Propagation of uncertainties in the modelling of MEMS resonators (using a 3-scale probabilistic approach)

Vincent Lucas[1*], Ling Wu[1], Jean-Claude Golinval[1], Stéphane Paquay[2], Ludovic Noels[1]

[1]Department of aeronautics and mechanical engineering
University of Liege
Chemin des chevreuils 1, B-4000 Liege, Belgium
vincent.lucas@ulg.ac.be

[2]Open-Engineering SA
Rue des chasseurs-ardennais b-4031 Liege (Angleur), Belgium
s.paquay@open-engineering.com

ABSTRACT

In order to ensure the accuracy of MEMS vibrometers, the first resonance frequency should be predicted at the design phase. However, this prediction is subjected to randomness: there is a scatter in the reached value resulting from the uncertainties involved in the manufacturing process.

The purpose of this work is to take into account these uncertainties of the microstructure. The objective is a non-deterministic model that can be used since the design stage. The material is the source of uncertainties: the beam resonator is made of a polycrystalline material in which each grain has a random orientation. Solving the problem with a full direct numerical simulation combined to a Monte-Carlo method allows the probability density function of the resonance frequency to be computed. However this methodology is computationally expensive due to the number of degrees of freedom required to study one sample, motivating the development of a computationally efficient method. Towards this end a 3-scales stochastic model for predicting the resonance frequency of a micro-beam made of a polycrystalline linear anisotropic material is described.

At the lower scale, we model the micro-structure with micro-volume elements. Due to the small-scale involved, the representativity of these micro-volume elements is not achieved and thus Statistical Volume Elements (SVE) are considered. These SVEs are generated under the form of a Voronoï tessellation, each grain being assigned a random orientation. Computational homogenization is applied over the SVEs, along with a Monte-Carlo procedure, to obtain a stochastic characterization of the elasticity tensor at the second scale of interest, the meso-scale. The spatial correlation between SVEs is also estimated. A generator based on spectral methods is implemented. Afterwards, using a stochastic finite element method, these meso-scale uncertainties are propagated by taking account of the spatial correlation up to the higher scale to predict the probabilistic behavior of the MEMS resonator.