Predicting Mechanical Behavior of Reinforced Plastic and Composite Parts

Sylvain CALMELS - e-Xstream Engineering

1 Introduction

All the main industries worldwide are progressively adopting the usage of reinforced plastic and composite material for their product and have to face one major difficulty when it comes to design them: predicting the mechanical behavior of multi-phases and heterogeneous materials. On the structural side, each of these materials show a specific heterogeneous and anisotropic behavior in terms of stiffness, failure or electrical behavior as well as strain rate or thermal dependency fully driven by the microstructural organization of the reinforcements in the matrix. On the other side, the manufacturing process drives the final fibers orientation and distribution throughout the part. This means the design teams need a material and structural engineering technology able to create the link between the manufacturing process and the structural behavior of the components. Such technology is based on a micromechanical material modeling strategy based on the combination of the constituents' behaviors and the local microstructure definition. This extended abstract address briefly how this technology can be used to obtain accurate prediction of reinforced plastic and composite parts for any performance. A brief example is shown here. Other application examples will be shown during the presentation.

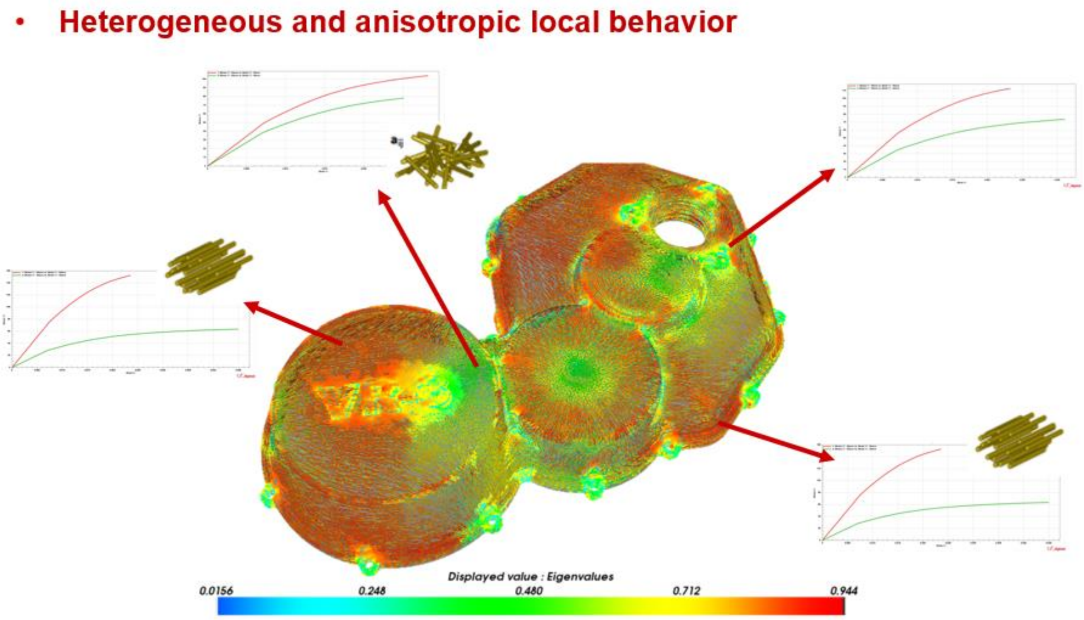

Fig. 1
The local mechanical behavior is driven by the result of the manufacturing process: the fiber orientation distribution

2 The multi-scale material modeling strategy

Reinforced plastics and composites consist of a material matrix with embedded inclusions**.** The constituents commonly used are short, long or continuous fibers, mainly glass or carbon, combined with thermoplastic or thermoset matrices. Parts made of these materials can be manufactured using different processes: injection molding, compression molding, RTM and so on. Their specific performance depends a lot on the local microstructure in the part. Fiber orientations are heavily influenced by the processing step which drives the final distribution of material properties over the part. This is where the complexity of composite design sets in. The manufacturing step, the local microstructure, material properties and final performance of the part depend on each other. To be really able to take advantage of tailored properties and hit the goal of finding the optimal overall design, it is mandatory to take all influences into account.

The multi-scale material modeling approach starts with an in-depth investigation of multi-phases materials on the microscopic level. Based on the lessons learned, homogenization technology delivers a micromechanical model that can take into account the impact of the fiber orientation on the requested material performance, e.g. stiffness and failure. In structural analyses, be it on dumbbell, part or system level, this material model is coupled to results from processing simulations.

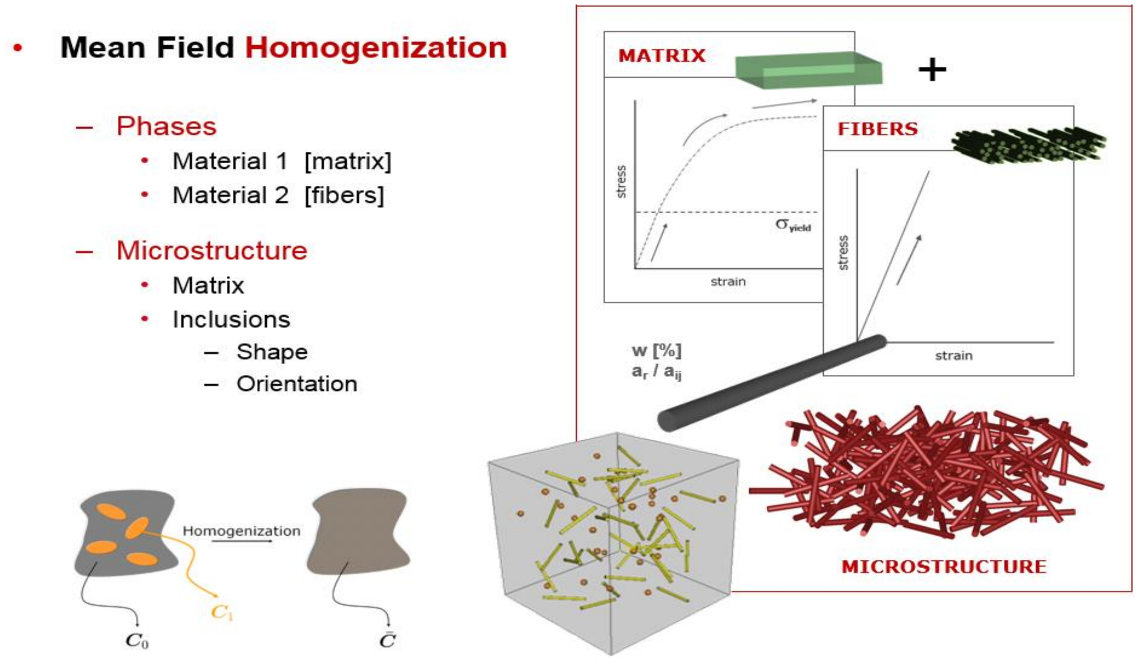

Fig. 2
The multi-scale material modeling strategy is based on the Mori-Tanaka homogenization method applied on material models built on the matrix and reinforcement materials combined with the microstructure definition of the given reinforced plastic or composite.

3 Micromechanical material models coupled to LS-Dyna explicit solver

To complete the answer for design teams, a complete easy to use workflow must be available for the end user which allow to assign the multi-scale material model to the concerned part and to map onto its structural mesh the fiber orientation definition resulting from the process simulation or measurement previously performed on a different mesh.

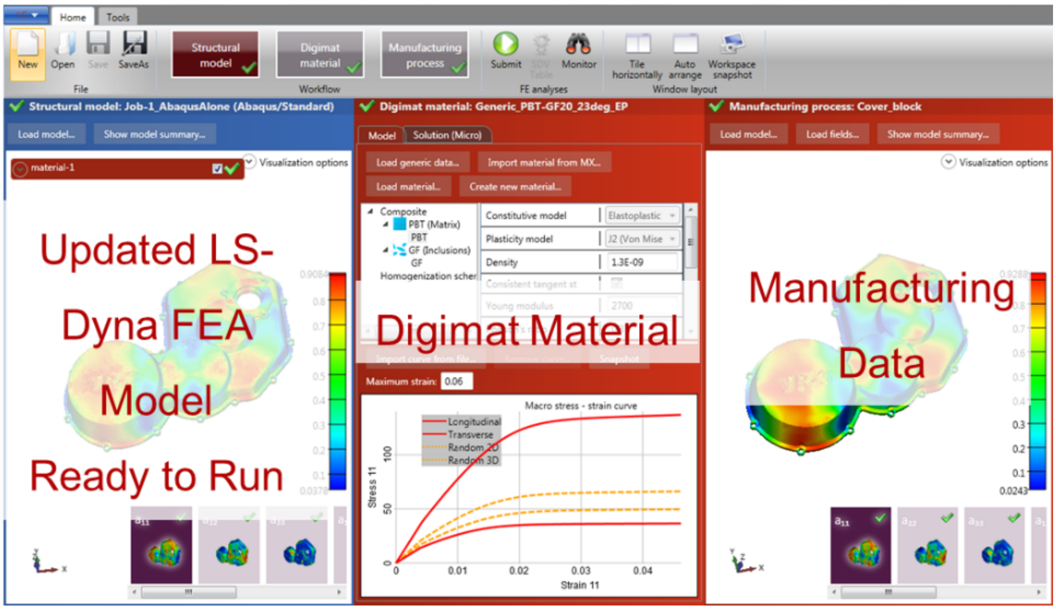

Fig. 3
An efficient and quick tool dedicated to design engineer to set up LS-DYNA FE models with micromechanical material models and taking into account the manufacturing effect on the fiber orientation distribution for an accurate behavior prediction

The results of the FEA taking into account the heterogeneity and then the variable local anisotropic behavior of the material induced by the effect of the manufacturing process throughout the part will show highly different response of the structure compared to an isotropic approach quickly unable to be accurate enough with such material.