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SUMMARY

This work is dedicated to the stochastic analysis of the elasticity tensor random field for composite materials at the mesoscale. Two probabilistic models are proposed and identified experimentally. The approaches are used to investigate the representative volume element size with respect to the mesoscopic spatial correlation lengths.

Keywords: probabilistic model, composite materials, Karhunen-Loève expansion, Polynomial Chaos expansion, representative volume element, random elasticity tensor.

Introduction

For some classes of materials, the size of the Representative Volume Element (RVE) can be much larger than the one of the domain typically used in experimental testing or structural applications. This is typically the case of some concrete or composite materials reinforced by micrometric inclusions, for instance. As a result, one may face a large amount of scatter in experimental results, yielding an extensive use of safety factors. Then, it turns out necessary to model both the spatial and statistical fluctuations exhibited by such media: such a modeling can be achieved by considering some microstructural features as random fields. This work is dedicated to the construction, experimental identification and use of a probabilistic model of the random elasticity tensor at mesoscale. For this purpose, two kinds of approaches are considered.

Modeling the random elasticity tensor through stochastic homogenization

The first one is based on the construction of a probabilistic model for the mesoscopic volume fraction (see [1]) and relies on two classical probabilistic representations, namely the Karhunen-Loève and Polynomial Chaos expansions. A mean-field homogenization technique then allows the realizations of the mesoscopic elasticity tensor random field to be computed. As a very first application, the methodology is applied to a two-phase injected material whose experimental characterization is performed by using an ultrasound analysis. The results allow the experimental trajectories of the random field to be identified by solving an inverse problem (see figure 1). The identification of the of the probabilistic model parameters is carried out by using the Maximum Likelihood Principle.

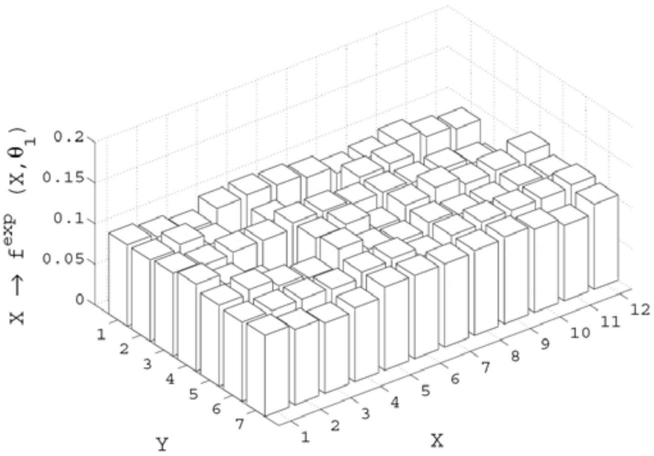

Figure 1. First experimental realization of the volume fraction random field.

Direct probabilistic modeling of the elasticity tensor random field

The second approach is based a probabilistic model for the elasticity tensor random field that was recently proposed in the literature (see [2]). The parameters of the model are computed by combining the ultrasound results with an optimization problem which is solved making use of a stochastic research method. Trajectories of the random field are then simulated by using Monte-Carlo numerical simulations.

Probabilistic analysis of the RVE size

Finally, both approaches are compared. Furthermore, a probabilistic convergence analysis is performed and allows one to discuss the size of the RVE in terms of the correlation lengths of the mesoscopic random field. It is seen that when the volume under investigation is defined by a characteristic length that is five times higher than the mesoscopic correlation length, the statistical fluctuations of the effective random elasticity tensor are less than 2.9% with probability level 0.99. Consequently, this methodology can be used to define the size of the RVE with respect to the mesoscopic correlation lengths, as well as to integrate mesoscopic randomness into the design and modeling of composite structures.

References

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