

# Case Study: e-Xstream engineering

## Effect of Residual Stresses Induced by Manufacturing Process in Discontinuous Fiber Composites (DFC) Made Part

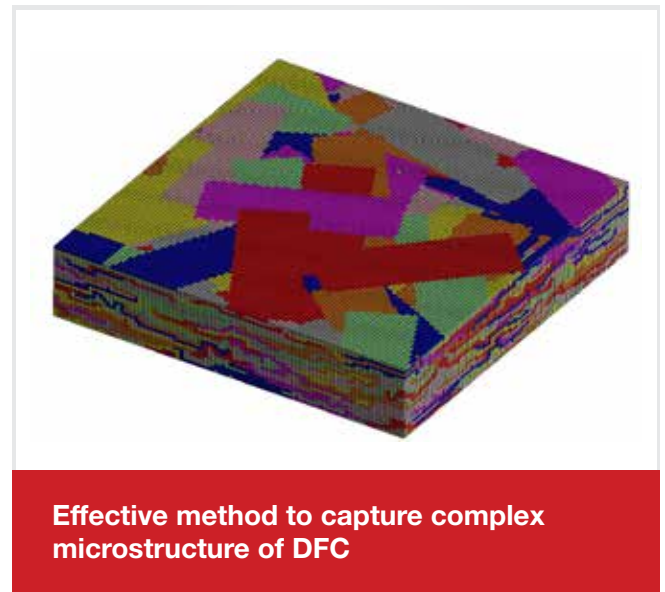
### Challenge

**Definition of a multi-scale methodology to account residual stresses generated during the curing cycle in the design process**

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.





**“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**

**Digmat, effective modeling solution**

In this application case, the local orientation due to the randomized repartition of the chips is measured experimentally 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’s nonlinear FEA solution, 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.

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

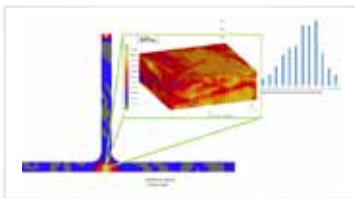


Figure 2: De-homogenization process to compute the risk of failure and defect based on a detailed description of the stresses

two chips can be directly connected to the normal stress at the interface of these two chips.

**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 for the apparition of defects between the chips for a given set of parameters of manufacturing

**Key Highlights:**

**Product:** Digimat-MF, Digimat-FE, Digimat CAE

**CAE Technology:** Marc

**Industry:** Aerospace

**Application:** Manufacturing Process Simulation

**Application:** Residual stress and defect prediction

(pressure, temperature histories). Though their nature is different, this procedure can be applied for both, thermoset or thermoplastic resin.

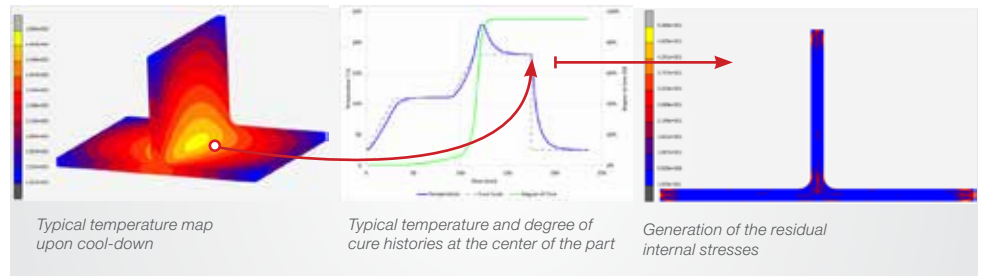


Figure 1

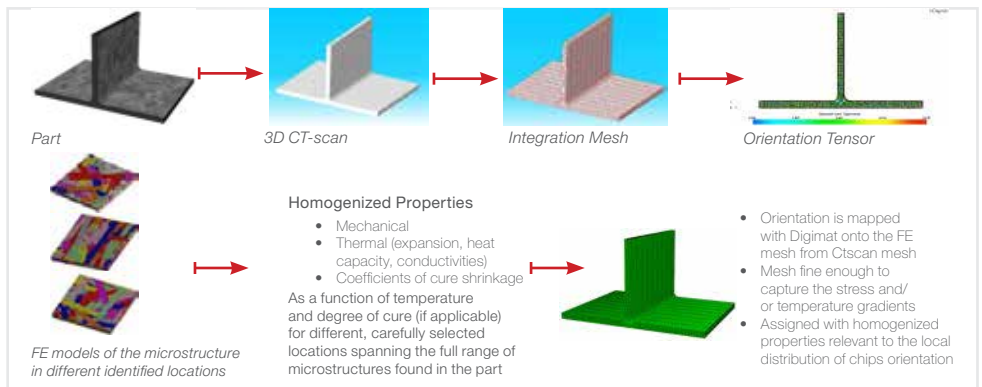


Figure 3: Methodology for the computation of the homogenized properties of DFC and transfer to the analysis mesh.

For more information on Digimat and for additional Case Studies, please visit [www.e-Xstream.com](http://www.e-Xstream.com)

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