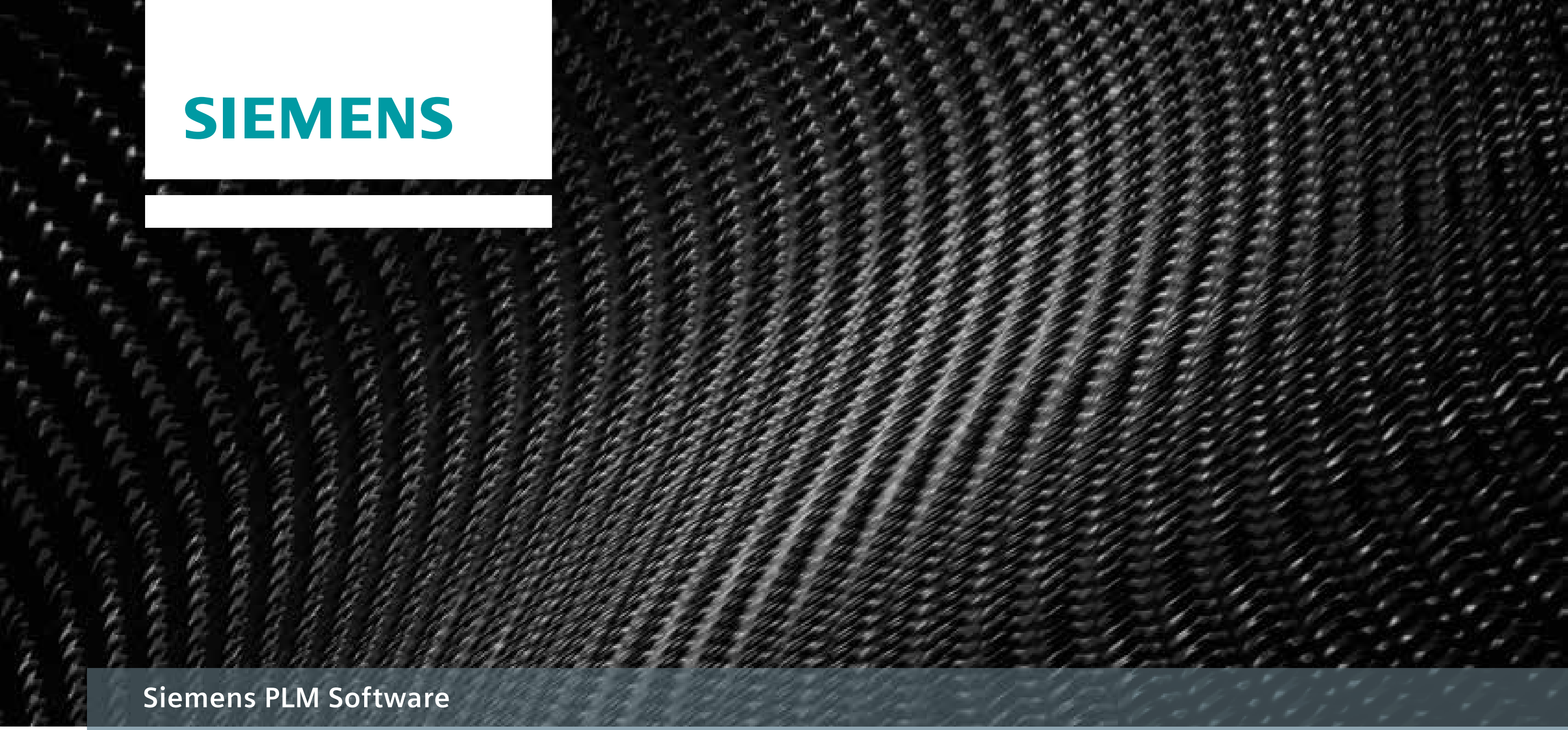


SIEMENS

Siemens PLM Software

LMS Samtech Samcef Composites

Increasing structural efficiency and reliability while minimizing weight

Benefits

- Analyze complex laminated and sandwich structures
- Capture the highly nonlinear behavior of thin-walled composite structures
- Identify the failure modes in laminated composite structures
- Predict damage propagation inside the plies and at the interface
- Determine tight safety margins
- Reduce weight and provide safe structures
- Replace some physical tests by virtual prototyping at different stages of the pyramid of tests
- Reduce costs associated with manufacturing process setup

Summary

All industries are facing new economic, regulatory and environmental constraints that force them to explore and implement strategies for developing lightweight designs. As a result, industries must be able to replace metallic parts with composites without degrading mechanical performance. This means using solutions based on laminated materials made of fiber reinforced polymer unidirectional or woven fabric plies. In order to study and size such laminated composite materials and structures, it is necessary to use adapted simulation tools.

LMS Samtech Samcef™ Composites software from Siemens PLM Software provides answers to these challenges. Based on customer engagements conducted over the last 30 years as well as the idea of extending the boundaries of the classical finite element analysis (FEA) method, LMS Samtech Samcef Composites can be used to study the highly nonlinear behavior of composite materials and structures, increase structural efficiency and reliability plus minimize weight.

Image courtesy of Airbus.

LMS Samtech Samcef Composites

Features

- Comprehensive finite element library
- Nonlinear implicit solver for static and dynamic analyses
- Thermomechanical analysis for manufacturing process simulation
- Specific progressive damage models for inter- and intralaminar composites and their coupling
- Parameter identification for the damage models
- Fracture mechanics
- Powerful optimization algorithms and sensitivity analysis modules

The challenge of minimizing weight

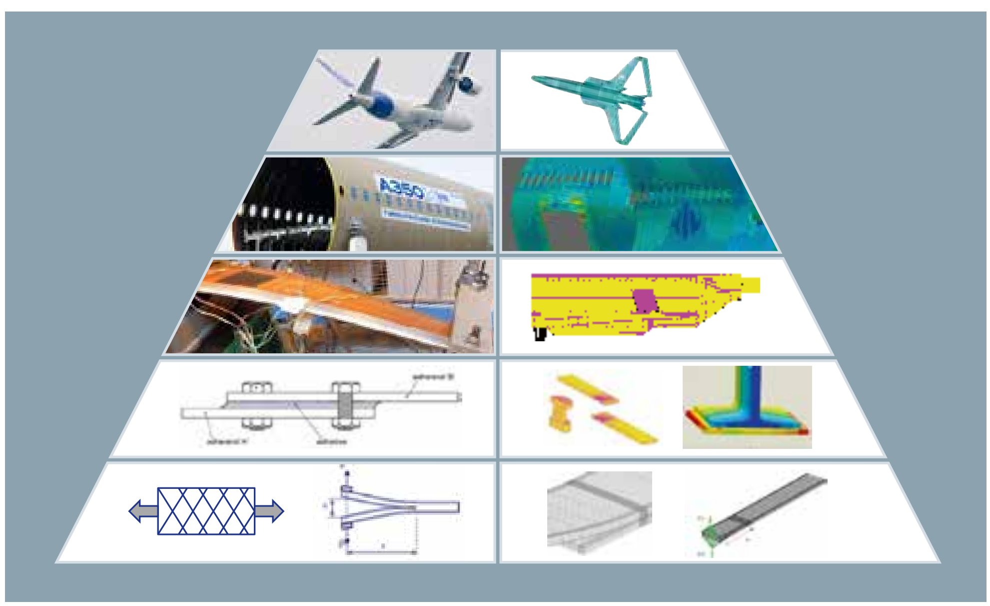
Due to economic and environmental pressures, developing safe and light mechanical systems and structural components has become essential. There are three ways to decrease structural weight. The first is to use lightweight materials such as laminate structures based on continuous fibers in order to keep mechanical performance intact compared to equivalent metallic solutions. The second way is to use optimization algorithms, which help engineers identify feasible designs of minimal weight. The third way is to use nonlinear analysis that allows you to eliminate solutions that are too conservative because of linear assumptions – perhaps even keeping or adding unnecessary weight – so you don't get the full value of composite materials.

The keys to success are being able to model laminated composites, and provide optimization and nonlinear analysis capabilities.

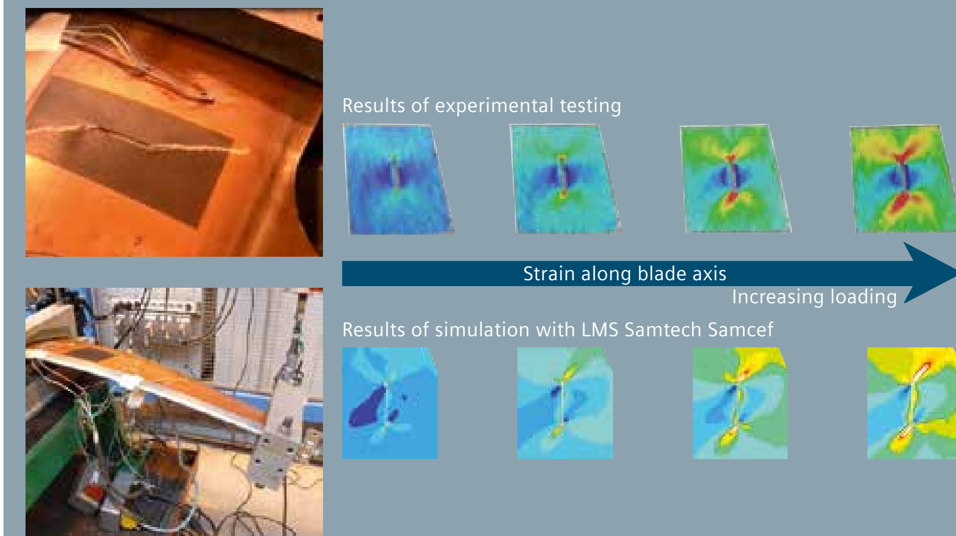
From coupon to large-scale models

The sizing process for composites is based on the building block approach, also known as the pyramid of tests. The knowledge of nonlinear material and structural behavior is built step-by-step, from the coupon to the full-scale structure. Replacing some physical tests of this pyramid by using simulation allows you to estimate the quality of different possible designs without having to build physical prototypes, leading to significant time and cost savings. This challenge can only be surmounted by using predictive analysis tools.

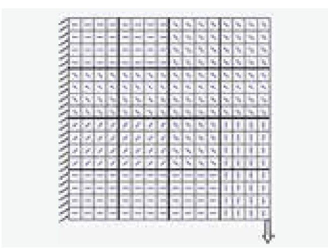
Numerous test results have demonstrated that the analysis capabilities of LMS Samtech Samcef Composites make it the right complement to physical prototypes. Thanks to its advanced modeling and nonlinear analysis capabilities as well as its unique damage models for composite materials, LMS Samtech Samcef Composites can be used at different stages of the pyramid to replace some physical tests with virtual testing.



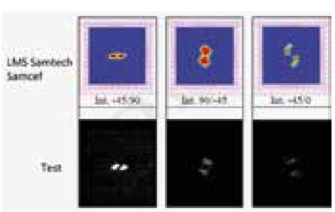
Building block approach including the composite structure along with virtual and experimental material testing.



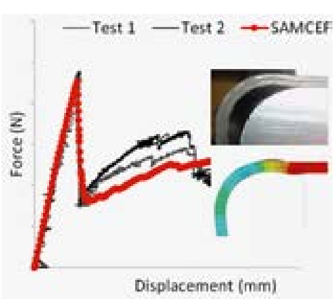
Correlation between LMS Samtech Samcef and test results showing damage on a helicopter blade. Images courtesy of Airbus Group Innovations.



Example of optimal fiber orientation in composite plies.



Application of damage tolerant approach for composite design. Image courtesy of Honda R&D.



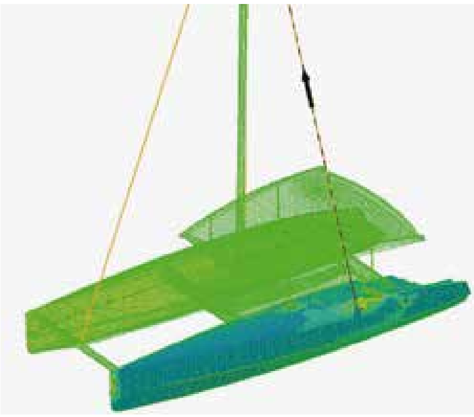
Prediction of inter- and intra laminar damage propagation. Image courtesy of Honda R&D.

Progressive damage in composites
Laminated composite materials exhibit very specific failure modes, such as fiber failure, matrix cracking, fiber-matrix decohesion and delamination. Unlike metals, composites damage not only relates to fatigue, but also appears in quasi-static loading situations. This is often the case for low energy impacts that lead to invisible or barely visible impact damage (BVID) in the composite structure. The sensitivity of composites to impacts and the resulting degradation of mechanical performance is the major concern of stress engineers working with composites. There is a need for analysis tools that enable the engineer to reproduce and predict the effects of these impacts, and simulate damage propagation when the structure is submitted to the in-service load.

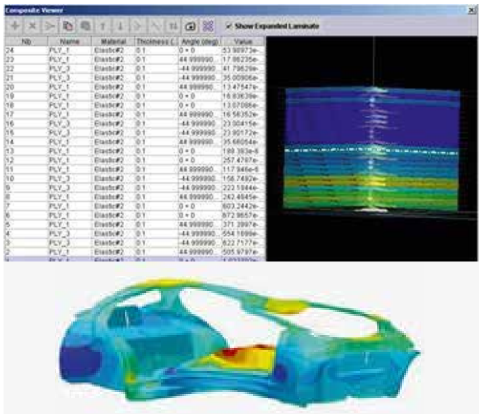
Several damage models have been published in the literature over the last 20 years. LMS Samtech Samcef Composites includes a native implementation of specific progressive damage models based on the continuum damage mechanics approach, which is defined at the ply and interface levels. The key reason for working with these models is to predict the physics of degradation as observed in real composite materials, including plasticity and coupling between intra- and interlaminar damages. LMS Samtech Samcef Composites experts know the parameters identification procedure of these damage models and can support customers in their implementation of detailed test protocols.

Even though these advanced damage models are fully implemented in the LMS Samtech Samcef Composites, user material routines are also available and can be used for quasi-static and fatigue scenarios.

Nonlinear structural analysis
Laminated composite structures are thin-walled structures that are sensitive to geometrical instabilities as they are quite often subjected to shearing and compression. Even if linear buckling analyses can provide first information on structural behavior, the geometric nonlinear analyses performed with LMS Samtech Samcef Composites enable you to go beyond the linear assumptions and limitations, and provide comprehensive information on the post-buckling behavior up to the final collapse. These analyses can be conducted in static with the help of the arc-length method, or in dynamic, possibly with damping.



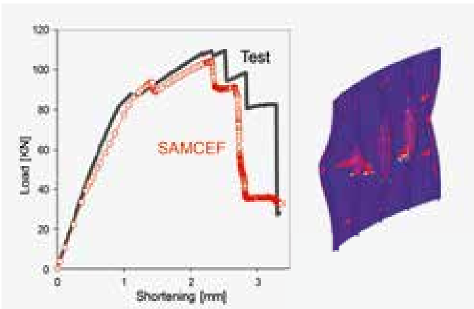
Assessment of composite strength based on classical failure criteria and advanced damage analysis. Image courtesy of Aerofleet.



Evaluation of dynamic behavior and torsional rigidity. Image courtesy of PSA.

Structural optimization of composite structures

Working with composites involves the management of a very large number of parameters and results, as failure indices are typically computed for each ply and element of the finite element model. The process requires determining the optimal number of plies and stacking sequences that satisfy classical design rules together with ply shapes and location in the structure complying with the ply continuity constraints over regions of different thickness. LMS Samtech Samcef Composites offers a variety of optimization algorithms so you can confidently optimize the composite structure using: gradient-based methods, genetic algorithms, specific integer programming approach, surrogate-based optimizer and topology optimization capabilities.



Comparison between LMS Samtech Samcef and tests results to develop a predictive model to further optimize the design. Image courtesy of DLR.

Manufacturing process simulation

Residual stresses inducing shape distortion in the composite part are generated during the manufacturing process for thermoset and thermoplastic matrices. This defect will influence the structural integrity and performance, and impact assembly of the composite parts. Manufacturing process simulation of composites is becoming more important as virtual prototypes help you design it right the first time with the correct tooling and process parameters.

With its combined thermal and structural analysis capabilities, LMS Samtech Samcef Composites offers best-in-class thermomechanical capabilities, which can be used to simulate the effects of the composite manufacturing process, such as shape distortion and residual stresses resulting from the curing (for thermosets) or the crystallization (for thermoplastics) of the matrix.

LMS Samtech Samcef Thermal software also enables engineers to model not only classical heat transfer problems (conduction, convection and radiation), but also moisture absorption problems, pyrolysis and ablation.

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