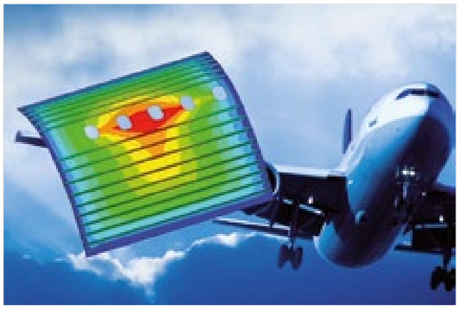
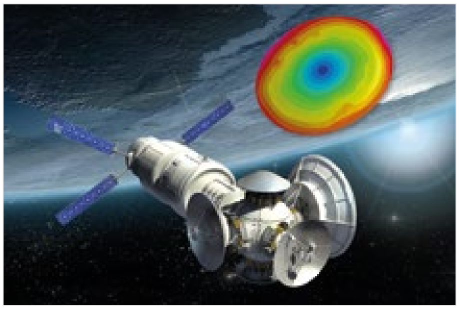
composites

PAM-COMPOSITES





PREVENT AND CORRECT MANUFACTURING DEFECTS OF COMPOSITE STRUCTURAL PARTS

Manage Each Step of the Composites Manufacturing Chain with PAM-COMPOSITES

PAM-COMPOSITES allows you to define and optimize the process parameters to minimize manufacturing defects and increase final product quality, taking into account each step of the manufacturing chain.

PAM-COMPOSITES is a unique suite of Finite Element simulation tools dedicated to the manufacturing of composite parts made of continuous fibers - carbon, glass or natural fibers; unidirectional, woven or non-crimp-fabric - and a thermoset or thermoplastic matrix.

Main Applications

- Draping of dry textiles
- Thermoforming of thermoset or thermoplastic prepregs
- Liquid Composites Molding - infusion or injection in a preform
- Curing of thermoset composite materials
- Computation of Residual stresses and geometrical distortions induced by curing

Each step of the manufacturing process is simulated and analyzed. Then, material information and history, such as shearing, temperature and degree of cure, are transmitted from one stage of the process to the next.

Towards a Product/Process Design Approach

Manufacturing results can then be transferred to static or dynamic structural analysis to realistically simulate the product "as-built" as opposed to "as-designed". Thanks to this product/process design approach, design margins are minimized and weight reduction is pushed further.

Define and optimize process parameters

Minimize manufacturing defects upfront in the development process

Reach and exceed required quality criteria for the produced part

BENEFITS

- Save time and minimize cost by drastically reducing the number of trial-and-error loops
- Shorten the overall production cycle
- Improve the final quality of manufactured products
- Troubleshoot problems with existing processes
- Certify robustness of your manufacturing process (less scraps)
- Accounts for manufacturing effects in structural analysis

Develop the manufacturing process of your composite part "right the first time"

For more information: **www.esi-group.com/composites**
Contact: **www.esi-group.com/company/contact-us**

Draping and Thermoforming

PAM-COMPOSITES is used to simulate the preforming process of dry textiles or the thermoforming of pre-impregnated materials (pre-pregs) made of thermoset or thermoplastic resins.

Processes that can be modeled

- Stamping - using two rigid molds
- Rubber pad forming
- Thermoforming
- Diaphragm forming

Typical Simulation Results

- Final fiber orientation
- Thickness distribution
- Optimum initial flat pattern
- Bridging prediction
- Wrinkling prediction
- Strains and stresses
- Fiber volume content
- Compaction ratio

All of these results are available at ply level and not just at laminate level allowing for, as an example, the prediction of internal wrinkles.

Save Time and Reduce Defects

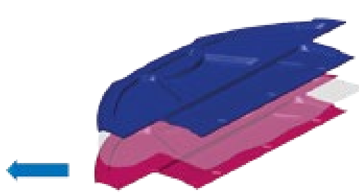
With PAM-COMPOSITES, manufacturing defects are eliminated and product quality is improved in the initial product development process before cutting tools. Simulation can also be used later on in the process of correcting issues that have already been identified.

TO SIMULATE:
- Preforming
- Draping of thermoset pre-pregs
- Thermoforming of organo-sheets

TO DETERMINE AND OPTIMIZE PROCESS PARAMETERS SUCH AS:
- Kinematic of the tools
- Temperature cycle
- Pressure cycle
- Clamping conditions
- Clamping forces
- Initial flat pattern

CAN PREDICT:
- Wrinkles
- Thicknesses
- Bridging
- Strains (shearing and in fibers)
- Stresses (shearing and in fibers)
- Fibers orientation and volume content
- Compaction ratio

BENEFITS:
- Quickly determine draping feasibility
- Minimize scraps and material loss
- Determine accurate fiber orientations for structural analysis

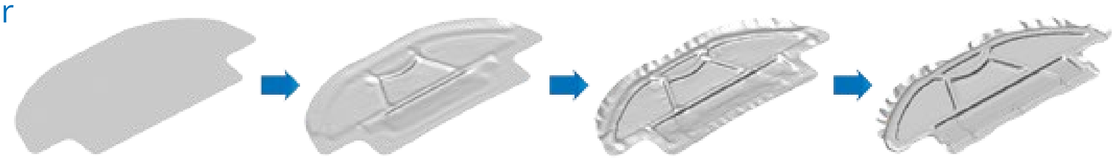


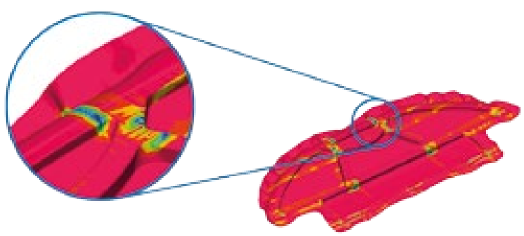
Upper tool

Lower tool (lock)

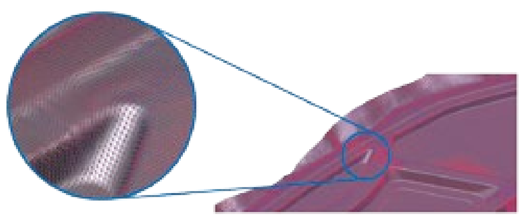
KTM Front Splitter

PAM-FORM case study





Defect area with excessive thickening



Export fiber orientation for injection simulation or structural analysis

Selected Customer References: Aciturri, Airbus Helicopter, Airbus Innovation, Andaltec, Audi, Avic, Basf, Benteler, BMW, Bombardier Aerospace, Brose, Cemcat, Cetim, Composite Integrity, Dassault Aviation, DLR, Euros, Fidamc, Fuji Heavy Industries, Galazzi Spa, GE, Gestamp, Honda, Ihi Corporation, Inpro, Kawasaki Heavy Industries, Kims, Letov, LG Electronics, Mercedes-Benz, Mitsubishi Heavy Industries, Mtorres, NCC, Nissan Motor, Onera, Safran Composites, Safran Herakles, Samsung Electronics, Snecma, Toho Tenax, Volkswagen

Liquid Composites Molding (LCM)

PAM-COMPOSITES is used to simulate the injection or the infusion of a resin in a preform that might contain inserts.

Processes that can be modeled

- Pre-heating of the mold and preform
- Resin Transfer Molding (RTM)
- Vacuum Assisted Resin Infusion (VARI)
- Compression RTM (C-RTM)
- High-Pressure RTM (HP-RTM)

Typical Simulation Results

- Dry zones prediction
- Level of porosity
- Injection time
- Temperature evolution

A Unique High Performance Solver

Thanks to its unique high performance solver and adapted graphical interface, PAM-COMPOSITES can deal with extremely large numerical LCM models using shell or solid elements. These computational performance levels are required for example, in the wind energy and aeronautical industries, because of the size of the components and the complexity of the lay-up. This is also the case in the automotive industry because of the detailed geometry that requires small element size.

Seamless link to Draping Simulation

Permeability, a key input parameter of LCM simulation, is highly dependant on fiber orientations. This is why it is important to take it into account in injection/infusion process simulation. Geometrical approaches can be used to approximate the orientations of the fibers in the preform. PAM-COMPOSITES goes one step further: it can seamlessly use accurate fiber orientations computed in its preforming analysis.

Detection of dry spots generated during injection of an automotive floor panel

Courtesy: TECABS project

TO SIMULATE:
- RTM
- VARI
- Light RTM
- C-RTM
- HP-RTM

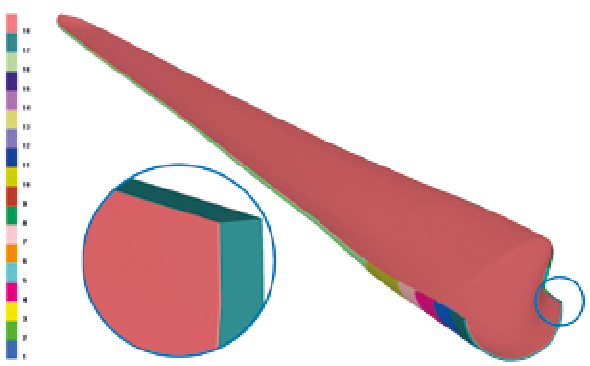
TO DETERMINE AND OPTIMIZE PROCESS PARAMETERS SUCH AS:
- Location and shape of injection gates
- Location and shape of vents
- Position and type of flow media
- Heating of the mold
- Injection pressure or flow rate

CAN PREDICT:
- Dry zones
- Porosity level
- Injection time
- Temperature evolution
- Pressure in the mold

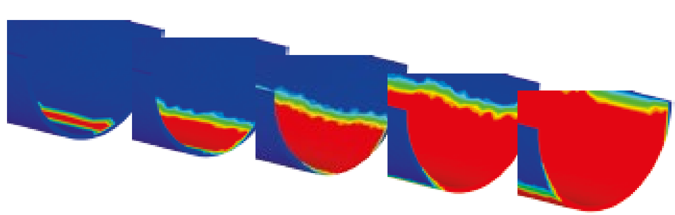
BENEFITS:
- Quickly evaluate multiple injection strategies
- Get the shortest injection/infusion time with a "no-defect" part

Solid modeling of a wind blade

Flow media in the inner surface (pink)



Impact of flow media on the resin flow during infusion



Curing and Distortions

PAM-COMPOSITES is used to compute residual stresses and geometrical deformations, such as spring-in and warping, induced by the manufacturing process of thermoset parts.
It accounts for strains generated by the modification of material properties due to the phase transformations - during curing the material goes from liquid to rubbery to glassy.
Temperature and degree of cure history computed during the curing simulation are retrieved in a seamless way in the distortion simulation.

To meet Geometrical Tolerances

PAM-COMPOSITES allows you to develop recommendations for process parameters in order to minimize the shape distortion of complex composites parts, upfront in the development process, before cutting any tools.
It is also used to generate a compensated mold based on computed geometrical distortions in order to obtain a final part geometry within the specified tolerance.

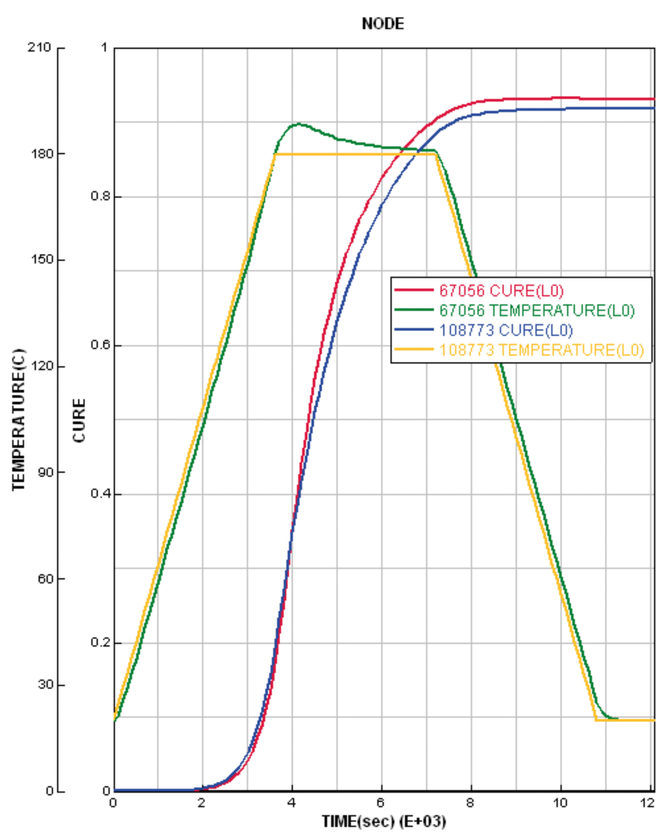
TO DEFINE AND OPTIMIZE:
- Stacking definition
- Curing cycle
- Mold material and design
- Mold geometrical compensation

CAN PREDICT:
- Curing time
- Degree of cure evolution
- Internal stresses during curing
- Residual stresses after demolding
- Deformation during curing
- Deformation after demolding

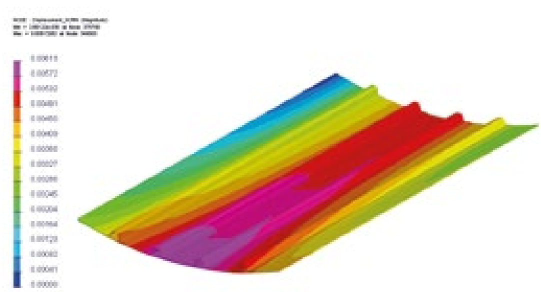
TAKES INTO ACCOUNT:
- Material history during curing process (temperature and degree of cure)
- Thermal and mechanical interaction with mold

BENEFITS:
- Meet requirements for geometrical tolerances
- Prevent assembly issues

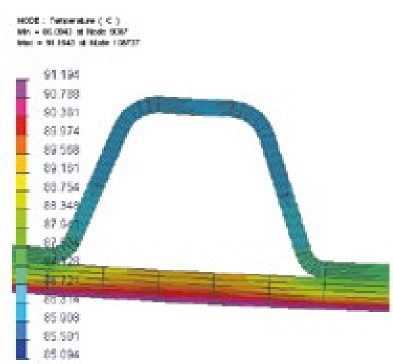
Temperature and cure history on a specific location of an aeronautic fuselage panel after going through a cure cycle



Normal displacement predicted after curing and demolding of an aeronautic fuselage panel



Detailed visualization of the normal displacement on a section of a stringer



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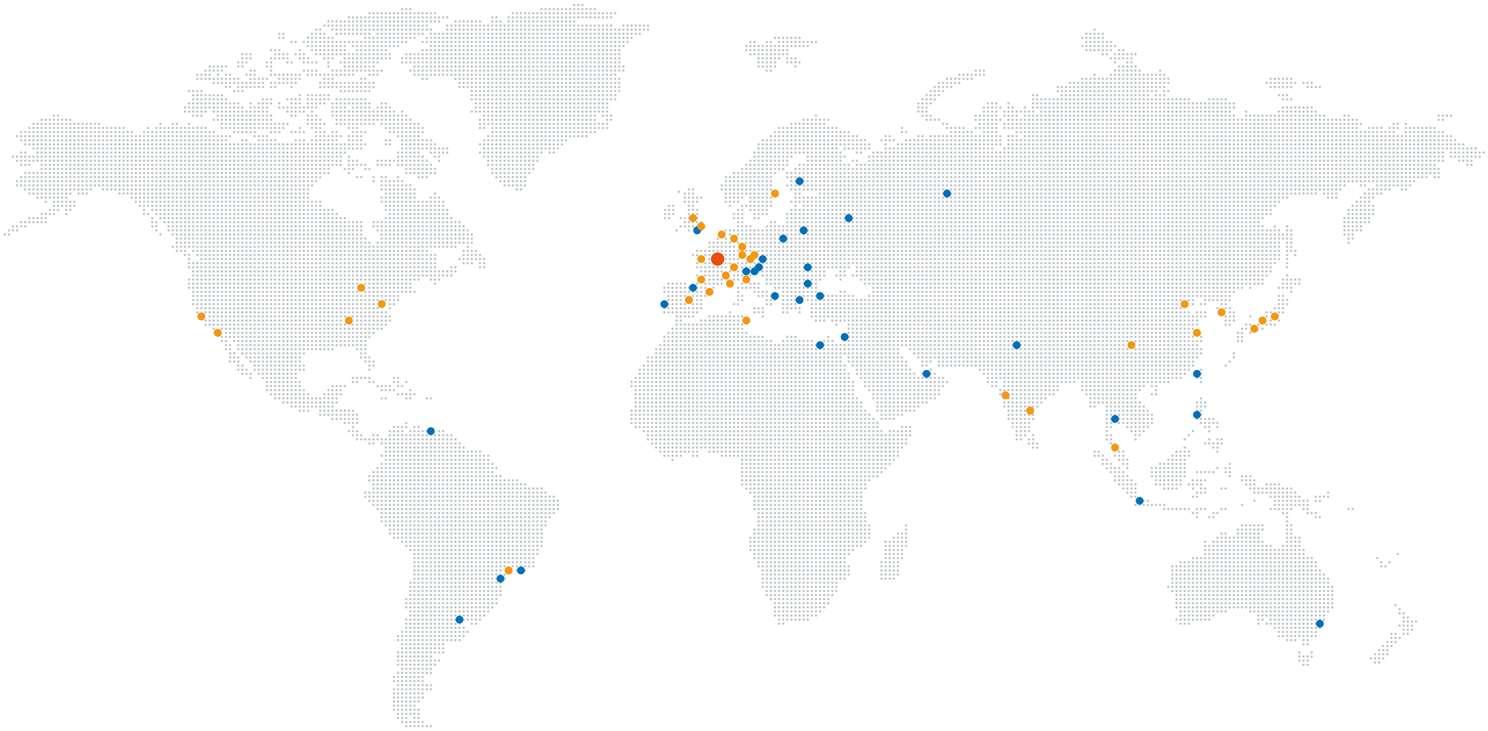

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