CONTRIBUTION TO THE PREDICTION OF THE EFFECTIVE ELASTIC BEHAVIOUR OF UNIDIRECTIONAL POLYMER MATRIX COMPOSITES THANKS TO THE MODELLING OF LOCAL MORPHOLOGICAL CHANGES AND MATRIX CONFINED AREAS

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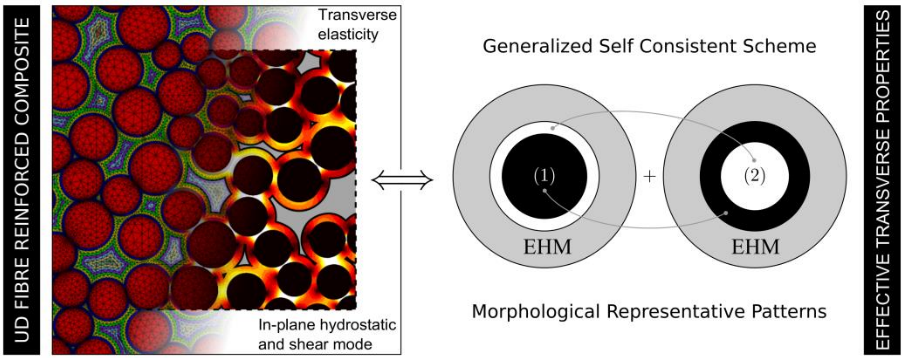

- Analytical model accounting for non-homogeneous distribution of fibers or matrix confined areas
- (n+1)-phases Generalized Self-Consistent Scheme and Morphologically Representative Pattern approach
- FE computation on virtual microstructure to "calibrate" the model
- Image analysis on real microstructure

Abstract:

One of the factors that make composite materials so attractive to many industrial sectors is their microstructural and multi-scale modularity. This specificity offers engineers the means to adapt them to a wide range of performance criteria. But it also makes it difficult to predict part efficiency. To cope with this complexity, engineers have for many years developed a robust approach requiring numerous physical structural tests. Today, a wider use of composite materials requires the development of cost-effective solutions including "virtual testing". One of the current trends is to develop multiscale simulations addressing the industry's requirements and able to accurately predict composites effective properties from the properties of their constituents and morphologies. In this context, coupled numerical and analytical micromechanical modelling approaches are an efficient way to move forward.

In this thesis with Michelin as industrial partner, the transverse elastic behaviour of transversely isotropic multi-phased materials is studied. In contrast to longitudinal properties, transversal properties are much more sensitive to the local morphology of the material and the transverse direction constitutes a weakness of the material which must be well apprehended. As an application example, the case of UD with "trapped" matrix regions is investigated. For this purpose, a “n-phase” Generalized Self-Consistent Scheme (GSCS) coupled with a Morphologically Representative Pattern (MRP) approach has been developed. Analytical solutions, depending on two parameters “m” and “c”, are provided to predict the transverse shear modulus and the transverse bulk modulus. Moreover, the proposed model, written in a transversely isotropic formalism, is valid for a wide range of inclusion volume fractions and specifically for the highest volume fractions we can find in high performance composites. Morphological descriptors are used in order to address the effect of “trapped” matrix on the transverse elastic behaviour of UD composites.
A microstructural Finite Element Model (FEM) is here used to handle the complex morphologies approaching as closely as possible real microstructures. Those numerical simulations help supplying the analytical implementation for a better description of interactions between the constituents and calibrate the “m” and “c” parameters. Then, we will have to find a convenient image analysis procedure on a real microstructure that will provide the desired settings using suitable morphological descriptors. Furthermore, estimations of the local fields such as displacement, stress or strain fields will be calculated either on an analytical way or on a numerical way thanks to a finite element modelling improved by using the p-version of the Finite Element Method.
Finally, mechanical testing would be performed to assess the relevance of the proposed approach.