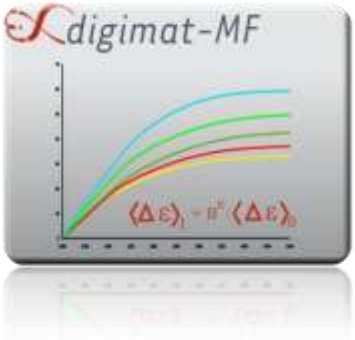
digimat®

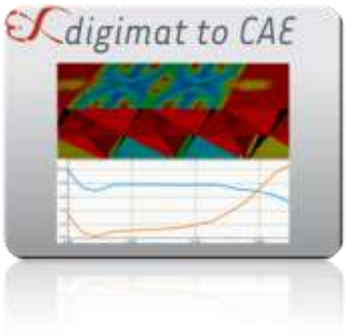
Release 4.0.2 – April 2010



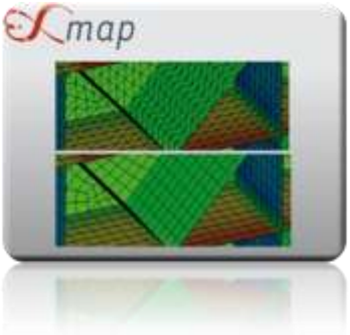
For fast & accurate prediction of the nonlinear behavior of multi-phase materials using Mean-Field homogenization Technology

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

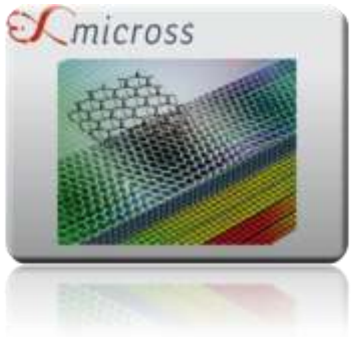
For the preparation, storage, retrieval and secure exchange of DIGIMAT material models between material suppliers and users, while protecting Intellectual Property.



Interfaces to injection molding and structural FEA codes for the accurate prediction of composite materials and reinforced platics parts performance using non-linear multi-scale modeling technology.



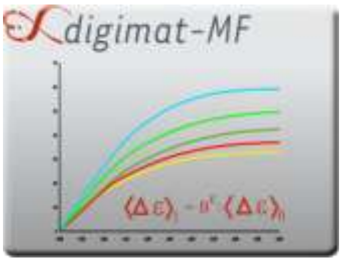
For the efficient mapping of data scalar & tensor data between dissimilar Shell and 3D FE meshes.



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.

e-Xstream ENGINEERING

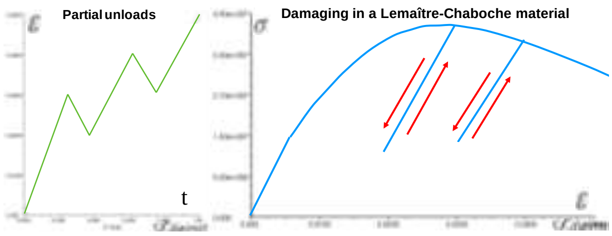


Digimat-MF aims at predicting the nonlinear mechanical, thermal and electric behavior of multi-phase materials based on the constitutive properties of the base materials and the composite morphology (inclusion weight fraction, length and orientation).

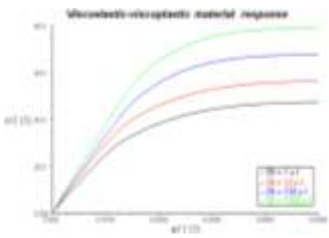
Digimat-MF is accurate, efficient and very easy to learn and use.

NEW IN DIGIMAT 4.0

- New ODF reconstruction method
- Viscoelastic-viscoplastic material model
- User-defined piece-wise linear loading
- General 2D and 3D loadings
- Loading definition from structural FEA results, *i.e.* Abaqus ODB file
- FPGF model with multi-layer microstructure
- Failure criteria on Leonov-EGP & hyperelastic material models
- Query material from Digimat-MX database
- Handling of encrypted material files
- 2D plot improvements



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

MAIN CAPABILITIES

Nonlinear (per-phase) Material Models

- Linear thermo-elasticity
  - Anisotropic phases
  - Temperature-dependent properties
- Linear viscoelasticity
- Elasto-plasticity:
  - Isotropic hardening: power, exponential or exponential linear laws
  - Small deformation with large rotation
- Cyclic elasto-plasticity: Kinematic hardening; linear with restoration
- Pressure-dependent elasto-plasticity (Drucker-Prager)
- Elasto-plasticity with damage (Lemaître-Chaboche)

Elasto-viscoplastic : Creep models: Norton laws, Power laws, Prandtl law

- Viscoelasticity-viscoplasticity
- Hyperelastic (finite strain): neo-Hookean, Mooney-Rivlin, Ogden, Swanson, Storakers (compressible foams)
- Elasto-viscoplastic (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

Loading

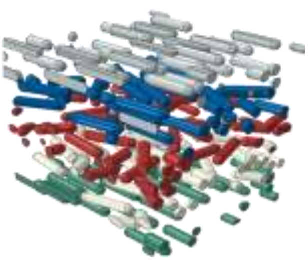
- Monotonic, cyclic or user-defined history loading
- Multi-axial stress or strain
- Mechanical and thermo-mechanical
- Prediction of thermal & electrical conductivities

Isotropic Extraction Methods

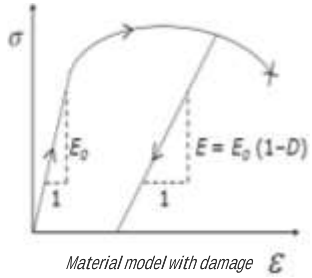
- General
- Spectral
- Modified spectral

More Functionalities

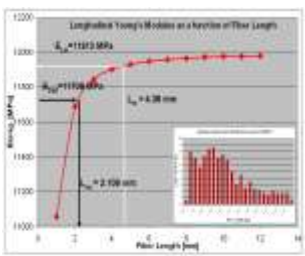
- Multi-analyses capability
- Interoperability with Digimat-FE and Digimat-MX
- Prediction of orthotropic engineering constants



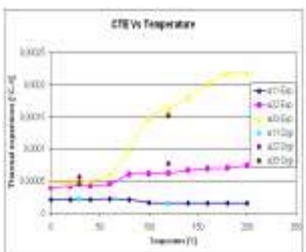
Multi-layer microstructure



Material model with damage



Modeling of fiber length distribution

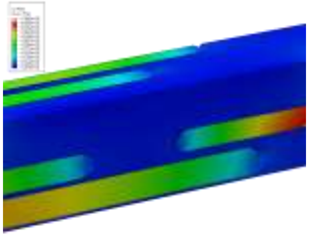


Prediction of temperature dependent coefficient of thermal expansion digimat-FE

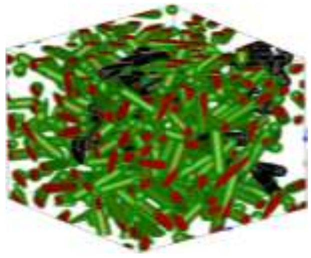
Digimat-FE is used to generate realistic Representative Volume Element (RVE) for a large variety of material microstructures (plastics, rubbers, metals, graphite,...). The resulting finite element models are solved using major FEA software. Digimat-FE has an extensive set of capabilities that enable user-friendly generation of extremely complex material micro-structure morphologies that are accurately modeled at a reasonable CPU cost.

NEW IN DIGIMAT 4.0

- Interface to ANSYS Workbench v12.1
- 2D RVE generation
- Filler/Matrix debonding
- Maximum packing algorithm
- RVE meshing using embedded beam elements, straight or curved
- User-defined piece-wise linear loading
- General 2D and 3D loadings
- Loading definition from structural FEA, *i.e.* Abaqus ODB file
- Computation of the percolation threshold
- Transversely isotropic Ohm & Fourier material models
- Thermo-hyperelastic material model
- New handling of filler orientation tensor
- Animation of RVE generation process
- Code and algorithm optimization for better CPU performances



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

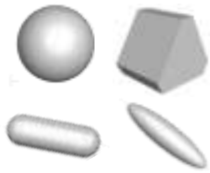


Percolation path shown with black inclusions

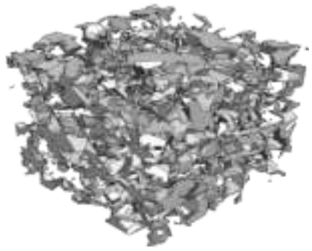
MAIN CAPABILITIES

Definition of Composite Constituents

- Inclusion shapes: any shape imported from a geometry file: spheroids, platelets, ellipsoids, cylinders (capped or not), prisms, polyhedrons made of 20 faces (icosahedrons)
- Definition of the constituents' material behavior: elastic, thermo-elastic, viscoelastic, hyperelastic, elastoplastic, elasto-viscoplastic, thermal, electrical
- Inter operability with Digimat-MF and Digimat-MX for material definition



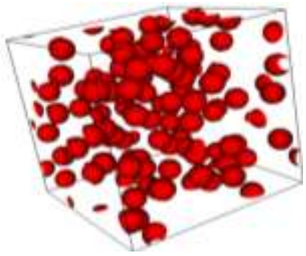
Basic inclusion shapes



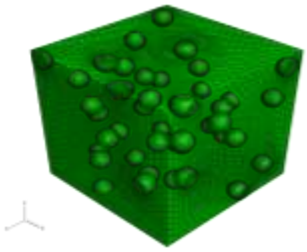
Microstructure generation of metal matrix composites

Microstructure(s) Definition(s) and Generation(s)

- Microstructure morphology definition: volume or mass content, multiple reinforcement phases, ellipsoidal reinforcements (fillers, fibers, platelets), general orientation (fixed, random, 2nd order orientation tensor), void inclusions, coated inclusions with relative or absolute thickness, clustering
- Multi-layer microstructure
- Microstructure generation with real-time preview



RVE generation using spherical inclusions



Mesh generation in ABAQUS/CAE

RVE Loading Definition and Export

- RVE loading: Strain, mixed stress/strain, periodic, thermal, electrical
- Prediction of thermal and electrical conductivities
- Export of RVE geometry in common formats: STEP, IGES, BREP
- Export geometry and model definition to Abaqus/CAE
- Export geometry to ANSYS Workbench

Polymer matrix reinforced with 2% (volume fraction) of carbon nanotubes

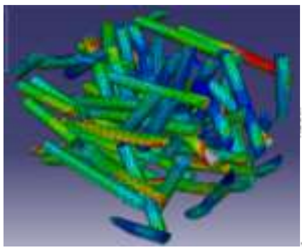
Multi-layered microstructures

FE Meshing

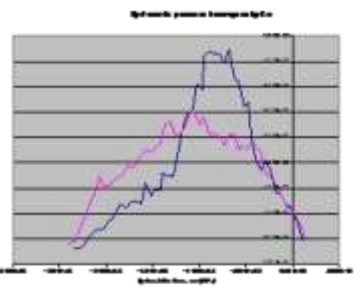
- Geometry export to Abaqus/CAE and ANSYS Workbench
- Automatic adaptative mesh seeding and iterative mesh generation in Abaqus/CAE

FE Solver & Post-Processing

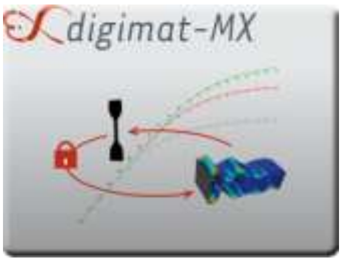
- FE solution: Abaqus/Standard, Ansys Workbench
- Post-processing: Digimat-FE, Abaqus/CAE, Ansys Workbench



Stress distribution in fiber reinforced materials



Statistical distribution of stresses



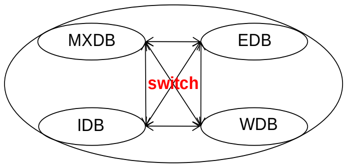
The Material eXpert system is used to prepare, to store, to retrieve and to securely exchange DIGIMAT material models between material suppliers and end-users, while protecting the Intellectual Property of the involved parties.
Digimat-MX is based on a cluster of material databases and the numerical tools needed to identify material law parameters and to reverse engineer missing data from a limited set of experimental measurements.

MAIN CAPABILITIES IN 4.0

Material database

- Gives access to:
  - Experimental data (traction, compression, ...)
  - DIGIMAT material and analysis files for homogeneous or composite materials
- Data available under various conditions:
  - Temperature
  - Relative humidity
  - Strain rates (for exp. data curves)
  - Loading angles (for exp. data curves)
- Digimat-MX is built around 4 databases:
  - Public Database (MXDB)
  - Working database (WDB)
  - Internal database (IDB)
  - External database (EDB)
- Import data files (experimental data, DIGIMAT material files)

Digimat-MX user interface: 4 separate sub windows



Cluster of databases - Structure of Digimat-MX

Parametric identification

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

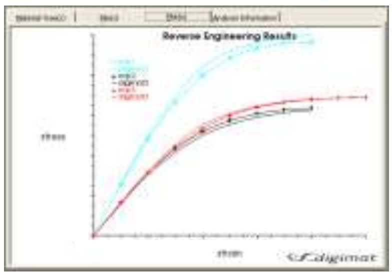
Reverse Engineering

- Can be done on one or several curves at the same time.
  - Various loading angles
  - Various strain rates
  - At homogeneous and macroscopic level
- List of material models that can be reverse-engineered:
  - Elastic
  - Viscoelastic
  - Elasto-Plastic
  - Elasto-Viscoplastic
- Multi-layer microstructures are supported

Query tool

Encryption

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



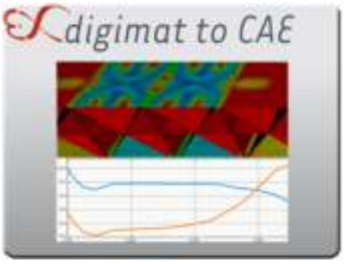
Reverse engineering performed on 3 experimental tensile curves

Interaction between Digimat-MX and other DIGIMAT products

- DIGIMAT material files from Digimat-MX can be transferred into Digimat-MF and Digimat to CAE
- When opening Digimat-MF, Digimat-FE or Digimat to CAE, it is also possible to query and import a DIGIMAT material or analysis file stored in one of the Digimat-MX databases

Additional Digimat-MX tools

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

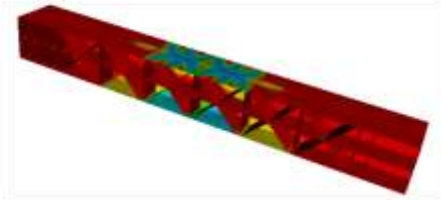


Digimat to CAE centralizes the interfaces between Digimat –MF, injection molding simulation and structural Finite Element Analysis (FEA). Digimat to CAE is used to define the nonlinear , micromechanically-based ,material models of a multi-phase material within linear or nonlinear FEA, taking into account the material processing. Digimat to CAE bridges the gap between injection molding simulation and the structural FEA via the material microstructure (e.g. fiber orientation, content, shape).

NEW IN DIGIMAT 4.0

- Generation of stiffness files during a structural FEA analysis
- Weak coupling for thermo-elastic analyses
- Query a material from Digimat-MX database
- Interface to ANSYS Workbench v12.1
- Interface to 3D TIMON
- Interface to RADIOSS under Windows 32 & 64 bit and Linux 64 bit (DMP)
- DMP version of the interface to PAM-Crash under Linux 64 bit
- Support ABAQUS 6.9.1 version
- Improvement of the ABAQUS plug-in and the ANSYS Workbench wizard

Altair

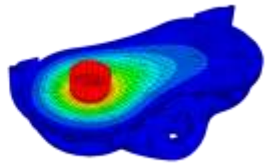


Apparent isotropic stiffness of the material at the end of loading – Courtesy of DSM

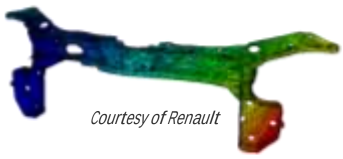
MAIN CAPABILITIES

DIGIMAT to Injection Molding Software

- Takes into account:
  - Orientation tensors
  - Residual stresses
  - Residual temperatures
- Coupled interfaces with:
  - 3D-Sigma
  - Moldex3D
  - Moldflow
  - 3D Timon
  - REM3D



Courtesy of Solvay



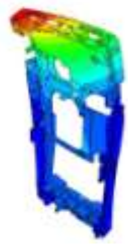
Courtesy of Renault

DIGIMAT to Finite Element Software

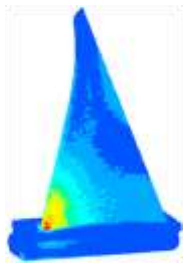
- FEA solver types:
  - Explicit
  - Implicit
- Element types:
  - Shell: 1st & 2nd order Triangles & Quadrangles
  - 3D: Tetrahedron, Hexahedron, 1st & 2nd order, reduced and fully integrated

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

- Micromechanical Material Model :
  - Linear
  - Nonlinear
  - Rate dependent
  - Finite strain
- Strong coupling interfaces to FEA:
  - Abaqus/CAE, Explicit, Standard
  - ANSYS Mechanical,
  - LS-DYNA
  - PAM-Crash
  - RADIOSS
  - SAMCEF-Mecano
- Weak coupling interfaces to all FEA solvers for thermo-elastic material properties

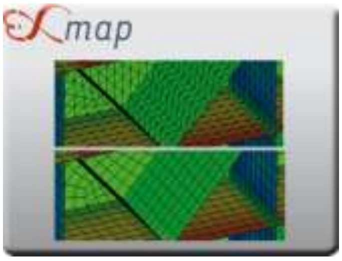


Courtesy of Nokia



Engine blade analysis

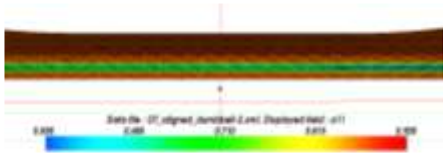
Courtesy of Rhodia/Trelleborg



Map is a Shell & 3D mapping software used to transfer fiber orientations, residual stresses, temperatures and weldlines between dissimilar injection molding and structural FEA meshes. Map helps assessing the level of difference between the data on the original and the final mapped solution. Map enables structural engineers to using the optimal mesh type needed for an accurate and efficient FEA.

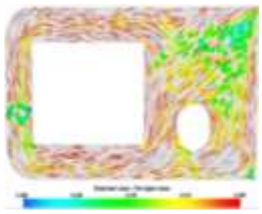
NEW IN DIGIMAT 4.0

- Cut plane on 3D meshes
- Through the thickness orientation plot for shell elements
- Display tensorial fields using ellipsoids
- Superposition display of the donor with the receiving meshes
- Selective display of element sets
- Handling of mesh translucency
- Display of local stiffness exported from FEA analyses
- Interface to 3D TIMON
- Interface to RADIOSS
- Mapping of Moldflow/Midplane and 3D TIMON weld lines
- Improved display and loading of big models
- Support Ideas mesh format



A11 display through the dumbbell thickness using the cut plane capability

Superposition of receiving dumbbell mesh on plate donor mesh



Fibre orientation using the ellipsoid display

MAIN CAPABILITIES

Shell & 3D Mapping

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

6 Mapping Methods

- Node to Node (temperature mapping only)
- Integration point, Node to Integration point
- Integration point, Node to Node, Integration point
- Element to Integration point
- Element to Node/Integration point
- Node to element (weld line mapping)

Supported File Format

- Meshes:
  - Abaqus
  - ANSYS
  - Patran
  - LS-DYNA
- Data:
  - Moldex3D
  - Moldflow Mid-Plane
  - Moldflow 3D
  - REM3D
  - SigmaSoft
  - 3D Timon
  - DIGIMAT

Error Indicators

- Local
- Global

Donor-Receiver Positioning

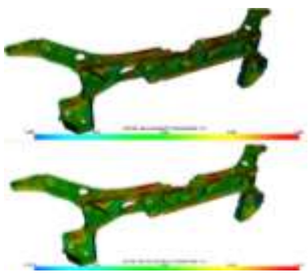
- Scaling
- Superpose
- Translation
- Rotation

Supported Elements

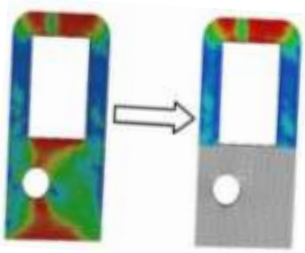
- Donor mesh:
  - 1st order tetrahedron or triangular shell elements
  - 1st order hexahedron and wedge elements
- Receiver mesh:
  - 1st order tetrahedron or triangular shell elements
  - 1st order hexahedron or quadrangular shell elements
  - 1st order wedge elements
  - 2nd order hexahedron and tetrahedron elements

Data Post-Processing

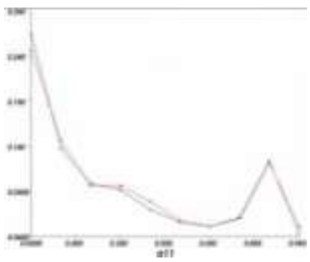
- Visualization of scalar & tensor data
- Contour or vector plots
- Synchronized display of donor and receiving meshes



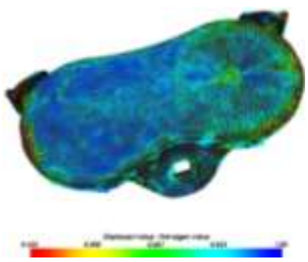
Mapping of midplane fiber orientation tensors Courtesy of Renault



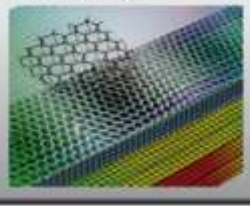
Partial mapping of 3D fiber orientation tensors



Global error field



Vector plot of fiber orientations on a 3D



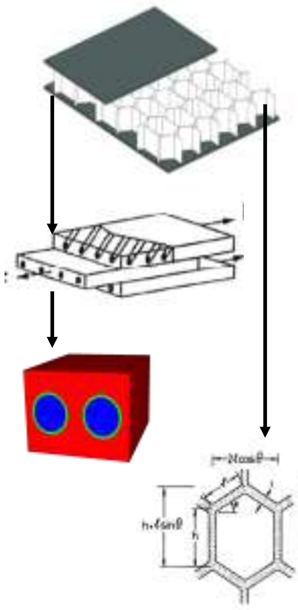
Micross is the accurate and easy-to-use software used to develop composite sandwich panels using numerical bending and shear tests. Material can be input at the Composite/Core (macro) level or at the Fiber-Resin/Cell level. Micross can be used by analysts and designers with no experience in micromechanics or finite element modeling.

MAIN CAPABILITIES

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

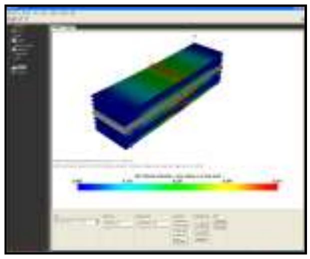


Definition of honeycomb core and skins pile-up

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)

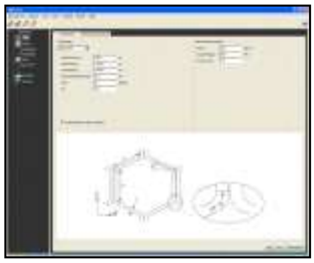


Computation of failure indicators for core and skin layers

Core Definition

- Honeycomb
- Foam

(Honeycomb properties are computed using micromechanical models based on the cell geometry and the bulk material properties)



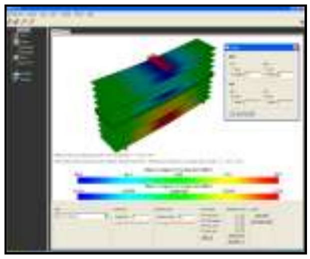
Definition of honeycomb cell geometry

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 speed-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. Our solutions are used by CAE engineers, materials scientists, chemists, specialists in manufacturing processes of composite materials,... to accurately predict the nonlinear micromechanical behavior of complex multi-phase composites materials and structures (PMC, RMC, MMC, nanocomposites, honeycomb sandwich panels, ...)

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 understanding 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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