11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

WOVEN POLYMER MATRIX COMPOSITES: CHARACTERIZATION AND MODELLING OF DAMAGE AT THE MESOSCALE

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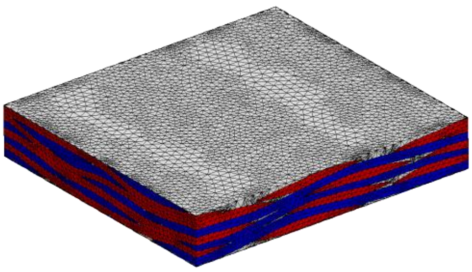
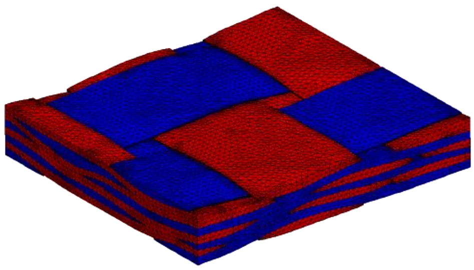
Key Words: *Woven Composites, Multiscale Modelling, Damage Characterization.*

Composite materials manufactured using textile architectures are receiving a growing interest in the field of advanced structural applications. The main reasons are related to the fact that the microstructure of fibre preforms can be tailored to satisfy the specific needs for mechanical performance, the ease of handling for automation, and the ability to generate complex shapes in a limited number of operations.
The multi-scale nature of woven composite materials poses a challenge to the development of reliable finite element models able to predict the macroscopic structural response of the mechanical part. In particular, at the mesoscopic level, that is the scale of a yarn, patterns for woven fabrics are defined by the smallest Representative Unit Cell (RUC), which describes the interlacing of the warp and weft yarns. In order to identify the damage phenomena, it is extremely important to have a proper geometrical and mechanical characterization of the woven fabric at this scale [1-3].
This paper deals with mesoscale analysis of two-dimensional textile composites in which the textile reinforcement is embedded in a solid matrix. A finite element strategy is proposed to evaluate the effects of intra-yarn transverse damage on the macroscopic mechanical properties obtained performing periodic homogenization. The finite element model is generated using the automated method proposed by Grail *et al.* [4]. This method is able to generate consistent Finite Element (FE) meshes of RUCs of textile composites with preformed and compacted reinforcements, and nesting between fabric layers, see Fig. 1. The elastic and strength parameters required for the yarns are obtained performing periodic homogenization on a representative volume element of the microscale (fibre/matrix).



(a)



(b)

Figure1. Optimized FE mesh of the compacted RUC of a plain weave architecture with the experimentally observed shift between the fabric layers. (a) Total RUC with matrix complement. (b) Mesh of the yarns only.

In order to characterize the damage mechanisms of a two-dimensional polymer matrix composite, multi-instrumented tensile tests have been performed at ONERA on a four-layer plain weave fiberglass fabric with epoxy matrix. Experimentally observed strain distributions obtained using digital image correlation techniques are compared with numerical results to validate the finite element model. Microscopic observations of the tested specimens allow for the characterization of the intra-yarn transverse damage sequence and locations. In the proposed procedure, discrete damage is introduced in the RUC in the form of cracks transverse to the loading direction. The number of cracks (ρ_s = number of cracks/mm^2) are based on the number of visible cracks observed by means of the microscopic observations. Microdecohesions at the crack's tips are also taken into account. This is done by means of the crack insertion algorithm developed by Chiaruttini *et al*. [5], see Fig. 2. The evolutions of the elastic moduli as function of the crack density ρ_s have been investigated both numerically and experimentally, and the results for the elastic modulus E_{11} are shown in Fig. 3. The numerical results are in good agreement with the experimental data. This confirms that the proposed procedure is promising for the prediction of damage effects on the macro-mechanical properties of woven composite.

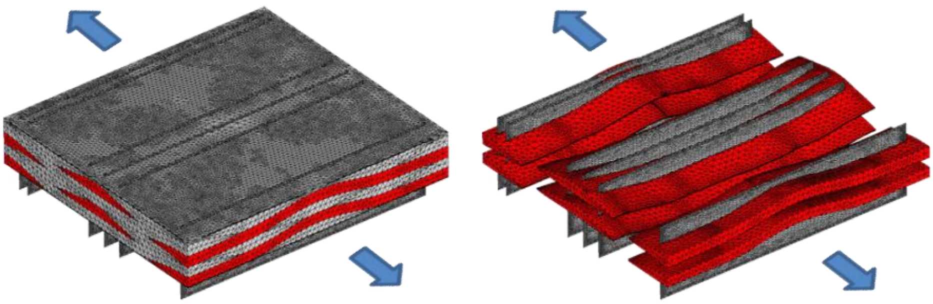


Figure 2. Cutting planes representing the crack fronts inside the RUC (only the yarns are cut).

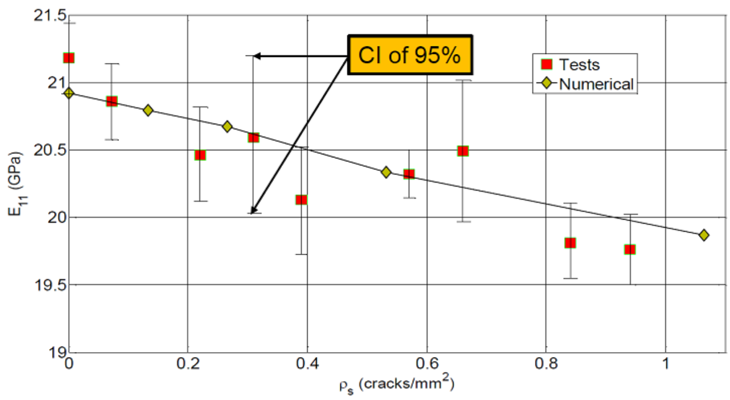


Figure 3. Experimental and numerical investigation of the effect of transverse damage on the module E_{11} as function of the crack density ρ_s.

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