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ON STOCHASTIC HOMOGENIZATION OF FIBER REINFORCED COMPOSITES EXHIBITING A RANDOMLY FLUCTUATING VOLUME FRACTION

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ABSTRACT

Many engineering materials exhibit fluctuations and uncertainties on their macroscopic mechanical properties. This basically results from random fluctuations observed at a lower scale, especially at the mesoscale where microstructural uncertainties generally occur. The main objective of this study is the characterization of volume fraction stochastic fluctuations in fiber reinforced composites. For this purpose, a theoretical stochastic framework and the associated experimental investigation are proposed and applied to a long fiber thermoplastic. First, relevant scales are introduced, allowing one to proceed to two successive homogenizations taking into account the random mesostructure of the composite, as shown on Fig. (1). Then, considering the nature of the fluctuations, the volume fraction at the microscale is modelled as a random field and the construction of a relevant probabilistic model is proposed. More precisely, a statistical reduction of the random field is performed using a Karhunen-Loève expansion and the probabilistic interpolation of the random vector involved in the representation is carried out using a Polynomial Gaussian Chaos expansion. The identification of the Chaos coefficients is classically performed using the Maximum Likelihood Principle, leading to a high-dimensional optimization problem solved by a random search. The random effective properties are further represented using a Polynomial Gaussian Chaos expansion whose coefficients are determined coupling the double-scale homogenization procedure with a non-intrusive stochastic solver. An experimental procedure dedicated

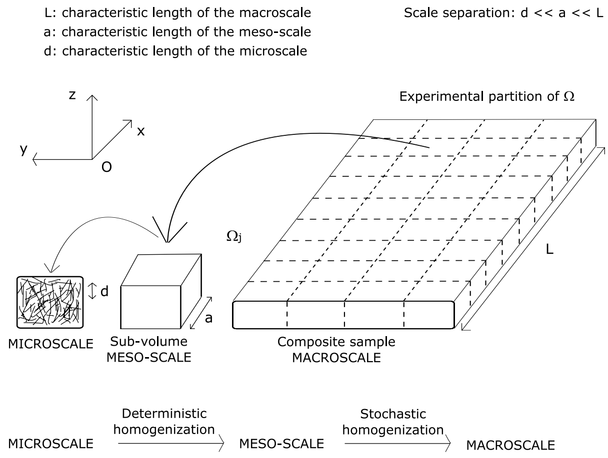

Figure 1: Top: experimental partition and scale separation. Bottom: successive homogenization procedures.

to the identification of the parameters involved in the probabilistic model is presented and relies on velocity measurements (using a non-destructive ultrasonic method). The combination of these experimental results with a micromechanical analysis basically provides realizations of the volume fraction random field (see Fig. (2)). As a result, it is seen that the volume fraction can be modelled by a homogeneous random field whose spatial correlation lengths are determined and may provide conditions on the size of the meso-volumes to be considered. Finally, the impact of such volume fraction random fluctuations on the stochastic overall properties is also investigated.

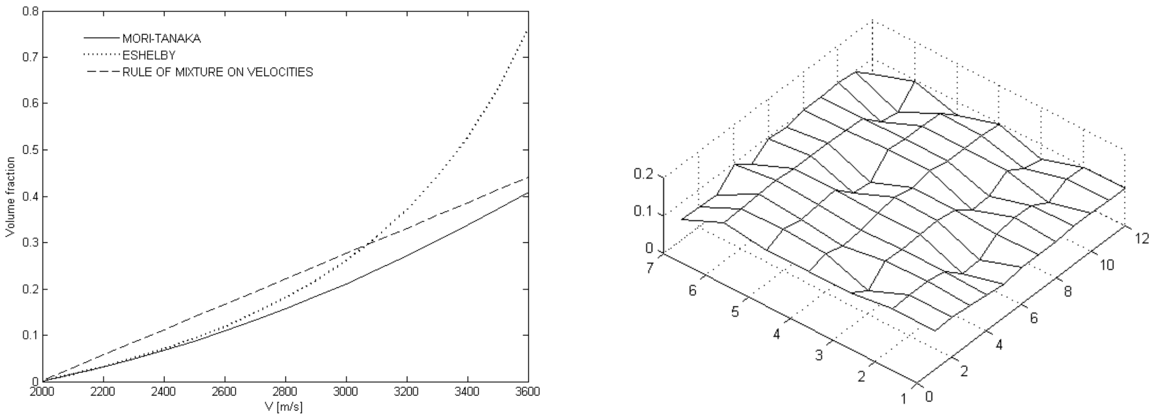

Figure 2: Left: micromechanics-based mapping between the wave velocity and volume fraction. Right: Volume fraction random field, Experimental realization 5.

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