Case Study: e-Xstream engineering

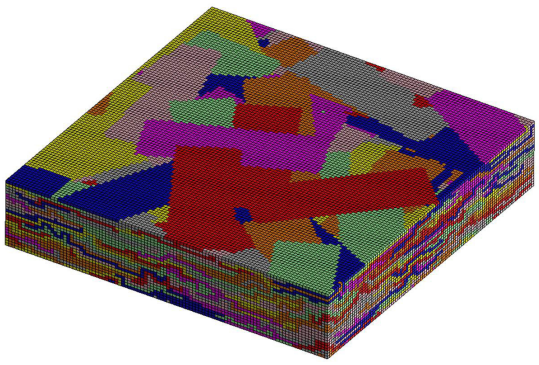
Effect of residual stresses induced by manufacturing process in Discontinuous Fiber Composites (DFC) made part

Challenge

Discontinuous fiber composites (DFC) are produced by compression molding of prepreg chips which are made of a combination of unidirectional fiber and a Thermoset or ThermoPlastic matrix. In some cases, matrix is made of thermoset which consolidate through a chemical/cure reaction at elevated temperature. However, when the curing cycle is not well monitored it can be observed some cracks that appear between the chips due to apparition of thermal stresses normal to two chips.

Due to their complex microstructure, these materials request the definition of new dedicated methods in order to capture accurately the local orientation and to compute the local homogenized properties in order to simulate correctly the curing and the design process.

Hence, the Digimat platform is used to build a complete methodology to compute these residual stresses and to take them into account during the design cycle of the part.



Effective method to capture complex microstructure of DFC

"Digimat enables us to perform in-depth analysis of the complete manufacturing cycle of very complex microstructure such as DFC. This complete solution is a cutting edge asset in the development of new composite materials and products."

– Philippe Martiny, Software solution architect, e-Xstream engineering

Solution

Digimat, effective modeling solution

In this application case, the local orientation due to the randomized repartition of the chips is measured experimentally by using a CT-scan technology. Using data analysis software, the local orientation tensors are extracted and provide information on how much this orientation varies all over the part. Using Digimat-FE to generate DFC-like RVE and this orientation tensor for each relevant location, homogenized properties are computed. For the need of this case, mechanical, thermal, shrinkage thermal-dependent properties are then computed using Digimat-FE. In a second step, these homogenized properties can be mapped on the mesh used to simulate the curing on the whole part.

The curing is simulated using a coupling between Digimat and MSC Marc and will provide results such as the thermal contraction due to the cool-down, the cure-shrinkage going with the chemical reaction and the residual stress in the structure. A transfer of the residual stresses can then be performed to be taken into account in a design step of the part under mechanical loads (Figure 1).

Finally, the risk of failure can be evaluated by going back at the RVE level and by applying the temperature and the strain history on the RVE's boundaries. The risk of crack between two chips can be directly connected to the normal stress at the interface of these two chips.

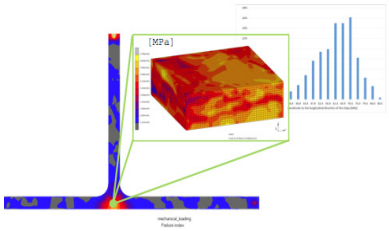


Figure 2: De-homogenization process to compute the risk of failure and defect based on a detailed description of the stresses.

Results/Benefits

Residual stress and defect prediction

The benefits of using Digimat can be illustrated as follows:

- Propose a complete methodology to analyze Discontinuous Fiber Composites: Understand the effect of the local microstructure on the behavior of the part
- Improve the understanding of the effects of the manufacturing cycle parameters: Evaluate the risk of the apparition of defects between the chips for a given set of parameters of manufacturing (pressure, temperature histories). Though their nature are different, this procedure can be applied for both, thermoset or thermoplastic resin.

Key Highlights:

Digimat:
Digimat- MF, Digimat-FE, Digimat-CAE

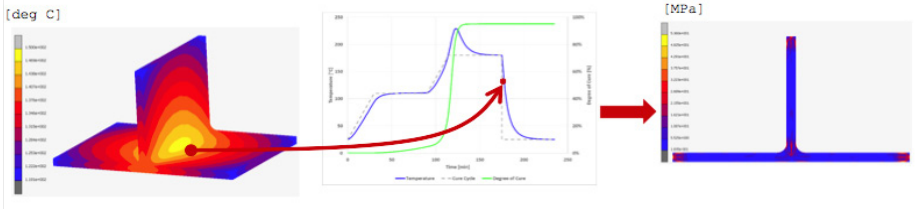
CAE Technology:
MSC Marc

Industry:
Aerospace

Application:
Manufacturing process simulation

Performance:
Residual stress and defect prediction

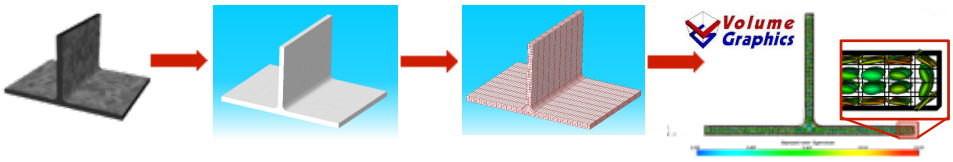
Figure 1



Typical temperature map upon cool-down

Typical temperature and degree of cure histories at the center of the part

Generation of the residual internal stresses



Part | 3D CT-scan | Integration mesh | Orientation tensor

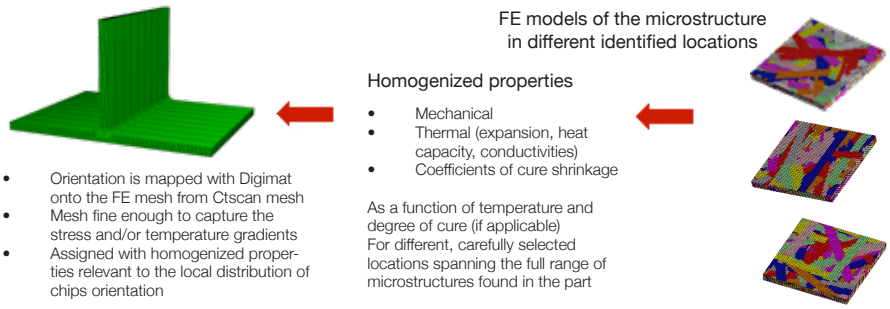


Figure 3: Methodology for the computation of the homogenized properties of DFC and transfer to the analysis mesh.

For more information on Digimat and for additional Case Studies, please visit www.e-Xstream.com

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