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STOCHASTIC REPRESENTATION OF A RANDOM FIELD BASED ON EXPERIMENTAL VIBRATION TESTS: A ONE-DIMENSIONAL COMPOSITE APPLICATION

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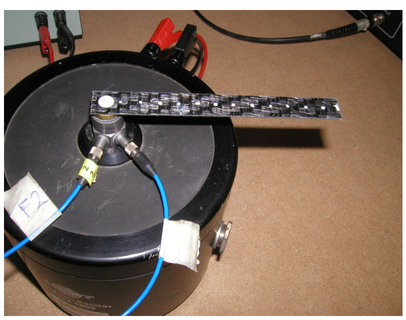
ABSTRACT

This paper is concerned with identifying a stochastic quantification of a spatially distributed random field (RF). The identification process uses the polynomial chaos expansion based on data obtained from vibrational experiments; in particular, the frequency response functions. The methodology involves two inverse problems in order to (i) estimate the realizations of the RF, projected on a finite element (FE) basis, by incorporating an optimization problem and (ii) estimate the coefficients of the polynomial chaos by incorporating the maximum likelihood principle. Thus, the experimental quantification enables a realistic and complete quantification of the RF, and consequently a realistic value of the correlation length; a measure of the distance over which the properties of the RF are correlated.

The presence of fluctuation in the geometry or the material properties of a plate in one or two directions are common examples of RFs. A RF is usually characterized by its statistical moments and a corresponding covariance function. In order to incorporate a RF into a numerical framework, it is mathematically expressed in terms of discrete random variables. Much literature is available on the mathematical concepts that describe the spatial variability of RFs assuming a certain covariance function. There is, however, very little expertise on the experimental quantification of spatial variability, i.e. the modelling of random fields based on direct or indirect experimental measurements.

Recently published works by Desceliers et al. [1,2] have proposed a methodology for the identification of a RF based on static and vibrational experimental tests. In these papers, the authors demonstrated their methodology numerically to quantify the Young's modulus of a random isotropic non-homogeneous material. The experimental measurements of the displacements (static case) or the frequency response functions (dynamic case) were numerically generated. The methodology can be briefed according to the following steps: (i) An experimental database is obtained, (ii) the random field is discretized by projecting it on a FE basis, thus, for each specimen, an optimization problem is solved that yields a realization of the RF corresponding to the measurements, (note that the covariance matrix is constructed using the experimentally determined realizations of all specimens), (iii) the Karhunen-Loève (K-L) expansion is used to project the FE-discretized RF on an orthogonal set of random variables (RVs) which enables through a truncation process to reduce the number of these RVs, (iv) a sample space of these RVs is obtained from the realizations computed in step (ii), (v) polynomial chaos decomposition is then used to describe the RVs in terms of standard normal RVs and some polynomial coefficients to be determined, (vi) the coefficients of the polynomial chaos representation are estimated using the maximum likelihood method. As a result, the RF is completely modelled in terms of some standard normal RVs.

The present study aims at testing this methodology using a database obtained from realistic experimental tests. A non-homogeneous elastic composite material made of twill weave fabric (glass-based fibres and polypropylene) has been used. The composition and the manufacturing process are expected to introduce variation in the material properties. Twenty specimens (beam structure) are cut from the composite plate so that the free length parallel to the warp direction is 120 mm, and the width parallel to the weft direction is 15 mm. The choice of the the beam model has been selected to enable a unidirectional variation of the RF modelling the Young modulus. A base excitation is applied on each specimen (burst random excitation signals) using a vibration exciter (electrodynamic shaker). The specimen is rigidly connected to the shaker through a piezotronic impedance head which measures both the force and the acceleration introduced to the base of the beam. A linear laser vibrometer has been used to measure the velocity at thirteen selected points on the beam. For each specimen, a set of 13 mobility FRFs are obtained. All FRF sets for all specimens constitute the experimental database that is used in step (i) to identify the FE based realizations of the Young modulus. An appropriate FE model of the structure has been simulated and implemented in the procedure; specific MATLAB codes are developed to execute steps (ii) to (vi) briefed above.



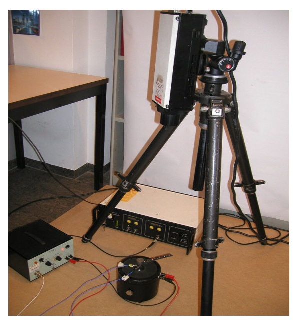


Figure 1 Experiment setup

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