Prediction of composite materials distortion with SYSPLY

THE CHALLENGE

As part of the LCM-SMART Research & Development project led by HEXCEL, Dr. Klinkova , from the LTDS, studied the prediction of composite materials distortion and residual stresses using ESI's simulation tool SYSPLY.

THE BENEFITS

- Predict the constraints and the residual stresses of a composite part
- Adapt the Finite Element model to any composite structure and manufacturing process
- Reduce manufacturing time and cost by conducting tests on a virtual prototype early in the development process
- Avoid distortion and delamination of the composite part

"We used SYSPLY to predict virtually the residual stresses, early in the development process. ***There was a good correlation between the virtual and the physical results. The use of simulation with SYSPLY was really successful****."*

Dr. Olga Klinkova,
Research engineer,
LTDS-ENISE & Centre de la Science des Matériaux et des Structures

The LTDS (Laboratory of Tribology and System Dynamics) analyzes the behavior of structures, materials, contacts and processes by using multiscale experiments, multiphysics models and numerical simulations to optimize their performance and predict their lifetime.

As part of the LCM-SMART French National Research & Development project, the LTDS studied the prediction of composite materials distortion and the residual stresses that occur during the Liquid Composite Molding (LCM) process, with the help of ESI's Finite Element (FE) simulation tool SYSPLY.

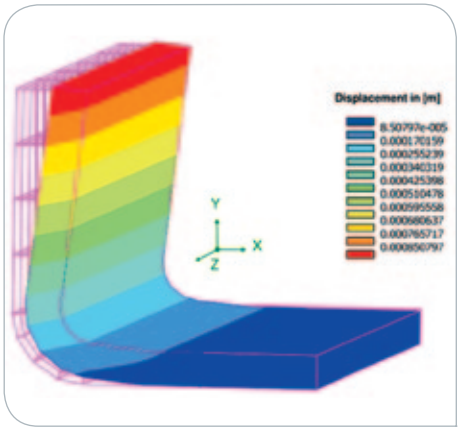
Choosing the right Finite Element method to save cost and time

Material properties are key data for the FE model and the quality of these data highly affects the accuracy of the results. Before building the FE model, the laboratory spent time to characterize the materials and led a sensitivity study in order to demonstrate the strong dependency between the final results and each material parameter.

The LTDS used SYSPLY to describe the resin response during curing and the residual stresses formation during the manufacturing and the machining processes. A FE test and trial method was used. It consisted in looking at the part and checking if any distorsions would have occured. If so, the geometry of the mold and the manufacturing parameters were adapted. The target was to save development cost and time through virtual testing.

Residual stresses in the composite materials are one of the important topics of investigation. Nowadays, the Liquid Composite Molding (LCM) process is typically used to manufacture aircraft/ aerospace components.

The base for this study was a composites "L" part used in aircraft stuctures. With a thickness of 12 mm, a length of 200 mm and a width of about 60 mm, the part was not complex. Indeed, the objective was to use a part where the distortion effects and the constraints could be easily visible.



Predicted spring-in due to residual stresses release at the end of the manufacturing process

The workflow which was used during the study was composed of two stages: the manufacturing and the machining of the composite mold. The possibility to simulate both stages in the same application and to adapt the methodology to any composite part gave to SYSPLY a significant competitive advantage. Simulation can thus considerably reduce the time and cost of mold optimizations.

Successfully determining residual stresses with simulation

FE simulation is very helpful especially for the two studied processes: the manufacturing and the machining of the composite part.

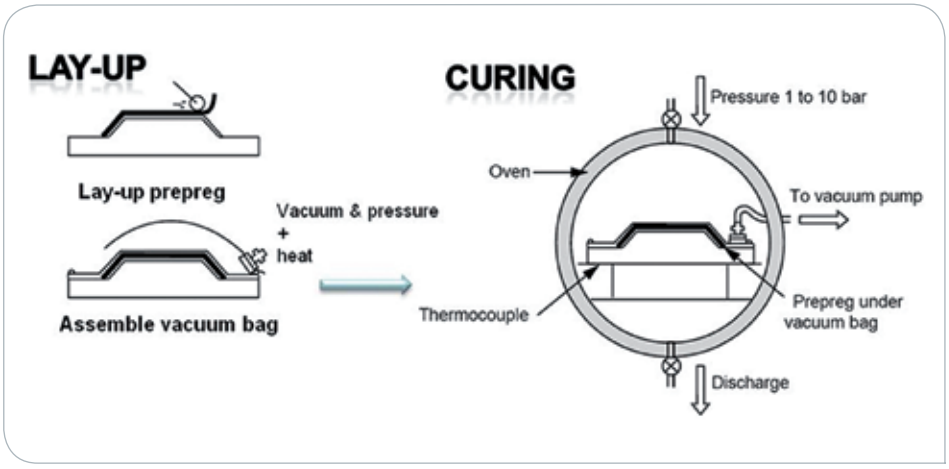
The manufacturing process consists in placing the composite material on the rigid mold and then putting it in the autoclave for curing. Once the part is removed from the mold (composites are rigid) the residual stresses (defects) appear. The machining process then deletes the rough surface to obtain a smooth surface instead.

The machining process consists in milling the residual stresses formed during the manufacturing process which are redistributed in the composite material. The composite machining process represents thermo-mechanical phenomena, which are modelled in simulation by thermal and mechanical loads applied directly to the final cut surface. The thermal source inducing the heat flux coming from the primary shear zone is related to the friction coefficient due to material removal process, and the mechanical source represents the pressure. Consequently, the challenge here consisted in the quantification of the geometry and the density.

These two processes are very different and SYSPLY is the right tool to simulate the part and to predict the residual stresses. When comparing the simulated distortions with the physical one obtained during the physical test, the results were coherent and very close. Thus, the laboratory succeeded in predicting the necessary level of residual stresses to avoid reaching material rupture. Another benefit was to know, before the manufacturing of the part, the distortion and constraints incurred during manufacturing.

For the purpose of this study, a composite mold was used, making easier the measure of the residual stresses induced on the model during the mold fabrication and then the mold machining process. It was also a great help to avoid the distortion, as the material fixing is easier with unstructured composite material which can be integrated rather than with structured composite material.

As for an industrial application, once the study was made, the laboratory gave its plans of the composite part molds to its customer. The benefit for the end customer was evident: he would not have to run the test and trial method, everything already being validated.



Composite mold manufacturing process

Composite part machining

To find out more about ESI's Finite Element simulation tool SYSPLY, please visit: www.esi-group.com/sysply

ABOUT LTDS

The Laboratory of Tribology and Systems Dynamics (LTDS) was created in 1992 and became in January 1995 a Mixed Unit of Research CNRS-MESR (ECL-ENISE) (UMR 5513) which depends on the Scientific department Engineering and Information Sciences and Technologies, depending on Section 9 of the Evaluation National Committee. LTDS is on two sites: Centrale Lyon (main site) and the National Engineering School in Saint-Etienne. Dr Olga Klinkova, former PhD student, won the PhD contest of the "Society for the Advancement of Material and Process Engineering" (SAMPE®) at a European level in 2010.

ABOUT ESI GROUP

ESI is a pioneer and world-leading provider in virtual prototyping for manufacturing industries that takes into account the physics of materials. ESI has developed an extensive suite of coherent, industry-oriented applications to realistically simulate a product's behavior during testing, to fine-tune manufacturing processes in accordance with desired product performance, and to evaluate the environment's impact on performance. ESI's solutions fit into a single collaborative and open environment for End-to-End Virtual Prototyping, thus eliminating the need for physical prototypes during product development. The company employs about 850 high-level specialists worldwide covering more than 30 countries. ESI Group is listed in compartment C of NYSE Euronext Paris. For further information, visit www.esi-group.com.

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