DIGIMAT

Faserverstärkte Kunststoffbauteile im Crash

DYNAMORE Infotag, Stuttgart, 26.10.2012

Jan SEYFARTH

Product Manager DIGIMAT

e-Xstream ENGINEERING

MSC Software Company

e-Xstream engineering

Company & Strategy

Who are we...? MSC Software Company!

- ✓ **A team of 24 persons**
  - 15 PhDs (62.5%)
  - 6 MS & BS Engineering (25%)
  - 3 Marketing, Finance & Admin (12.5%)

+ 9 TBH in 4Q2012 & 2013

- ✓ **Material experts**
  - Micromechanics

- ✓ **It's all about composites!!!**

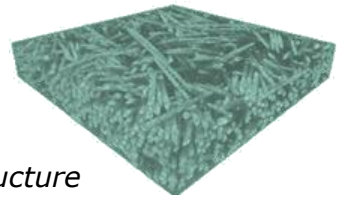
October 2012

What challenges do we tackle...?

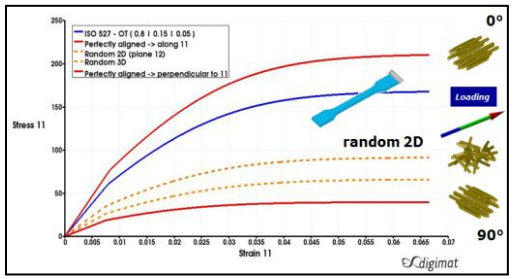
- ✓ **In-depth Understanding of the Material**
  - The microscopic level of composite materials
- ✓ **Material Performance**
  - „Digimat material models“
- ✓ **Multi-Scale simulations**
  - Include microstructure effects via Digimat material models
- ✓ **Influence of Processing**
  - Short fibers: Injection / compression molding
  - UD composites: Draping / fiber placement

Wholistic Multi-Scale Modeling!

- ✓ **MICRO**
  - Material →

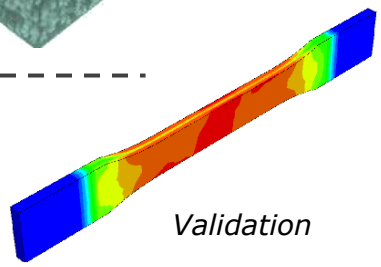


Microstructure



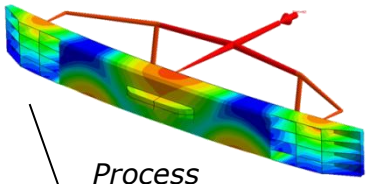
Material model

- ✓ **MACRO**
  - Dumbbell →

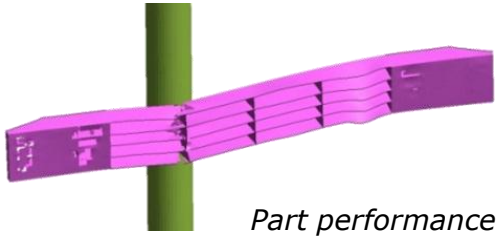


Validation

  - Part →



Process



Part performance

  - System →

System level

Digimat User groups

✓ **Material Engineers** → ***Material suppliers***
Experts (large companies)

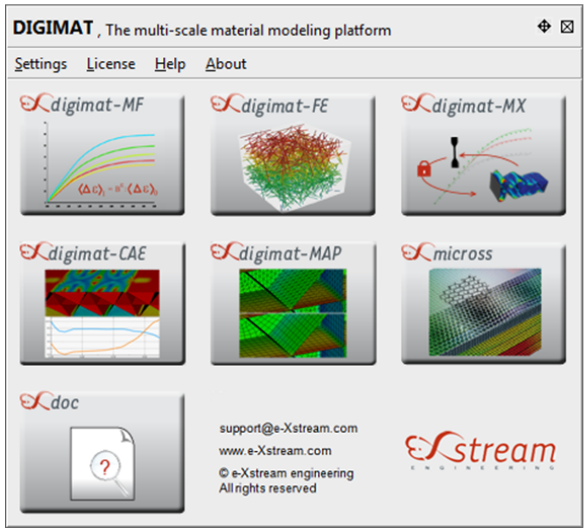
- Understand the material properties
- Develop new materials
- Set up DIGIMAT models
  - Support structural engineers

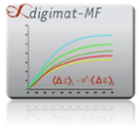
✓ **Structural Engineers** → ***Automotive***
Aerospace
Consumer Electronics
…

- Focus on structural design
- Take into account influence of processing on the structural response
- Use sophisticated material models

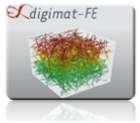
How do we do all this...?

✓ Digimat – The Nonlinear Multi-Scale Modeling Platform

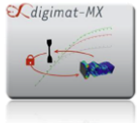




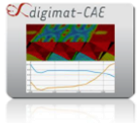
Digimat- MF
to predict the nonlinear constitutive behavior of multi-phase material.



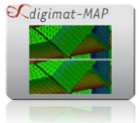
Digimat-FE
to perform Finite Element modeling of realistic Representative Volume Elements (RVE).



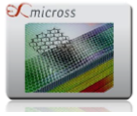
Digimat-MX
to reverse engineer, store, retrieve and securely exchange DIGIMAT material models.



Digimat-CAE
to interface to all major processing and structural FEA software codes.



Digimat-MAP
to map data between dissimilar meshes.



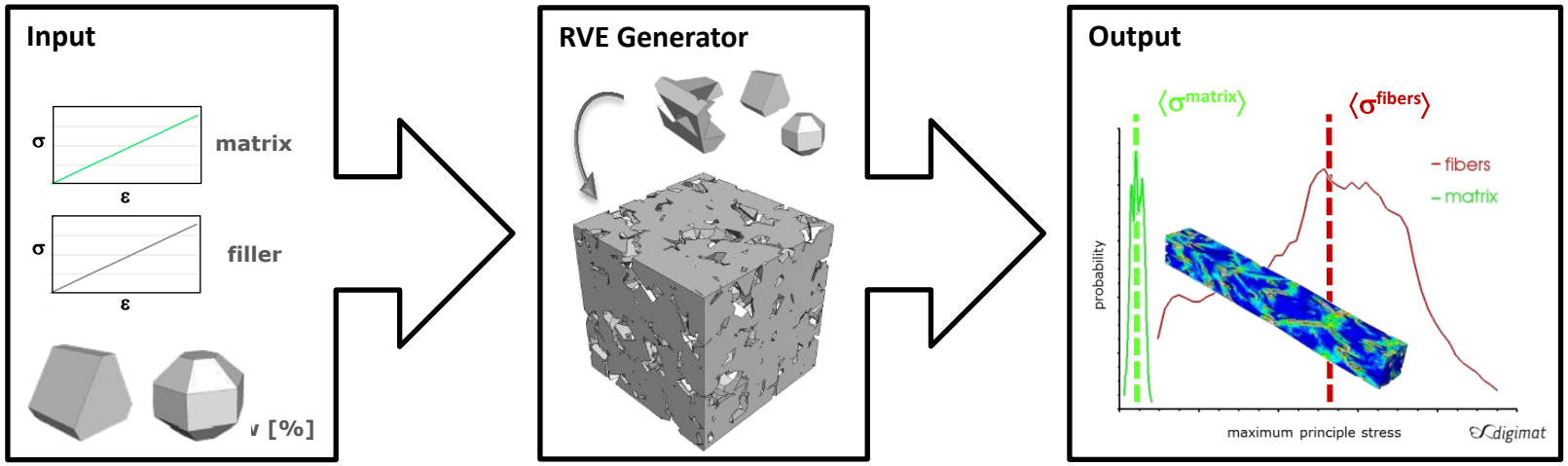
Micross
to design honeycomb core composite sandwich panels based on FE analyses.

Digimat-FE

*F*inite *E*lement Analysis

Digimat-FE

In-depth analysis of composite materials



Per-phase material properties + microstructure information +
RVE settings

Random creation of complex RVEs according to set of parameters

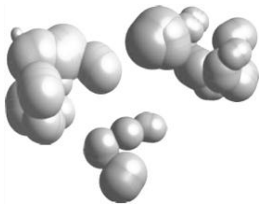
Pre: RVE with complex and realistic microstructure

Post: analysis of result file from external FEA solver

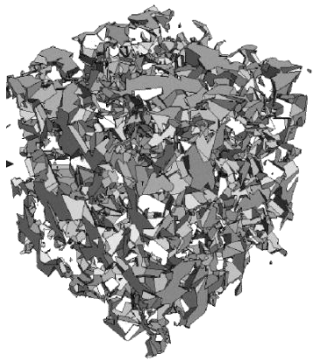
Digimat-FE

Multi-Materials

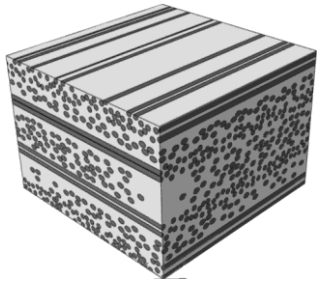
- ✓ **Metal (Alloys)**
  - Aluminium / Magnesium
  - Molybdenum / Titanium / Tungsten
- ✓ **Reinforced Plastics**
  - Epoxy + Glass / Carbon / Aramid fibers
- ✓ **Ceramics**
  - Titanium + SiC fibers



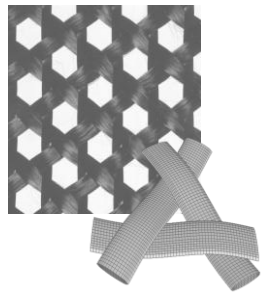
Pores



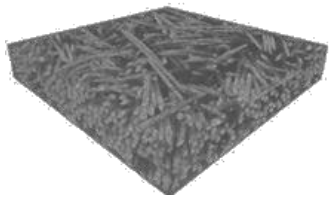
Complex structures



Stacking



Weaving

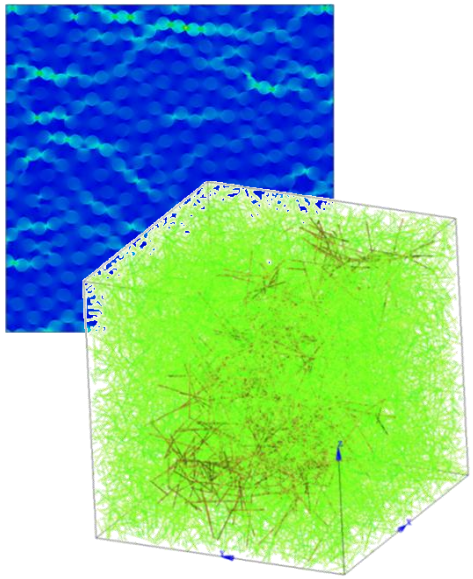


Random

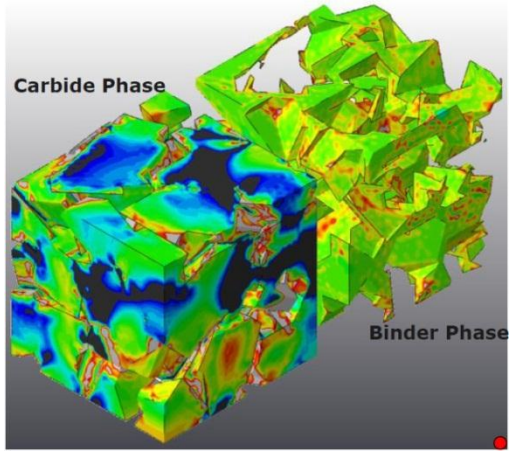
Digimat-FE

Multi-Physics

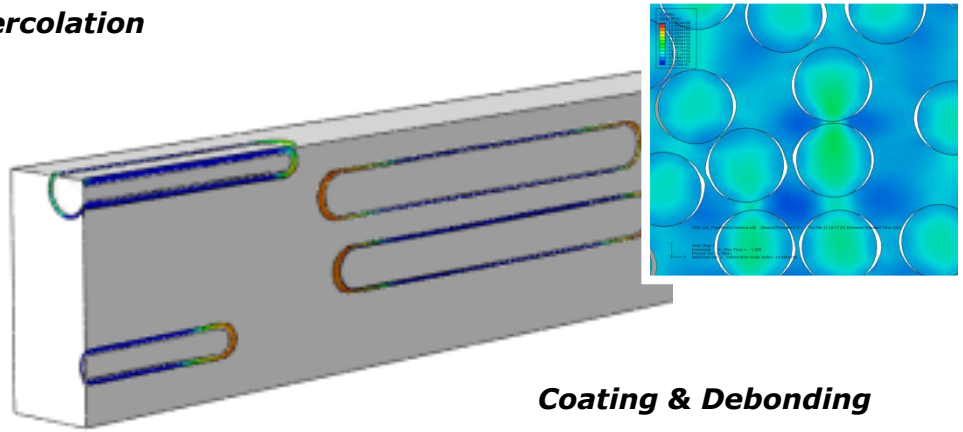
- ✓ **Mechanical properties**
  - Stresses
  - Strains
- ✓ **Thermal Conductivity**
  - Heat flow
- ✓ **Electrical Conductivity**
  - Percolation
- ✓ **Interphases & Debonding**



Percolation



Stresses in phases



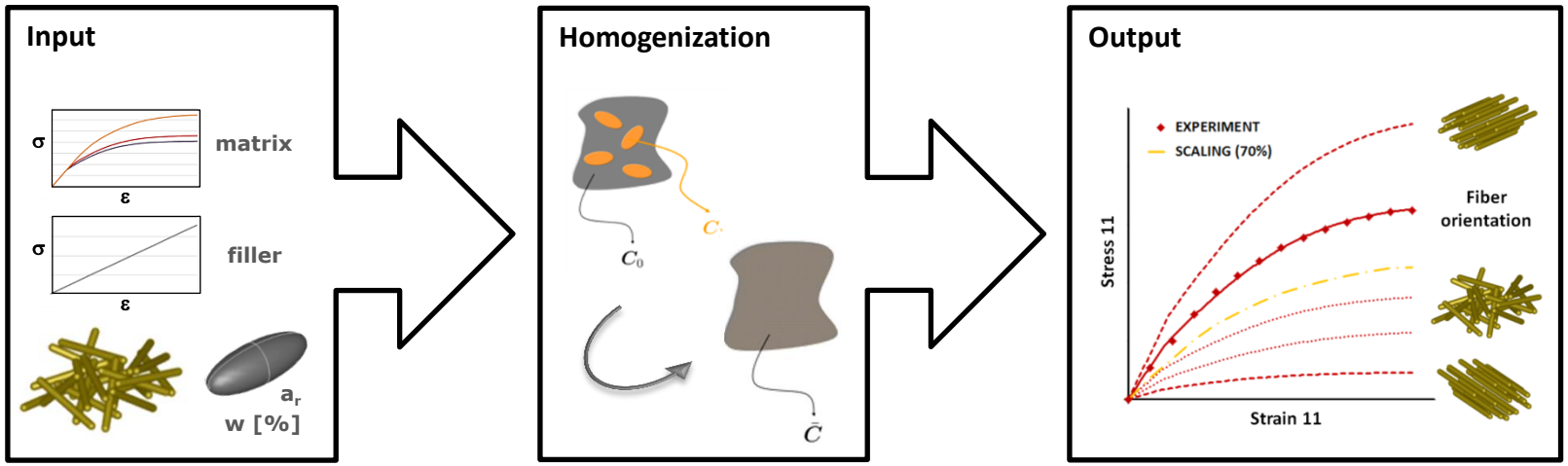
Coating & Debonding

Digimat-MF

*M*ean *F*ield Homogenization

Digimat-MF

Fast & efficient prediction of composite material properties



Per-phase material properties + microstructure information

State-of-the-art homogenization methods

DIGIMAT material model sensitive to composite microstructure

Digimat-MF

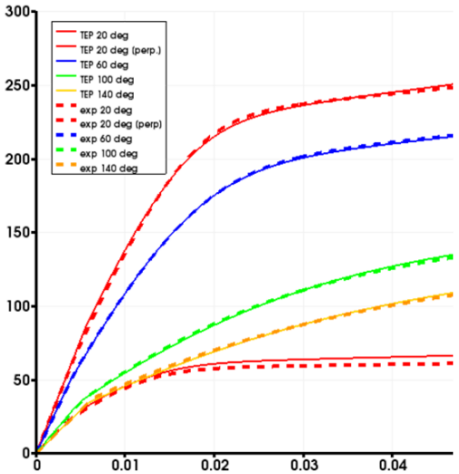
Fast & efficient prediction of composite material properties

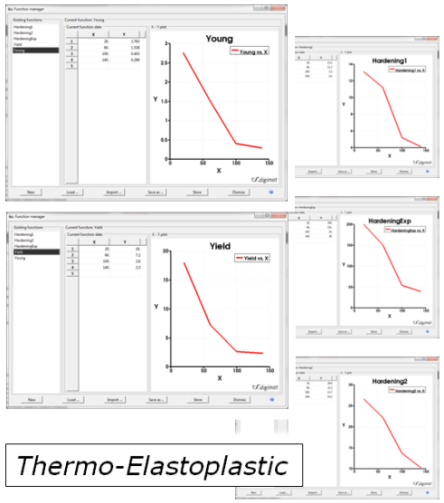
✓ Material focus

	MATERIALS		MICROSTRUCTURE			PROCESSING
	Matrix	Fibers	Inclusion	Orientation	Setup	Technology
Short fibers	Thermoplast	Glass (Carbon)	Straight	Random	Skin/core	Injection molding
Long Fibers	Thermoplast Thermoset	Glass Natural	Straight Wavy	Random Bundling	Complex Layers	Injection molding Compression molding
Continuous Fibers	Thermoset (Thermoplast)	Glass Carbon	Straight	Fixed	Stacked	Draping

DIGIMAT Material Models

- ✓ (Thermo-) Elastic
- ✓ (Thermo-) Elastoplastic
- ✓ (Thermo-) Viscoelastic
- ✓ (Thermo-) Elasto-Viscoplastic





Thermo-Elastoplastic

f(OT)

ANISOTROPY

f(T)

TEMPERATURE

f(τ)

STRAIN RATES

High strain rates

Creep

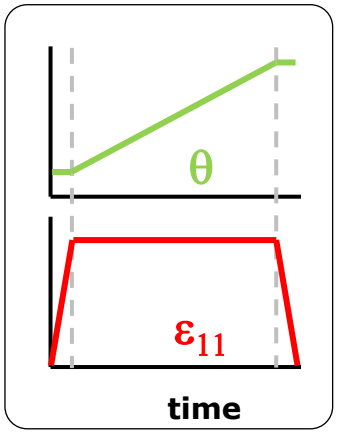
DIGIMAT Material Models

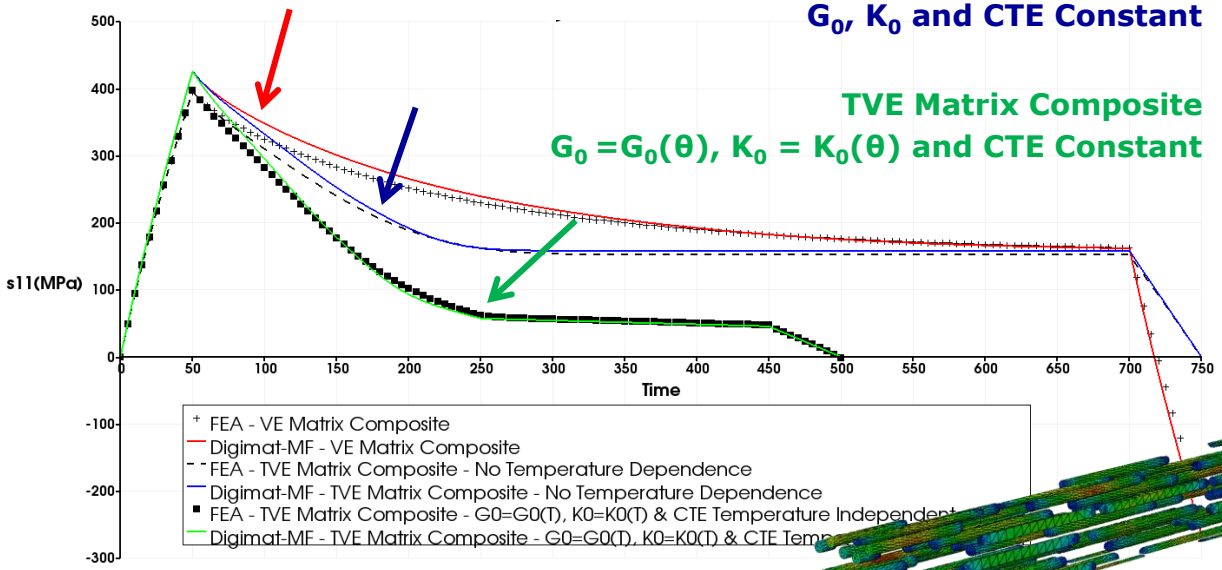
- ✓ (Thermal) Creep

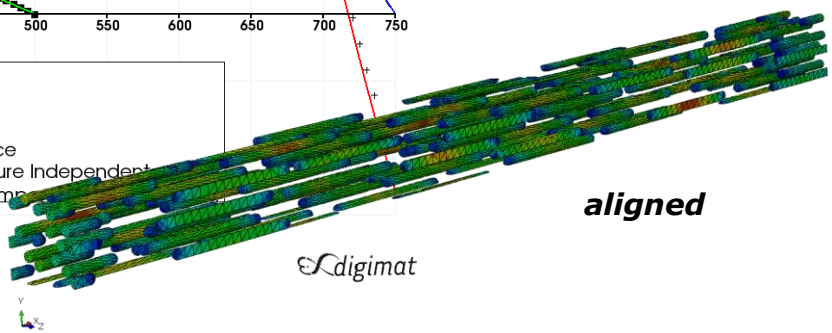
VE Matrix Composite

TVE Matrix Composite
G_0, K_0 and CTE Constant

TVE Matrix Composite
$G_0 = G_0(\theta)$, $K_0 = K_0(\theta)$ and CTE Constant





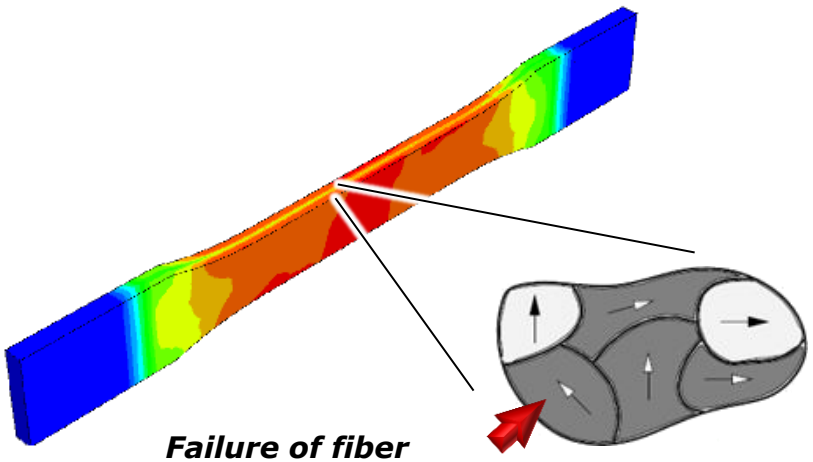


aligned

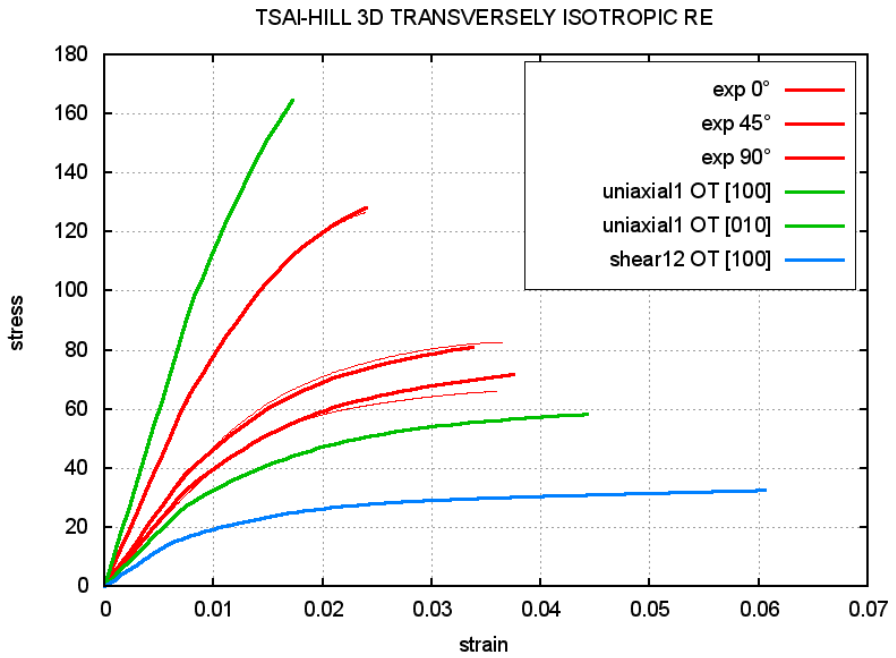
DIGIMAT Material Models

✓ Failure of SFRP (Short Fiber Reinforced Plastics)

- Pseudo grain level



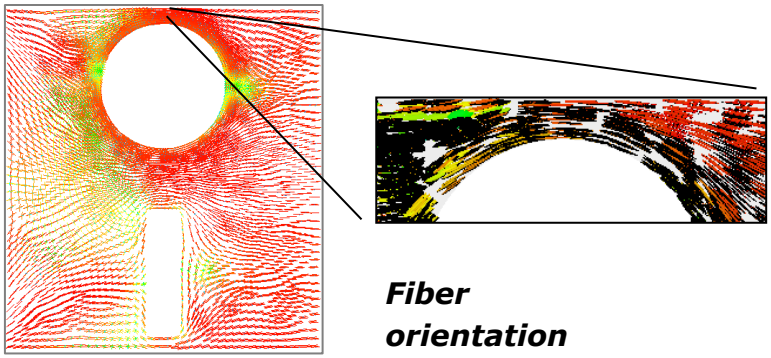
Failure of fiber reinforced plastics



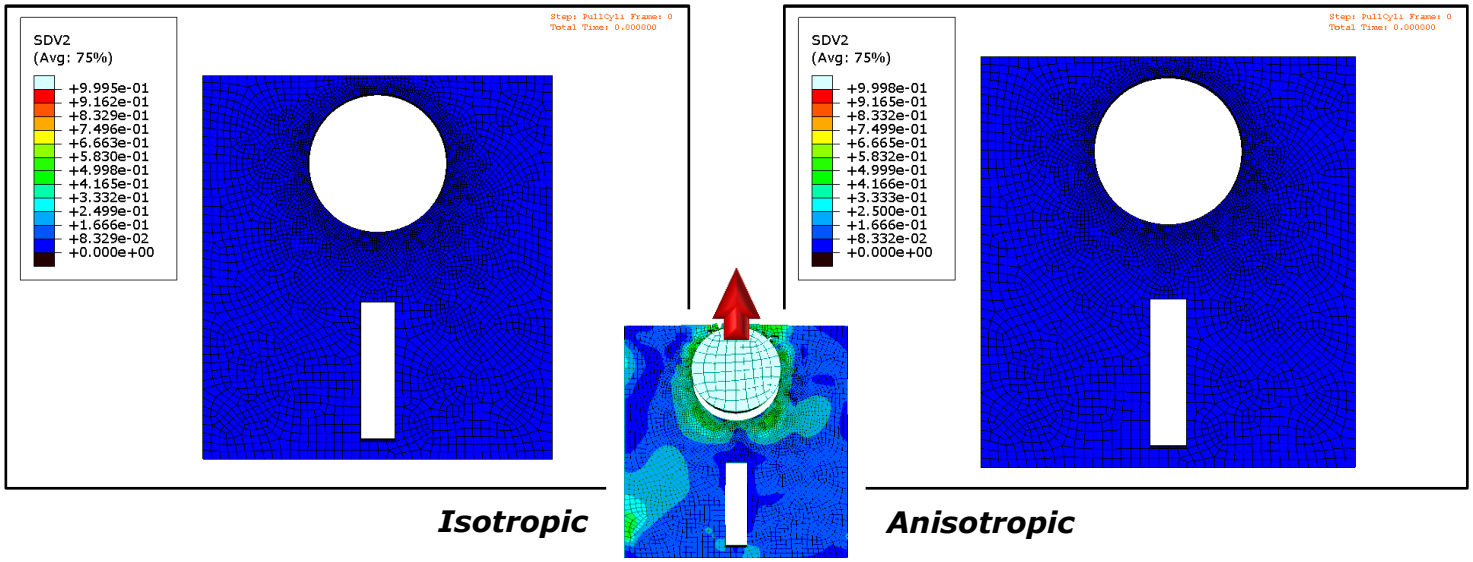
Digimat-MF

DIGIMAT Material Models

- ✓ Failure of SFRP
  - Pseudo grain level



Fiber orientation

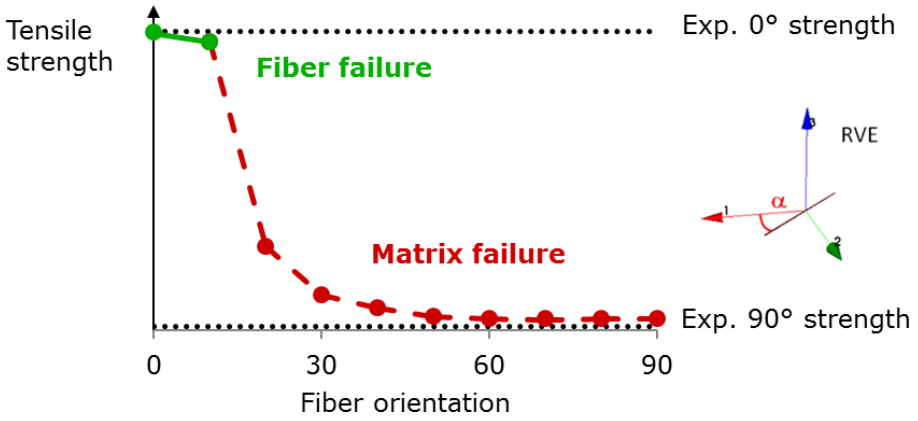


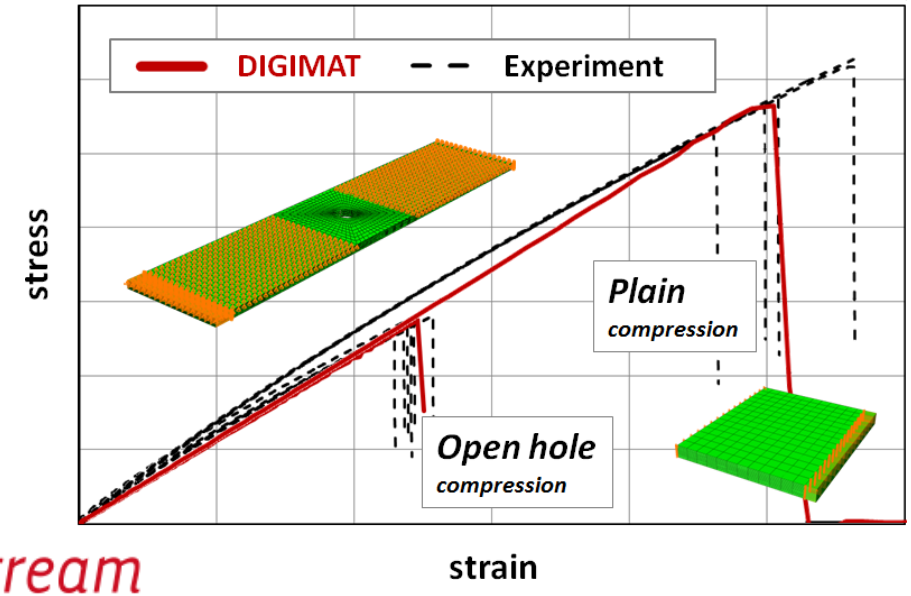
Isotropic ***Anisotropic***

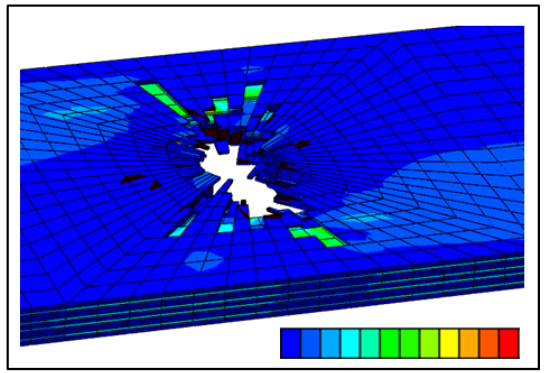
Loading

DIGIMAT Material Models

- ✓ Failure of UD composites
  - Ply level, from micro







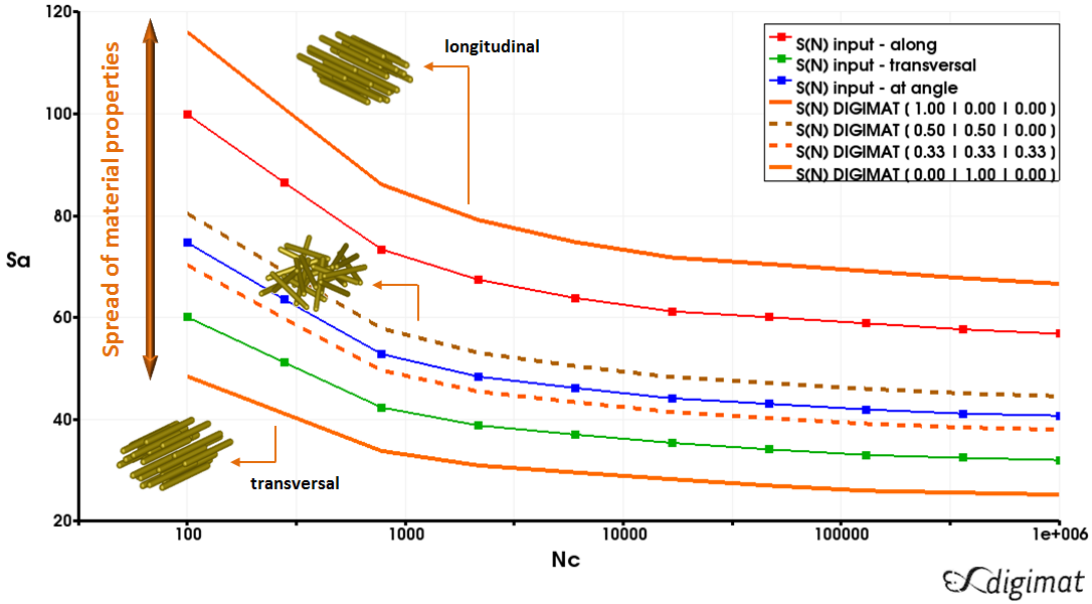
Failure in fiber phase

[sane | failed]

Digimat-MF

- Fast & efficient prediction of composite material properties

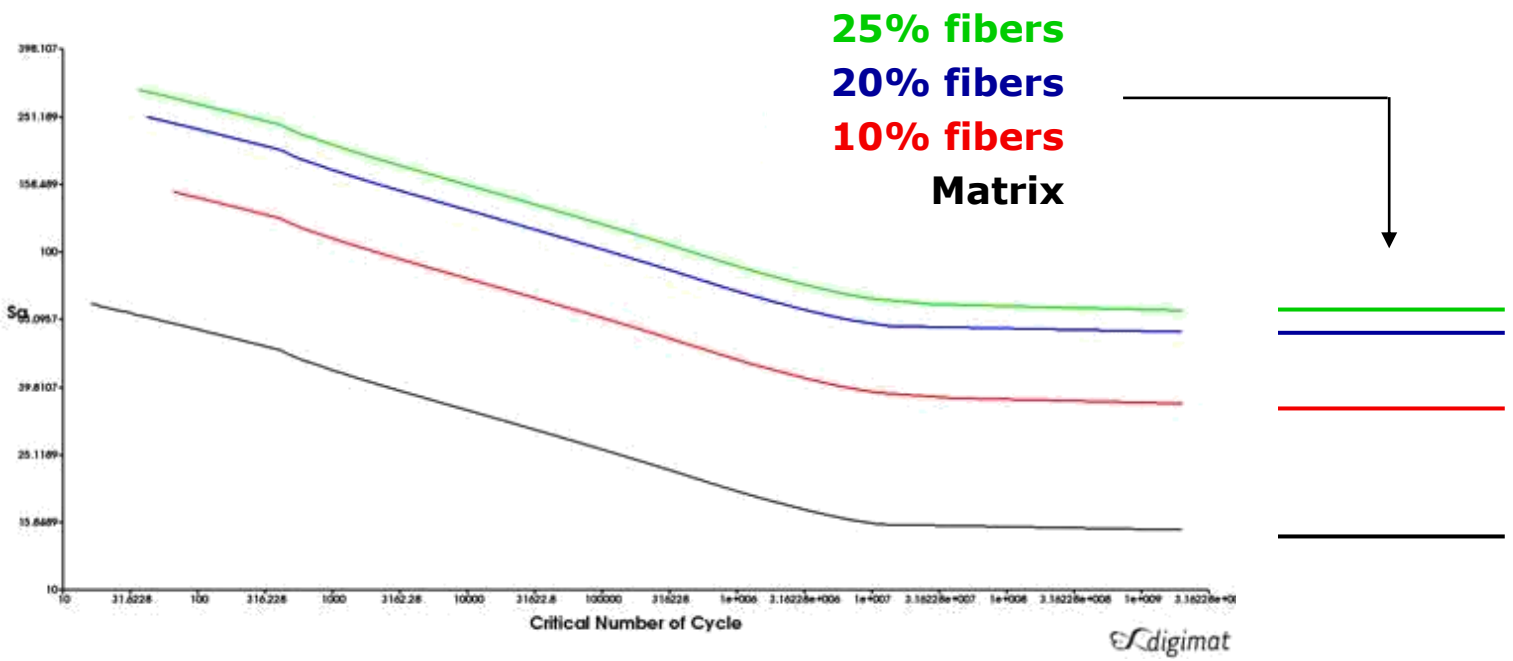
  - ✓ **Short fiber reinforced plastics & Classical Composites**
    - Fatigue
      - S(N) curves ***dependent on orientation*** of fibers



Digimat-MF

- Fast & efficient prediction of composite material properties

  - ✓ **Short fiber reinforced plastics & Classical Composites**
    - Fatigue
      - S(N) curves ***dependent on amount*** of fibers

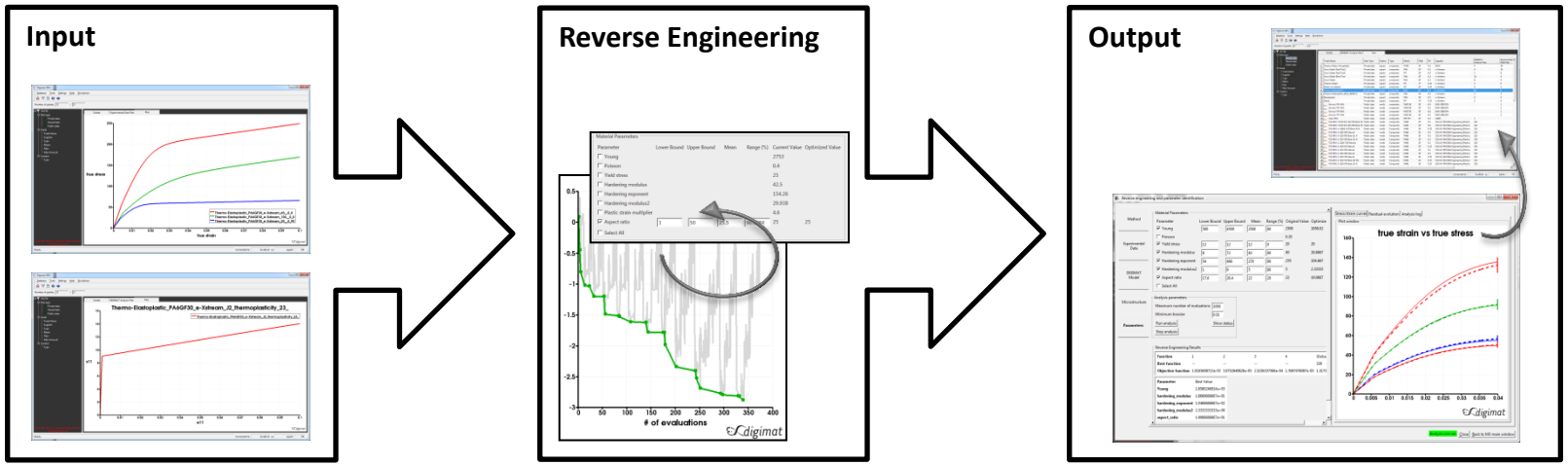


Digimat-MX

*M*aterial e*X*change Platform

Digimat-MX

- Parametrize & eXchange DIGIMAT material models



Experimental data, DIGIMAT material models stored in database

Calibration of DIGIMAT models based on experimental data

Calibrated DIGIMAT Material Model, stored in database and ready to be shared and used

Digimat-MX

- Parametrize & eXchange DIGIMAT material models

  - ✓ **Public data**
    - Ready-to-use DIGIMAT models
    - Experimental data for parametrization of DIGIMAT models

Digimat-MX

- Parametrize & eXchange DIGIMAT material models

  - ✓ **Database**
    - Public database
      - Contains entries from material suppliers
    - Sharing controled by priviliges
      - User/Group

  - ✓ **Encryption**
    - Intellectual property
    - Exchange of data between
      - Material suppliers
      - Application engineers

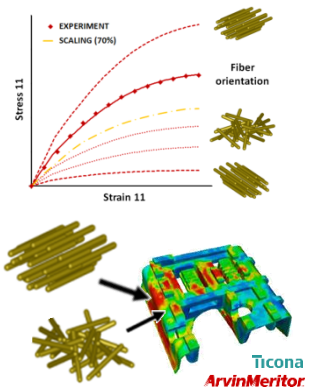
Digimat-CAE

Interfaces to FEA
Interfaces to Processing

Digimat-CAE

Bridge the gap between processing and structural mechanics

Input

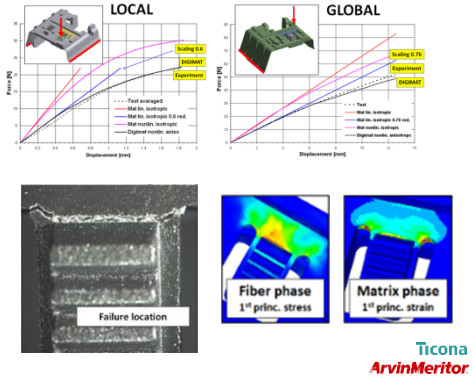


DIGIMAT material model + local microstructure (from processing simulation)

Interfaces

Weakly or strongly coupled analyses with implicit or explicit FEA solvers

Result



Predictive, high quality results for composite structures

Digimat-CAE

Bridge the gap between processing and structural mechanics

✓ All FEA

- **Implicit**
  - Marc
  - Nastran[5.0.1]
  - Abaqus
  - ANSYS
  - LS-DYNA
  - SAMCEF
- **Explicit**
  - Nastran (SOL700) [5.0.1]
  - LS-DYNA
  - Abaqus
  - Radioss
  - Pamcrash

✓ Integration into CAE environment

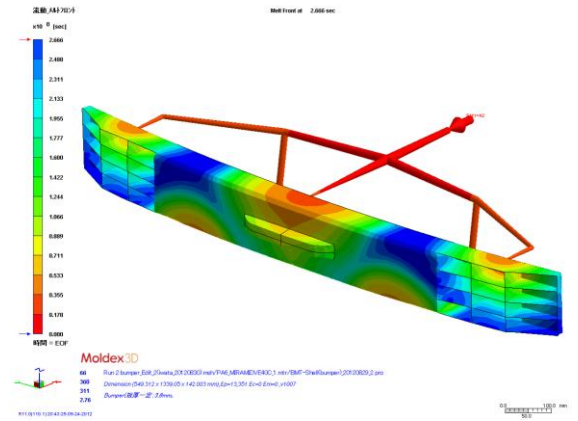
- Marc Mentat
- Abaqus CAE
- ANSYS WB
- Hypermesh

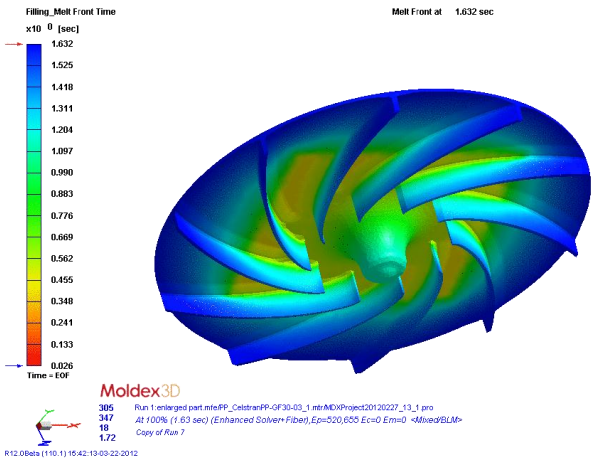
Digimat-CAE

Bridge the gap between processing and structural mechanics

✓ **All processes**

- **Short / long fibers**
  - Injection molding
  - Compression molding
  - Injection/compression molding
- **UD composites**
  - Draping
  - Fiber placement
- **Others**
  - Mucell





Digimat-CAE

From Processing to FEA

Measurements

σ/ε curves

Material Model

Anisotropic (non)linear

Mapping

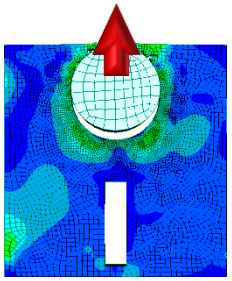
→ Structural mesh

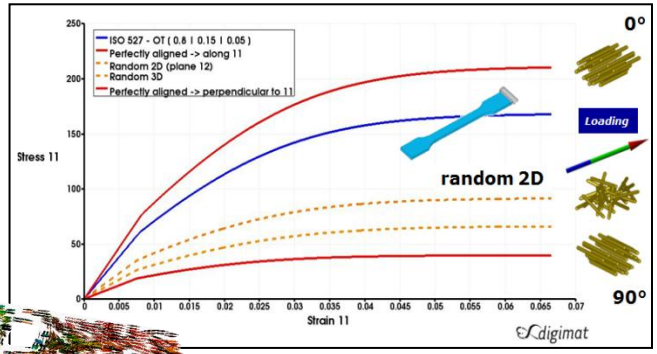
Process Simulation

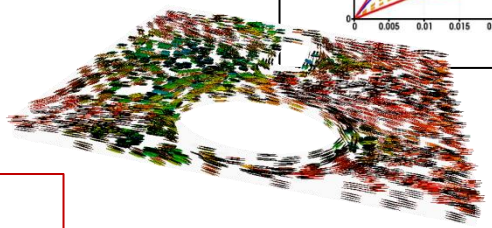
Orientation data on processing mesh

FEA

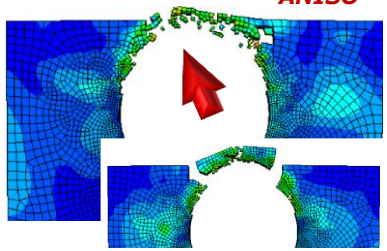
Structural analysis





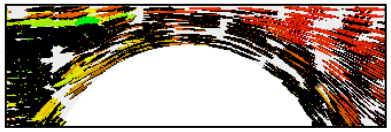


ANISO



ISO

failure

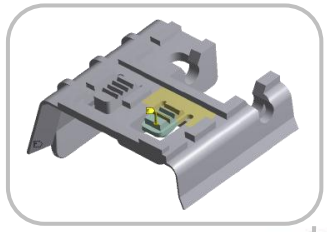


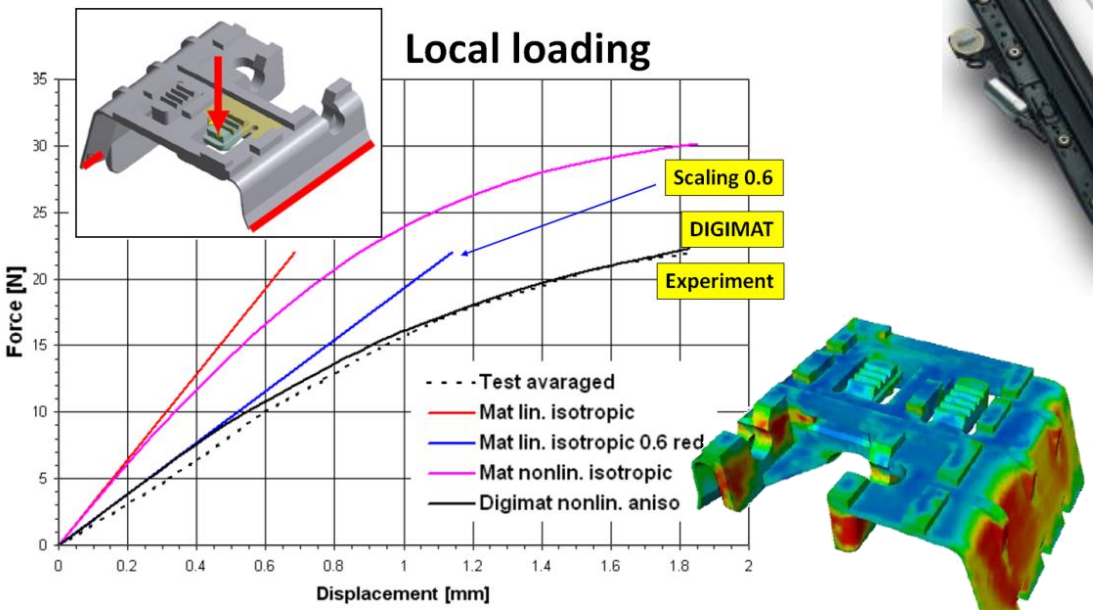
fibers

Digimat-CAE

Short fiber reinforced plastics

- ✓ **Part level**
  - High quality results





INTEVA PRODUCTS

Ticona

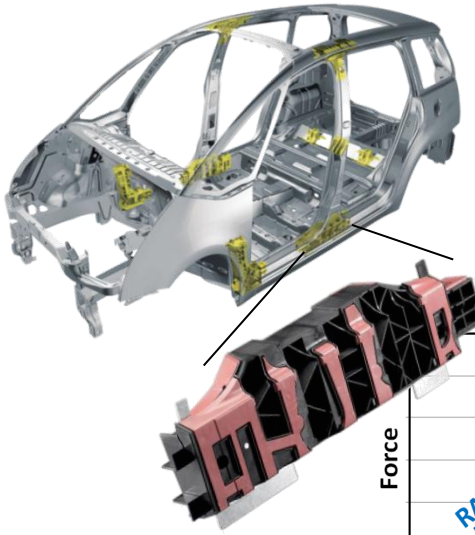
e-Xstream ENGINEERING MSC Software Company

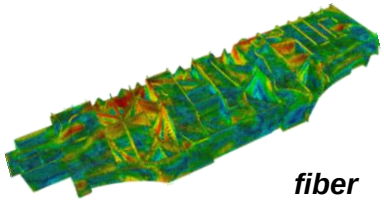
Digimat-CAE

Short fiber reinforced plastics

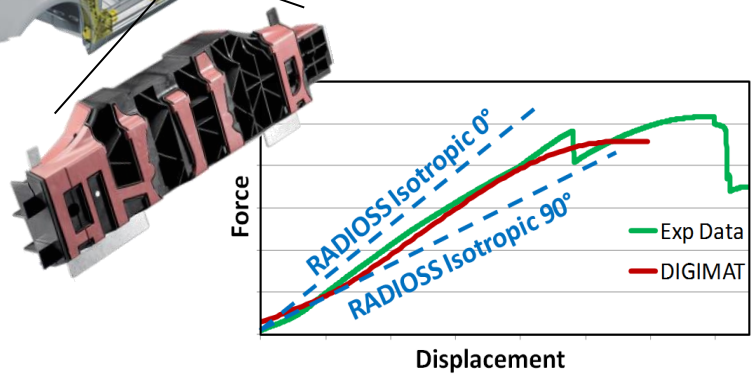
L&L Products Europe

- ✓ **Part level**
  - High quality results
  - Local response / failure predicted correctly

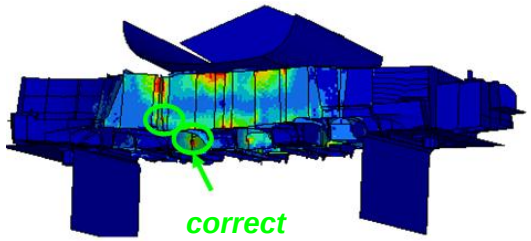




fiber orientations



DIGIMAT



classical design

e-Xstream engineering
MSC Software Company

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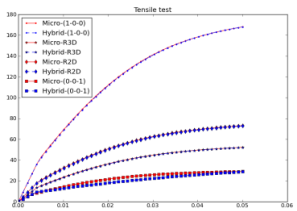
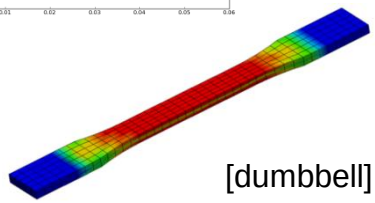
HYBRID Solution → speed-up for explicit simulations

- ✓ **CPU time can become critical**
  - Levels of application



[RVE]



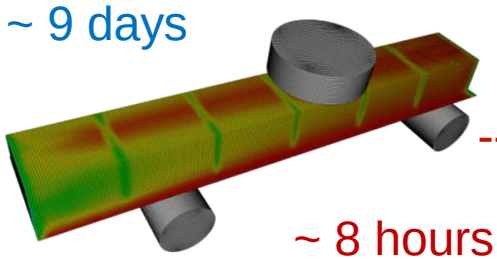
[dumbbell]

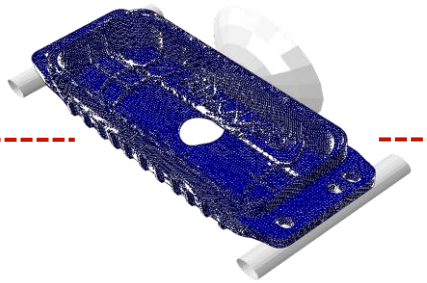
ACCURATE

MICRO

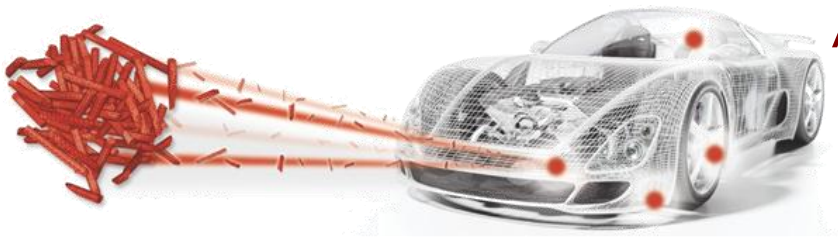
[part/assembly]

~ 9 days





~ 8 hours



APPROXIMATE

HYBRID

[system]

Digimat-CAE

HYBRID Solution → speed-up for explicit simulations

✓ **CPU time can become critical**

- Change in internal solution procedures
- Reduction of information exchange to the macroscopic level
  - Usage of homogenization („Micro“) approach in a pre-processing step
  - Reverse engineering to deliver a good approximation to the exact („Micro“) solution
  - Per-phase („Micro“) results skipped
- Available for
  - Stiffness for E, EP, EVP
  - Failure in 3D

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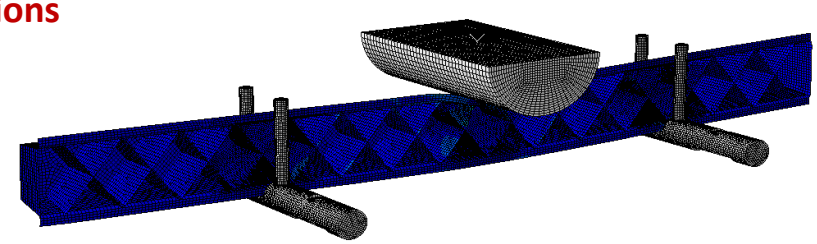
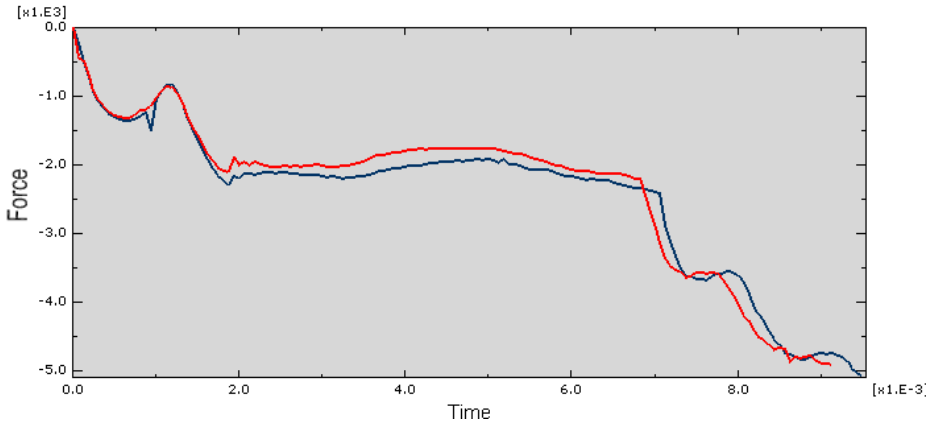
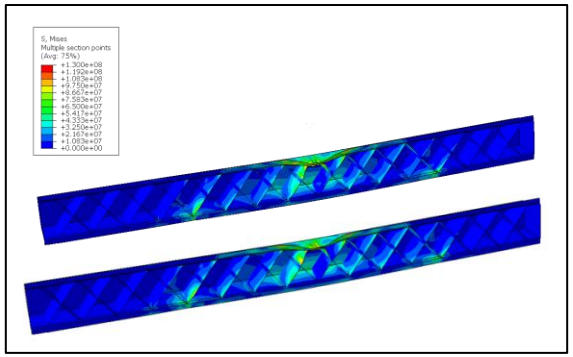
HYBRID Solution → speed-up for explicit simulations



✓ Results comparable to MICRO solution





Solution	Nb. Increment	CPU	CPU per increment and per proc	CPU ratio
Micro	24456	207 h 55 min (3 procs)	1,53 min	
Hybrid	29601	26 h 08 min (1 proc)	0,053 min	28,9

Speed-up: 9 days → 1 day + 3 variants

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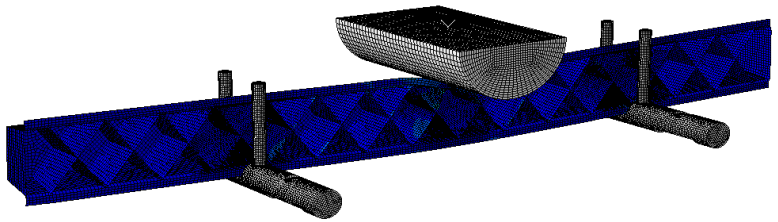
HYBRID Solution → speed-up for explicit simulations



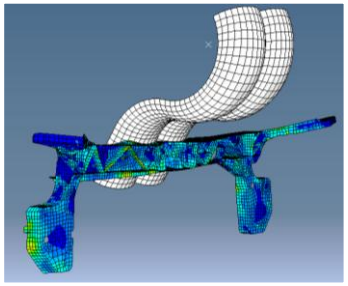
- ✓ **DIGIMAT 4.2.1** January 2012
  - 9 days / 3 CPUs → 1 day / 1 CPU
    - Good global response
    - Good local results

- ✓ **DIGIMAT 4.3.1** July 2012
  - Up to 50% decrease in memory

- ✓ **DIGIMAT 5.0.1** January 2013
  - About 30 – 50% gain in CPU
  - Up to 40% decrease in memory
  - Failure fully strain rate dependent

8 hours / 3 CPUs {4.2.1}

35 min. {5.0.1}



OT format	Version	1 Proc
.xml OT file	4.2.1	22 GB
	4.3.1	8 GB
.dof OT file	4.2.1	12 GB
	4.3.1	8 GB

Model size: 1.3 Mio elements

Digimat-CAE

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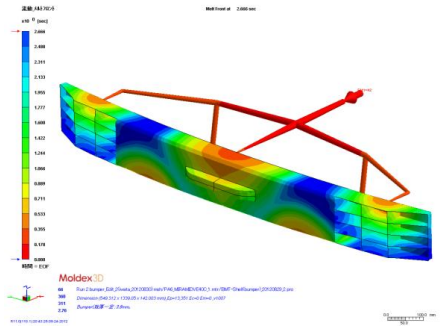
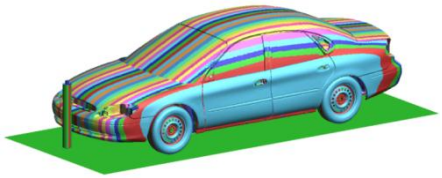
Full vehicle System Level

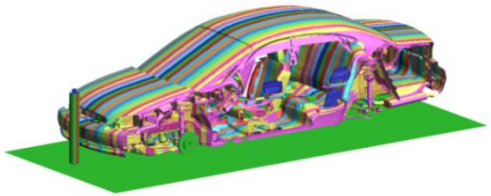


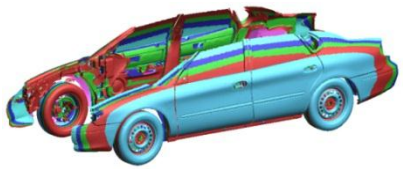
- ✓ **Pedestrian safety**
  - Bumper beam

Elements	3.1 Mio
Ave. elem size	5.0 [mm]
Min. time step	0.25 [µsec]
DIGIMAT	0.84% (26.000)



10 domains have no DIGIMAT elements





DIGIMAT elements in 22 domains

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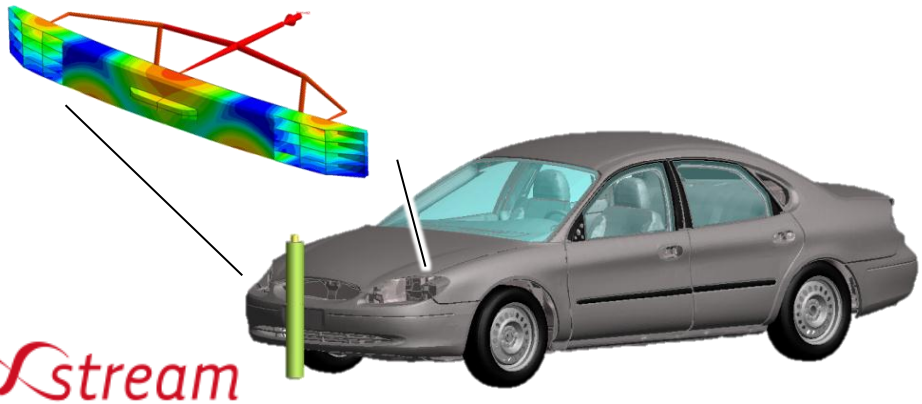
Full vehicle System Level

- ✓ **Acceptable increase of calculation time**
  - 9 →14 hours on 32 cores
  - Only 8 hours on 64 cores
- ✓ **Loss in efficiency for ISOTROPIC**
  - On 64 cores
  - Overhead of communication



YES – WE CAN…!!!!!

	16 cores	32 cores	64 cores
ISOTROPIC improved	17 h 59 m	9 h 17 m	10 h 0 m
HYBRID default	-	42 h 31 m	-
HYBRID improved	26 h 37 m	14 h 16 m	8 h 15 m
HYBRID optimized	-	12 h 5m	-
MICRO improved	-	152 h 51 m (6.4 days)	-

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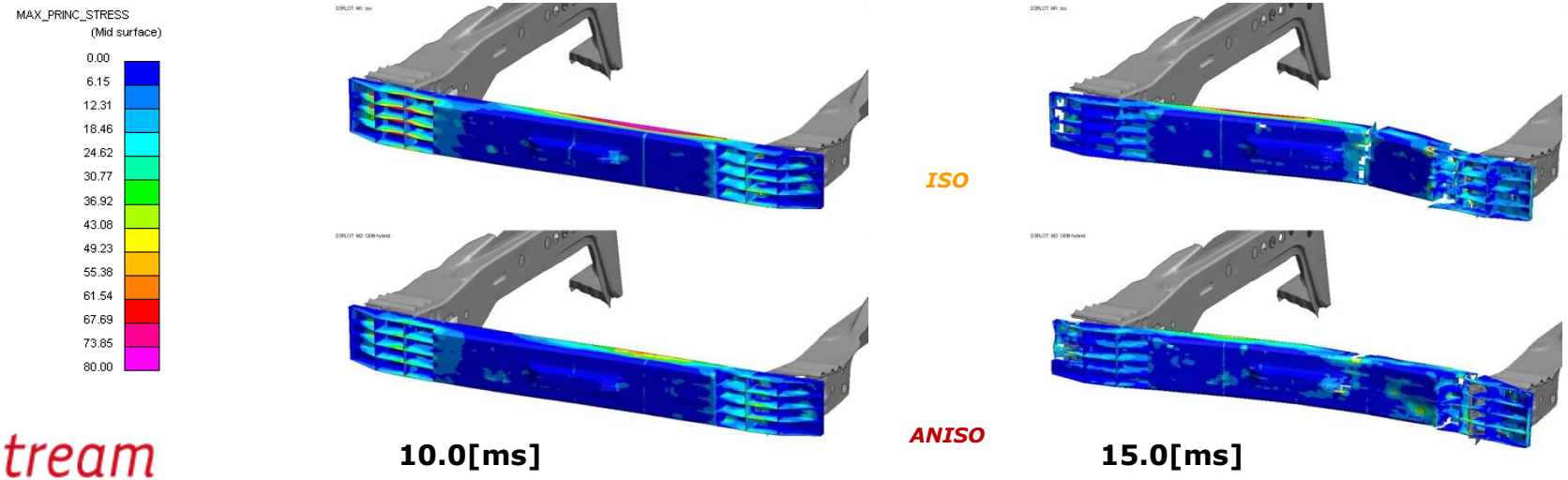
Full vehicle System Level

- ✓ **Front crash**
  - Comparison to isotropic
    - Stress distribution different
    - Failure area different



Digimat

- **Thank you for your attention!**

  - ✓ **Any questions…?**

e-Xstream engineering

Dr. Jan Seyfarth

Product Manager DIGIMAT

e-Xstream engineering (L)

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