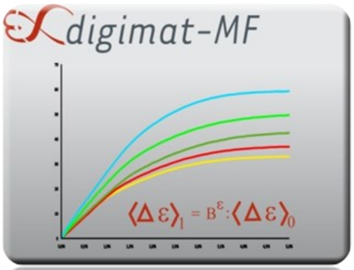
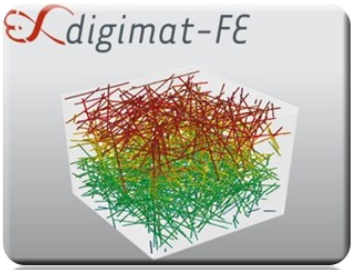
Digimat

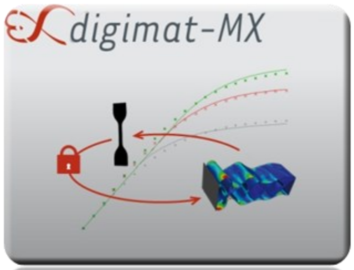
Release 4.5.1 – July 2013



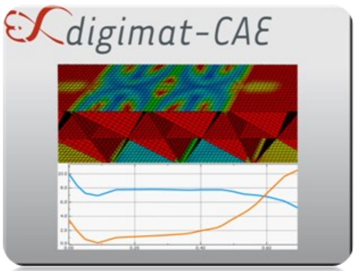
For a fast & accurate prediction of the nonlinear behavior of multi-phase materials using Mean-Field homogenization technology.



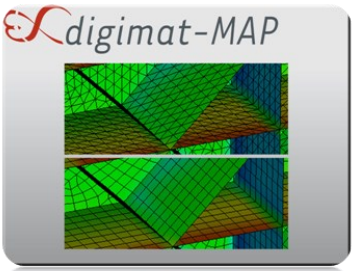
For an accurate prediction of the local/global nonlinear behavior of multi-phase materials using FEA of realistic Representative Volume Element (RVE).



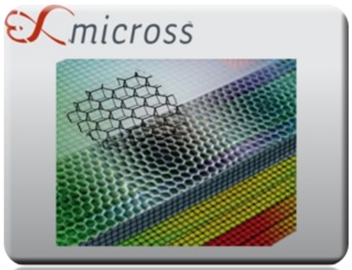
For the preparation, storage, retrieval and secure exchange of Digimat material models between material suppliers and users, while protecting Intellectual Property.



Interfaces to process and structural FEA codes for an accurate prediction of composite materials and reinforced platics parts performance using non-linear multi-scale modeling approach.

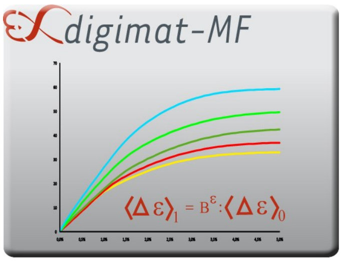


For an efficient mapping of scalar & tensorial data between dissimilar shell and solid FE meshes.



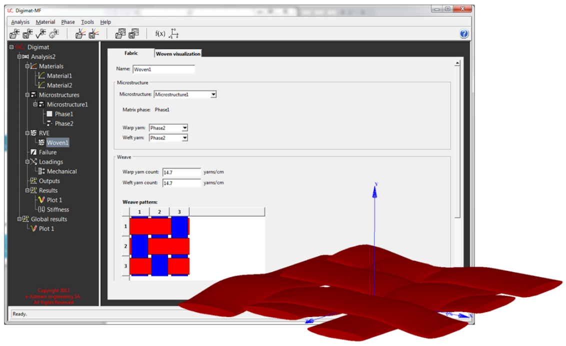
For an easy and efficient design of honeycomb sandwich panels using state-of-the-art micromechanical material modeling technology.

For material suppliers and end-users who suffer from long and costly development cycles, e-Xstream engineering offers Digimat, The nonlinear multi-scale material & structure modeling platform, an innovative and efficient suite of software to accurately predict the nonlinear behavior of composite materials and structures used across the industries.



Mean-Field homogenization software used to predict multi-physical nonlinear behavior of multi-phase materials.

Analyze your multi-phase composite materials in an accurate, efficient and easy way!



Advanced modeling of woven composites

NEW IN Digimat 4.5.1

- **Loading —** improved application of conditions
  - —> Better match with experimental data for
    - Short fiber reinforced plastics
    - UD composites
  - —> Influences prediction of
    - Tension with off-axis oriented fiber
    - Shear

MAIN CAPABILITIES

Nonlinear (per-phase) Material Models

- Linear (Thermo) Elasticity
  —> Isotropic / Transversely isotropic /Orthotropic / Anisotropic
- Linear Viscoelasticity
- (Thermo) Elastoplasticity
  - ◊ J2 Plasticity
    - + Isotropic hardening
      - - Power / Exponential / Exponential linear laws
    - + Kinematic hardening (linear with restoration)
      - - For cyclic elastoplasticity
  - ◊ Drucker-Prager
    - + Pressure-dependent elastoplasticity
- Elastoplasticity with Damage: Lemaître-Chaboche
- (Thermo) Elasto-Viscoplasticity
  —> Norton / Power / Prandtl laws
- Viscoelasticity-Viscoplasticity
- Hyperelasticity (finite strain)
  —> Neo-Hookean / Mooney-Rivlin / Ogden / Swanson / Storakers (compressible foams)
- Elasto-viscoplasticity (finite strain): Leonov-EGP
- Thermal & electrical conductivity: Ohm & Fourier

Microstructure Morphology

- Multiple reinforcement phases
- Multi-layer microstructure
- Ellipsoidal reinforcements (fillers, fibers, platelets)
- Aspect ratio distribution
- General orientation (fixed, random, 2nd order orientation tensor)
- Void inclusions
- Coated inclusions with relative or absolute thickness
- Deformable, quasi-rigid or rigid inclusions

Homogenization Methods

- Mori-Tanaka
- Interpolative double inclusion
- 1st and 2nd order homogenization schemes
- Multi-step, multi-level homogenization methods

Failure Indicators

- Applied at micro and/or macro scale, or on pseudo-grains using the FPGF model (First Pseudo-Grain Failure model)
- Failure models: Max stress and Max strain, Tsai-Hill 2D & 3D, Azzi-Tsai-Hill 2D, Tsai-Wu 2D & 3D, Hashin-Rotem 2D, Hashin 2D & 3D
- Strain rate dependent failure criteria
- Failure criteria on Leonov-EGP & hyperelastic material models

Loading

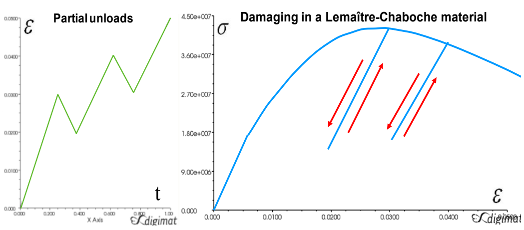
- Monotonic, cyclic or user-defined history loading
- Multi-axial stress or strain, General 2D & 3D
- Mechanical and thermo-mechanical
- Prediction of thermal & electrical conductivities
- Loading definition from structural FEA results, *i.e.* Abaqus ODB file

Isotropic Extraction Methods

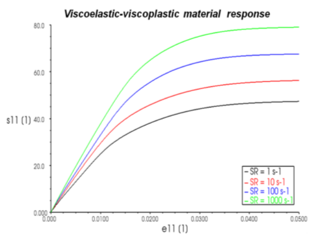
- General
- Spectral

More Functionalities

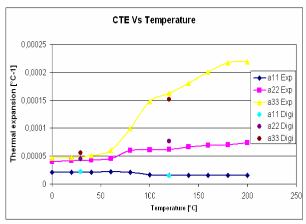
- Prediction of orthotropic engineering constants
- User defined outputs
- Interoperability with Digimat-FE and Digimat-MX
- Handling of encrypted material files



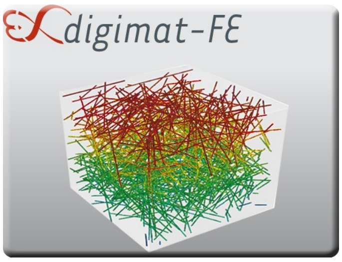
User-defined loading with intermediate unloadings used to identify the end of the elastic regime



Viscoelastic-Viscoplastic model: Strain rate dependency accounted on overall range of deformation



Prediction of temperature dependent coefficient of thermal expansion



Finite Element based homogenization software used to model the multi-physical nonlinear behavior of Representative Volume Elements (RVE) of realistic material microstructures.

Perform highly accurate in-depth studies of your composite materials!

MAIN CAPABILITIES

Definition of Composite Constituents

- Inclusion shapes: Spheroid, Platelet, Ellipsoid, Cylinder (capped or not), Prism / Icosahedrons, Any custom shape imported from a geometry file (.step)
- Material models: Elastic & Thermo-Elastic, Viscoelastic, Hyperelastic & Thermo-Hyperelastic, Elastoplastic, Elasto-Viscoplastic, Thermal, Electrical
- Inter-operability with Digimat-MF and Digimat-MX for material definition

Microstructure Definition

- Microstructure morphology definition:
  - Volume / Mass content
  - Multiple inclusion shapes
  - General orientation definition (fixed, random, 2nd order orientation tensor)
  - Fiber length with access to size distribution
  - Coating
  - Clustering of inclusions
- Filler / Matrix debonding
- Multi-layer microstructure

RVE Generation

- RVE microstructure generation with real-time preview & animation process
- Maximum packing algorithm
- 3D & 2D RVEs

RVE Analysis

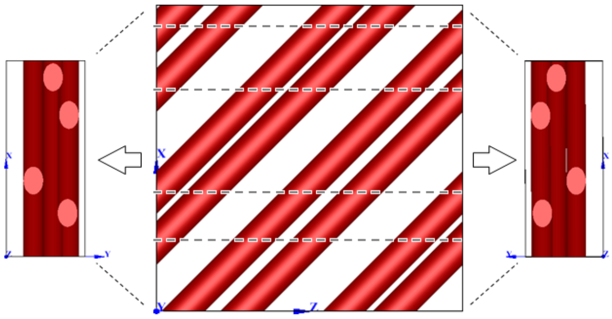
- Monotonic / Cyclic / User-defined history loadings
- Multi-axial stress or strain, General 2D & 3D
- Mechanical and thermo-mechanical
- Computation of the percolation threshold
- Prediction of thermal and electrical conductivities
- Loading definition from structural FEA, *i.e.* Abaqus ODB file
- Export of RVE geometry in common formats: STEP, IGES, BREP
- Export geometry and model definition to Abaqus/CAE and ANSYS Workbench

FE Meshing

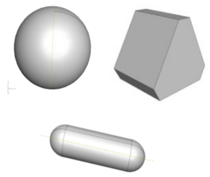
- Automatic adaptative mesh seeding and iterative mesh generation in Abaqus/CAE and ANSYS Workbench
- RVE meshing embedded beam elements, straight or curved

FE Solver & Post-Processing

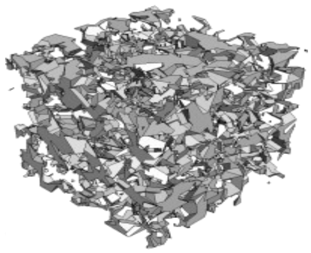
- FE solution: Abaqus/Standard, Ansys Workbench
- Post-processing: Digimat-FE, Abaqus/CAE, Ansys Workbench



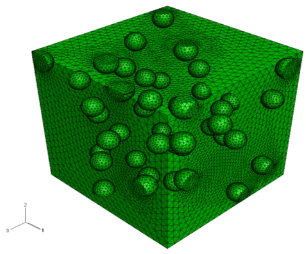
Periodic boundary conditions for RVE of UD composites



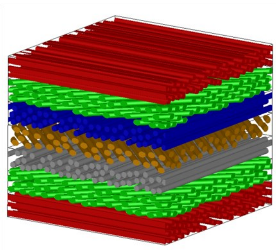
Basic inclusion shapes



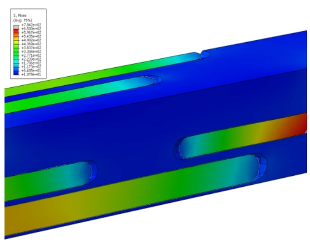
Microstructure generation of metal matrix composites



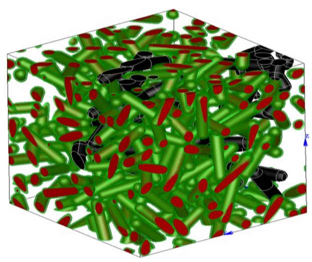
Mesh generation in ABAQUS/CAE



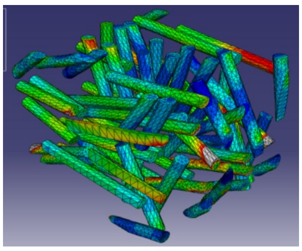
Multi-layered microstructures



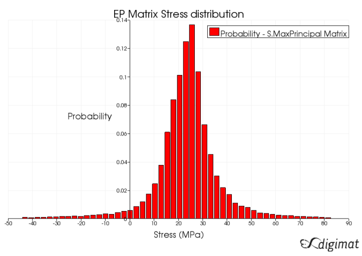
Decohesion seen at the tip of the fibers using shell cohesive elements



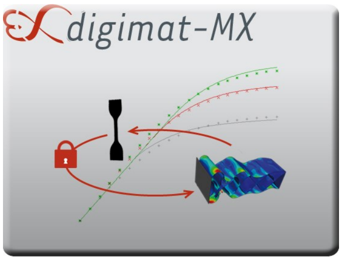
Percolation path shown with black inclusions



Stress distribution in fiber material



Statistical distribution of matrix stresses

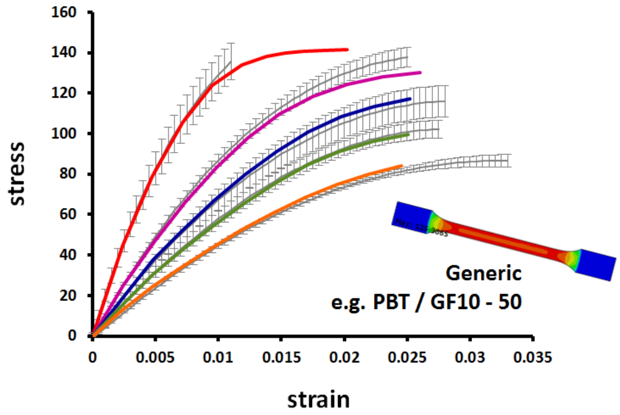


Material eXchange platform used to prepare, store, retrieve and securely exchange Digimat material models between material suppliers and end-users under full protection of the Intellectual Property.

Prepare, store and eXchange material models under protection of your intellectual knowledge!

NEW IN Digimat 4.5.1

- **Public data** — contribution from new supplier
  —> SOLVAY, materials added:
  Ketaspire KT-880 GF30
  Avaspire AV-651 GF30 BG20
- **Improved installation**
  —> MX database installed into Digimat working directory by default

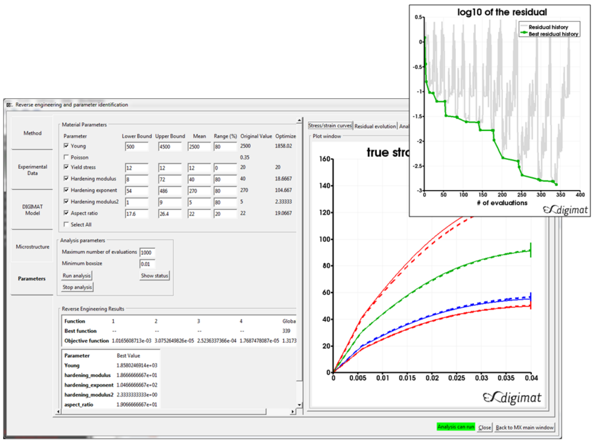


Generic models for a broad range of short fiber reinforced plastics

MAIN CAPABILITIES

Material database

- Gives access to:
  - Experimental data (tensile)
  - Digimat material / analysis files for homogeneous / composite materials
- Data available under various conditions:
  - Temperature, relative humidity, strain rates & loading angles
- Import, Filter & Reverse Engineering tools



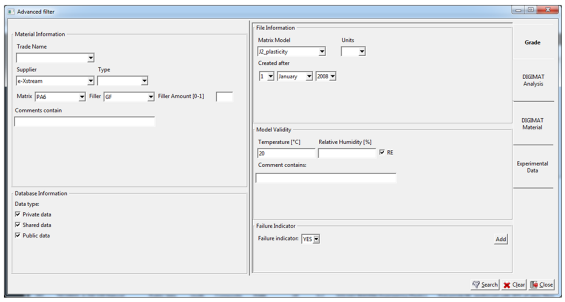
Reverse Engineering GUI tool

Parametric identification

- Identify material models' parameters based on the homogeneous material responses
- Can be done on one or several curves at the same time

Reverse Engineering

- Can be done on one or several curves at the same time:
  - Various loading angles, strain rates and / or temperatures
  - At homogeneous and macroscopic level
- Material models that can be reverse-engineered:
  - (Thermo) Elastic
  - Viscoelastic (2 RE techniques available)
  - (Thermo) Elastoplastic
  - (Thermo) Elasto-Viscoplastic
- Other features that can be reverse-engineered:
  - Aspect ratio of inclusion phase
  - Strength parameters of failure indicators
  - Thermal dependencies of thermo-mechanical material parameters
- Multi-layer microstructures are supported



Advanced Filter tool

Encryption

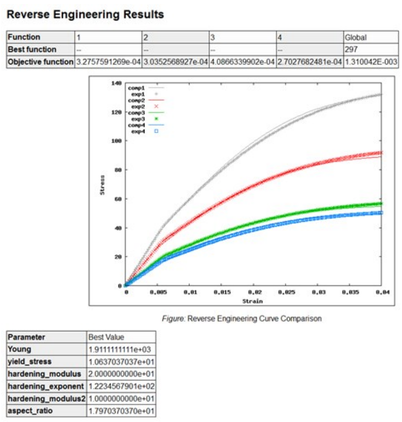
- Material files can be encrypted for confidentiality purposes (available in MX+)
- Encrypted files can be used in Digimat-MF and Digimat-CAE, the material parameters being hidden
- Encrypted material files can be attributed an expiration date (available in MX+)

Interaction between Digimat-MX and other products

- Interoperability with Digimat-MF, Digimat-FE & Digimat-CAE

Additional Digimat-MX tools

- Data sheet generation of DIGIMAT material models, as well as of experimental files, in pdf format.
- Database visualization

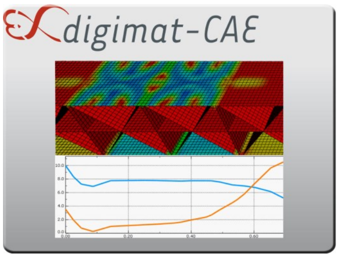

Reverse Engineering Results

Function	1	2	3	4	Global
Best function	--	--	--	--	297
Objective function	3.2757591269e-04	3.0352568927e-04	4.0866339902e-04	2.7027682481e-04	1.310042E-003

Figure: Reverse Engineering Curve Comparison

Parameter	Best Value
Young	1.9111111111e+03
yield_stress	1.0637037037e+01
hardening_modulus	2.0000000000e+01
hardening_exponent	1.2234567901e+02
hardening_modulus2	1.0000000000e+01
aspect_ratio	1.7970370370e+01

Generation of Reverse Engineering reports



Digimat linear and nonlinear interfaces to major process and structural FEA software to enable multi-scale analyses of composite materials and structures.

Bridge the gap between processing and FEA by using Digimat material models in your structural design!

NEW IN Digimat 4.5.1

- **Hybrid Solution**
  —> Improved accuracy for the anisotropic nonlinear hardening
    Elastoplastic
    Elasto-viscoplastic

- **Initial stresses**
  —> Support of ANSYS v14.5

- **Support of FEA Software**
  —> Support of ANSYS v14.5
    Abaqus 6.12
      Windows 32bit
      Windows 64bit
      Linux 64bit
    Radioss v11

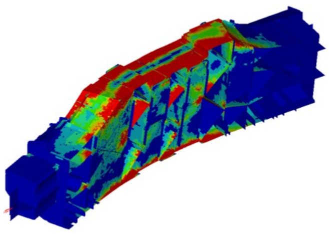
- **Post-Processing of short fiber reinforced plastics results as a function of the local fiber orientation**
  —> Micro & Hybrid solution procedures
  —> Default output
    First eigenvalue of orientation tensor a_{ij}
    Ratio between apparent stiffness (computed from local orientation) & ideal stiffness (computed in fiber direction)
  —> User choice
    Scalar product between the first eigenvectors of the orientation a_{ij} and the stress tensor σ_{ij}

MAIN CAPABILITIES

Digimat-CAE/Process

- Takes into account:
  - Fiber orientation
  - Residual stresses
  - Residual temperatures
  - Weldlines

- Coupled interfaces with:
  - 3D Timon
  - Autodesk Moldflow Insight
  - Moldex3D
  - REM3D
  - SigmaSoft
  - Simulayt



Strain Energy — Courtesy of L&L Products

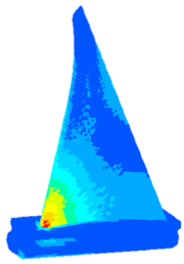
Digimat-CAE/Structural

- FEA solver types:
  - Explicit
  - Implicit

- Plug-ins in:
  - Abaqus/CAE
  - ANSYS Workbench
  - HyperMesh

- Element types:
  - Shell: 1st & 2nd order Triangles & Quadrangles
  - 3D: Tetrahedron, Hexahedron, 1st & 2nd order, reduced and fully integrated

(For 2nd order elements, each individual integration point can be assigned fiber orientation by using the DIGIMAT orientation file format)

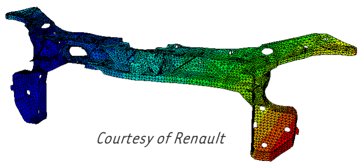


Engine blade analysis

- Micromechanical Material Model :
  - Linear
  - Nonlinear
  - Rate dependent
  - Thermo dependent
  - Finite strain

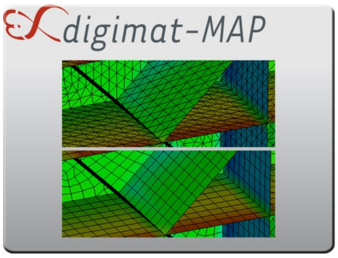
- Weak coupling available to all FEA solvers for thermo-elastic material properties

- Strong coupling interfaces to FEA:
  - Abaqus/CAE, Standard & Explicit
  - ANSYS Mechanical
  - LS-DYNA, Implicit & Explicit
  - Marc
  - Optistruct
  - PAM-CRASH
  - RADIOSS
  - SAMCEF-Mecano



Courtesy of Renault

Courtesy of Rhodia/Trelleborg



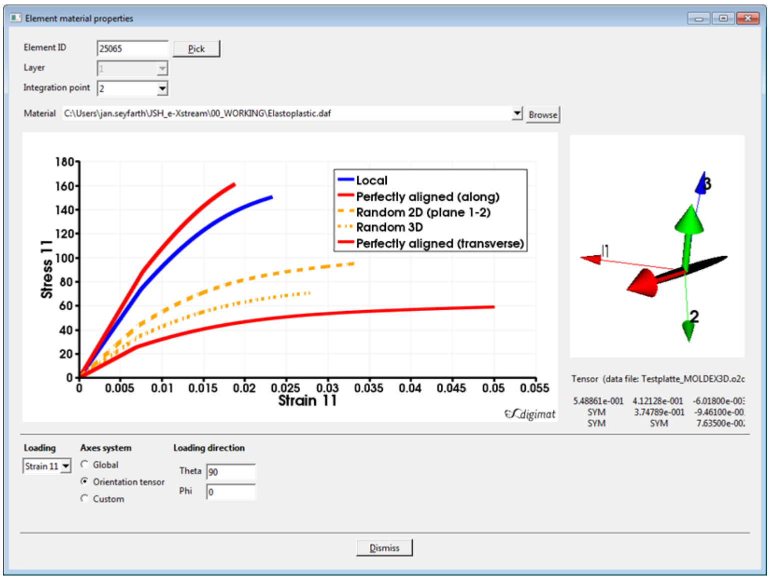
Shell & 3D mapping software used to transfer fiber orientation, residual stresses and temperatures between dissimilar injection molding and structural FEA meshes.

Use the optimal mesh and increase the accuracy and efficiency of your FE analyses!

MAIN CAPABILITIES

Data Types Managed by Digimat-MAP

- Fiber orientation tensors
- Residual stresses
- Temperature field
- Weld Lines



Visualization of local material properties at an integration point

Supported Elements

- Donor mesh:
  - Tetrahedron or triangular shell elements
  - Hexahedron and wedge elements
- Receiver mesh:
  - Tetrahedron or triangular shell elements
  - Hexahedron or quadrangular shell elements
  - Wedge elements

Shell & 3D Mapping

- From midplane to multi-layered shell
- Between Continuum 3D elements
- Across the shell thickness

Supported File Formats

- Meshes:
  - Abaqus
  - ANSYS
  - Ideas
  - LS-DYNA
  - PAM-CRASH
  - Patran
  - RADIOSS
  - REM3D
  - SAMCEF
  - 3D Timon
- Data:
  - DIGIMAT
  - Moldex3D
  - Moldflow Mid-Plane
  - Moldflow 3D
  - REM3D
  - SigmaSoft
  - 3D Timon

Data Post-Processing

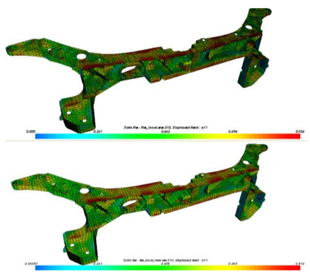
- Contour or vector plots
- Display tensorial fields using ellipsoids
- Synchronized display of donor and receiving meshes
- Through-the-thickness orientation or temperature plot for shell elements
- Cut plane on 3D meshes
- Superposition display of the donor with the receiving meshes

Error Indicators

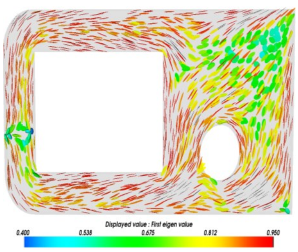
- Global & local error indicators to validate mapping quality

Donor-Receiver Positioning

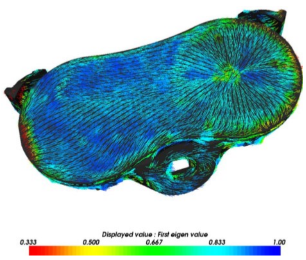
- Scaling, Translation, Rotation, Superposition



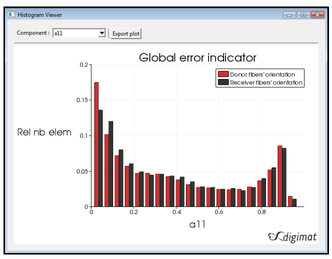
Mapping of midplane fiber orientation tensors
Courtesy of Renault



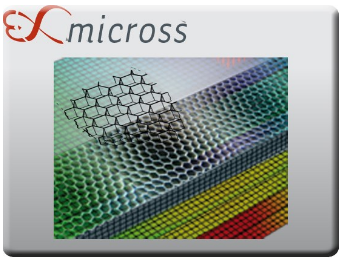
Fiber orientation using the ellipsoid display



Vector plot of fiber orientations on a 3D



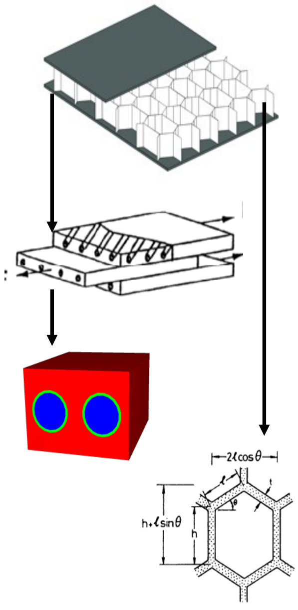
Global error indicator (histogram plot)



Accurate and easy-to-use software for the development of composite sandwich panels using standard numerical bending and shear tests. The software can be used by analysts and designers with no experience in micromechanics or finite element modeling.

Easy and accurate prediction of composite sandwich panels micromechanical behavior!

MAIN CAPABILITIES



Definition of honeycomb core and skins pile-up

Skin Definition

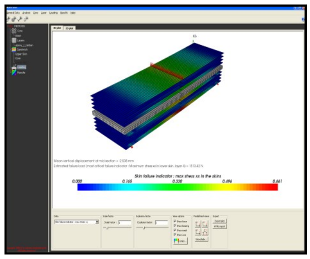
- Pile up:
  - Symmetric
  - Anti-symmetric
- Material properties:
  - Orthotropic elastic properties of the ply
  - Ply orientation
- Resin/Fibers:
  - Isotropic elastic properties of the resin and fibers
  - Fiber weight fraction, length and orientation

The equivalent, homogenous, properties of the skins are computed using micromechanics

FEA Model

- Automatic mesh generation following selected mesh refinement:
  - Coarse
  - Average
  - Fine
- Loading:
  - Three-point bending
  - Four-point bending
  - In-plane shear

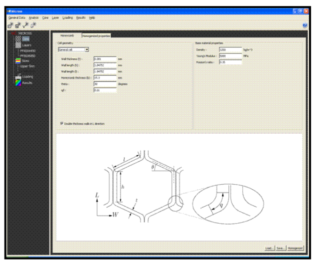
Customized positions and amplitudes for loading points and fixations.



Computation of failure indicators for core and skin layers

Core Definition

- Honeycomb: honeycomb properties are computed using micromechanical models based on the cell geometry and the bulk properties
- Foam



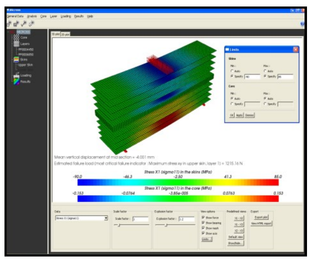
Definition of honeycomb cell geometry

Post-processing

Integrated post-processing including 3D and through-thickness views of stresses, strains and failure indicators

Failure Indicators

- Core:
  - Maximum stress (comprehensive, shear)
- Skin:
  - Maximum stress
  - Tsai-Wu
  - Tsai-Hill
  - Azzi-Tsai-Hill



Per layer post processing of results

Automatic Report Generation (html)

Automatic Generation and Solving of the FEA Model using a Built-in FEA Solver

e-Xstream engineering develops and commercializes Digimat suite of software, a state of the art multi-scale material modeling technology that speeds-up the development of optimal composite materials and parts for material suppliers and end users in the automotive, aerospace, consumer goods and industrial equipment industries. e-Xstream provides material scientists and simulation engineers with innovative material modeling tools to allow them to accurately predict the microme-chanical behavior of reinforced materials and perform accurate design of composite structures (PMC, RMC, MMC, nanocompo-sites, honeycomb sandwich panels, ...). An optimal design of composite parts is then materialized into lighter, cheaper and higher quality products brought faster to the market.

Digimat, The nonlinear multi-scale material & structure modeling platform, is an efficient predictive tool that helps our customers designing and manufacturing innovative and optimal composite materials and parts fast and cost efficiently. With major customers in Europe, America and Asia, we have added to our deep expertise in numerical simulation the business un-derstanding of a large variety of materials such as reinforced plastics, rubber, hard metals, nanocomposites and honeycomb sandwich panels used across the automotive, aerospace, consumer and industrial equipments industries.

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