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

**KTM Front Splitter**

PAM-FORM case study

Defect area with excessive thickening

Export fiber orientation for injection simulation or structural analysis
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

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

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

Courtesy: TECABS project
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.

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

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

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

Detailed visualization of the normal displacement on a section of a stringer
ABOUT ESI GROUP

ESI Group is a leading innovator in Virtual Prototyping software and services. Specialist in material physics, ESI has developed a unique proficiency in helping industrial manufacturers replace physical prototypes by virtually replicating the fabrication, assembly and testing of products in different environments. Today, coupled with Virtual Reality, animated by systems models, and benefiting from data analytics, Virtual Prototyping becomes immersive and interactive: ESI’s clients can bring their products to life, ensuring reliable performance, serviceability and maintainability. Benefiting world-leading OEM’s and innovative companies alike, ESI empowers engineers and decision-makers with the guarantee that their products will pass certification tests, before any physical prototype is built, and that they will deliver competitive products to their markets. ESI’s Virtual Prototyping solutions address the emerging need for products to be smart and autonomous and support industrial manufacturers in their digital transformation.

Today, ESI’s customer base spans nearly every industry sector. The company employs about 1100 high-level specialists worldwide to address the needs of customers in more than 40 countries. For more information, please visit www.esi-group.com

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