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► To cite this version:

M.-T. Nguyen, Christophe Desceliers, Christian Soize. Identification of an elasticity-tensor random field at mesoscopic scale using experimental measurements at mesoscopic and macroscopic scales for complex hierarchical microstructures. Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2012), Vienna University of Technology, Sep 2012, Vienna, Austria. pp.1-2. hal-00734172

HAL Id: hal-00734172

<https://hal-upec-upem.archives-ouvertes.fr/hal-00734172>

Submitted on 20 Sep 2012

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Identification of an elasticity-tensor random field at mesoscopic scale using experimental measurements at mesoscopic and macroscopic scales for complex hierarchical microstructures.

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Key words: Elasticity tensor, random field, mesoscopic, experimental identification, microstructure, stochastic homogenization, image field, statistical inverse method.

Biomechanical materials are among the most complex materials to be modeled with respect to the complexity level of their constitutive materials at the micro-scale. For instance, it is the case of the cortical bone for which several scales must be defined. At a macro-scale, such a medium is often modeled as a homogeneous material for which the effective mechanical properties can be identified using experimental tests. At micro-scale, this material is not only non homogenous and random but it also cannot be described in terms of mechanical constituents. It is the reason why we consider a meso-scale for which the medium is modeled with apparent properties represented by an elasticity-tensor random field. A complete methodology is proposed for the experimental identification of the random field at meso-scale (1) using image field measurements at macro- and meso-scales, (2) introducing two associated boundary value problems for which the change of scale is performed in the context of stochastic homogenization and (3) using statistical inverse methods. A validation will be presented for cortical bone with experimental simulations which measure displacement (or strain) fields at the macro- and meso-scales for a given sample submitted to a given load. The experimental displacement (strain) field is measured on the whole domain (1x1 cm) at the macro-scale while, at the meso-scale, the displacement (strain) field is measured only on a representative elementary volume (1x1 mm). First, at the macro-scale, the experimental effective elasticity tensor is identified by solving an inverse problem for the sample. Second, the effective elasticity tensor at the macro-scale is computed using the stochastic model of the elasticity-tensor field at meso-scale. Finally, the displacement (strain) field is computed at meso-scale by solving a stochastic boundary value problem using the stochastic model of the elasticity-tensor field and for which the Dirichlet conditions correspond to the experimental displacement field measured on the boundary of a representative elementary volume. Then, the identification of the parameters of the stochastic model of the elasticity-tensor field at meso-scale is carried out by (1) maximizing the likelihood of random displacement (strain) field computed by the stochastic boundary value problem with the experimental displacement (strain) field at meso-scale and by (2) minimizing the distance between the experimental effective elasticity tensor and the

effective elasticity tensor of the material at macro-scale. For the numerical proposed application, the experimental database is computationally constructed.

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