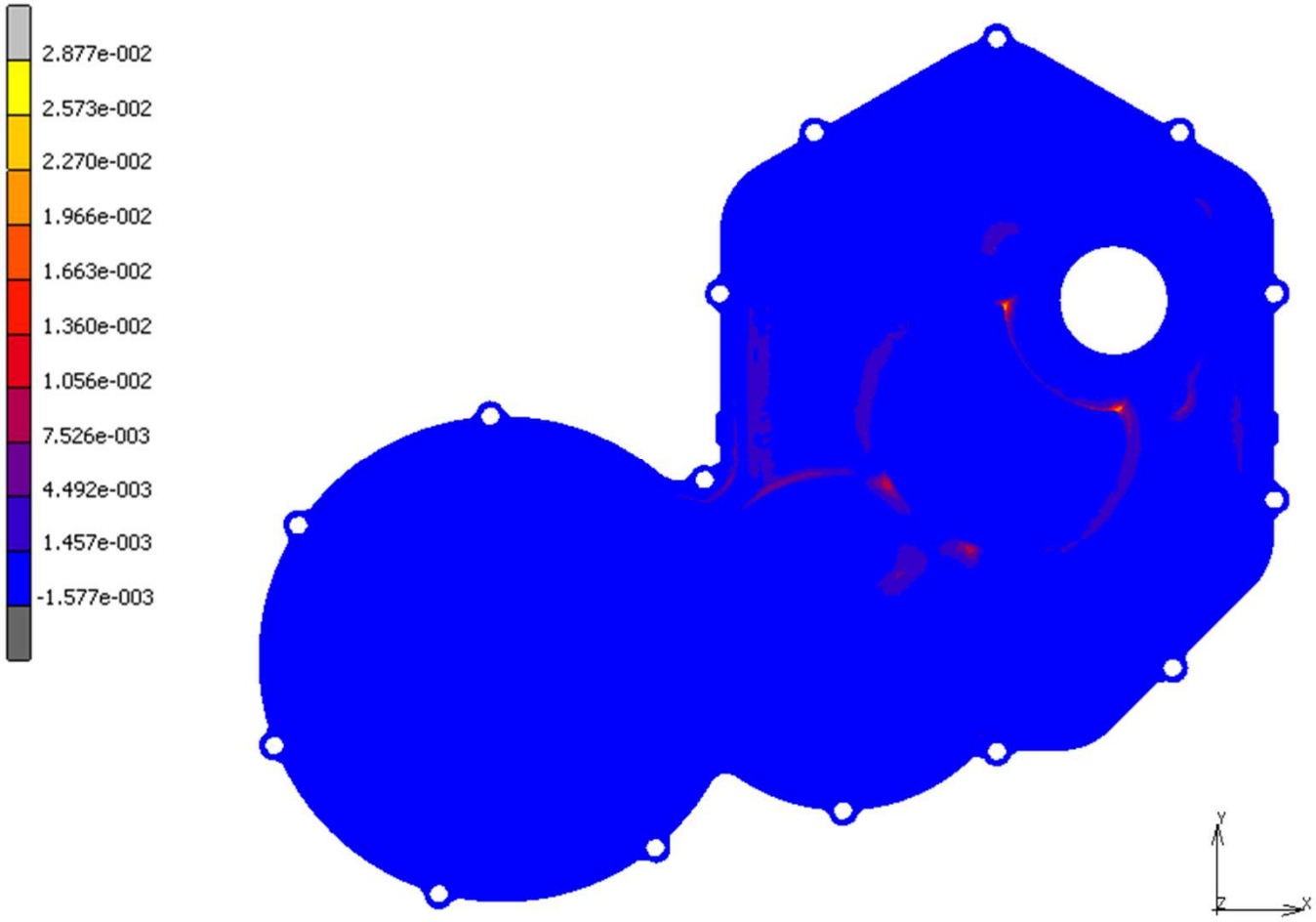
> Max. principal strain



- Isotropic and Digimat solution predicts three common failure area (yellow box) due to geometrical specificities. These zones are larger in Digimat than in isotropic solution.
- Due to fiber orientation, a fourth zone is detected by Digimat (red box).

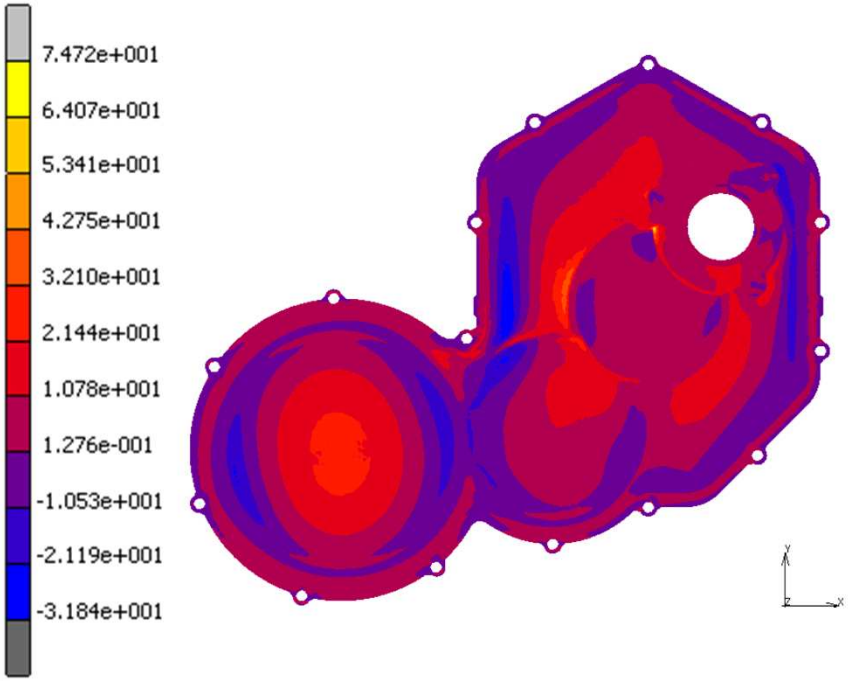
Digimat to FEA solution per-phase results

> Accumulated plastic strain in the resin

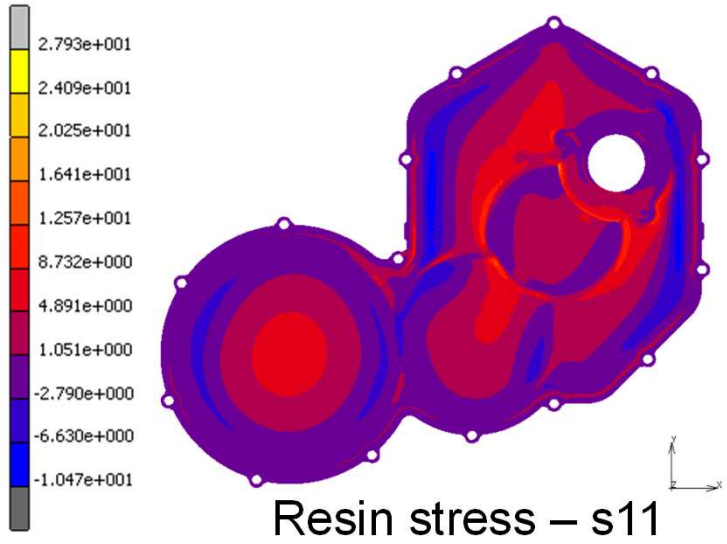


Digimat to FEA solution per-phase results

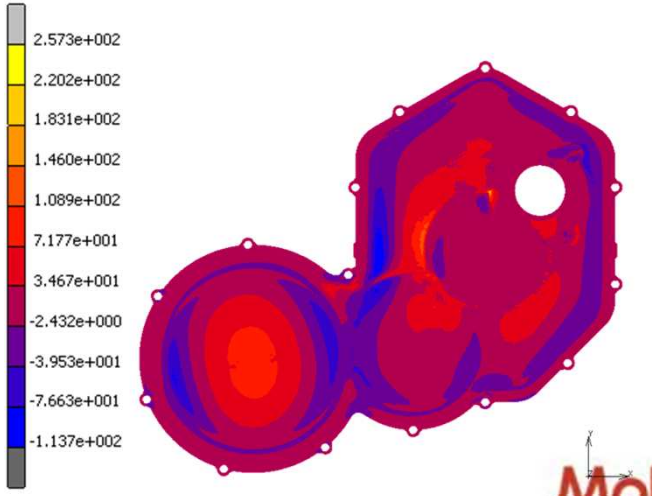
> **Stress distribution between the composite, the fibers and the resin**



Composite stress – s11



Resin stress – s11



Fiber stress – s11

Conclusion

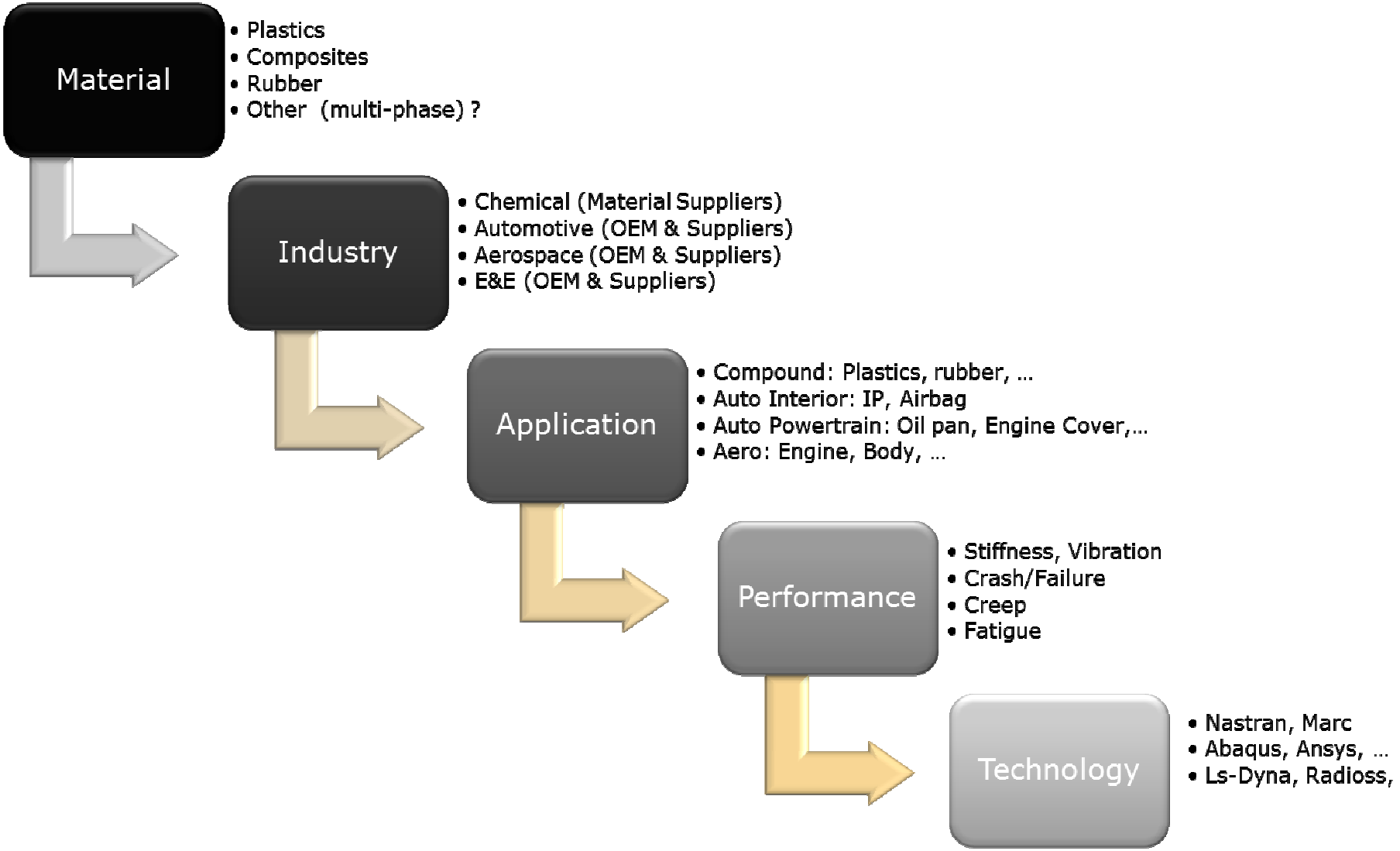
> Capture the local microstructure of the cover engine block and his effect on the material behavior is crucial to predict accurately its deformation under a given loading.

> Stiffness of the cover engine block is predicted by Digimat by taking into account the spatial variations of the material properties and the non-linear behavior of the composite.

> DIGIMAT is used across the industries to

- **Model the behavior of composites as a function of their underlying microstructure.**
- **To bridge the gap between the composite microstructure, as induced by the manufacturing process, and the end-performance of the composite structure.**

Application field – Digimat Performance



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Digimat USERS' MEETING 2014

The material modeling conference

ROME

Crowne Plaza St Peter's

October 21-23, 2014

Tools, Solutions and Expertise for the end-to-end analysis of Chopped and Continuous Fiber Composite Materials and Structures.

The Highlights of DigimatUM'14 are:

- Progressive Failure analysis of CFRP coupon to Aero Structures
- End-to-end finite element analysis of material RVE
- Robust, Fast and Easy analysis of reinforced plastic parts

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Further info & registration → *www.e-Xstream.com*