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ON THE IDENTIFICATION OF MATERIAL PROPERTIES OF COMPOSITE LAMINATES USING GENETIC ALGORITHMS

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ABSTRACT

Knowledge of elastic properties of composite materials is essential for design and application in manufacture and the measurement of these properties during manufacturing offers the potential for improvements in material properties identification field. An effective and inexpensive technique for identification of orthotropic material properties of composite laminates is based on experimental data of modal vibration testing and finite element modeling. The first eigenfrequencies and eigenvectors can be measured using different methods, e.g., impulse technique and contact measurements by accelerometers. The aim of finite element modeling and optimization is to guess the material properties rendering the same vibration frequencies and modes [1, 2].

Proposed programmable identification technique is designed to input the vibration data using external files and to employ finite element package ANSYS [3] for the numerical simulation. Different laminated bending plate finite elements can be applied in simulation depending on the vibration test specimen parameters. Genetic algorithm is used as an optimization tool [4].

Poisson's ratios and transverse shear moduli are not as sensitive to the change of eigenfrequencies as other material parameters are [5]. However, for the specific characteristics of test specimen (plate dimensions, angles of orthotropy directions, thickness), the number, and the set of frequencies taken for identification, the influence of those parameters on the vibration data can be highlighted. These characteristics differ remarkably for different composite materials of the same laminate class.

Therein lies proposed two-step identification technique. First, the rough identification of material properties using test specimen of random characteristics; here only the approximate values of Poisson's ratios and shear moduli will be ascertained. Then the optimization problems are posed to maximize the sensitivities of natural frequencies to those material properties p:

$$\max \; {}^{\partial T(x)}\!\!\diagup_{\partial p}\,, \qquad \text{s.t. } x \in D \tag{1}$$

where the objective function $T(x)$ includes the residuals between experimental (measured) and calculated natural frequencies:

$$T(x)=\sum_{i=1}^{n}\frac{\left(f_i^e-f_i^c\right)^2}{f_i^{e2}}. \qquad (2)$$

The set of design parameters x includes the specimen characteristics and the set of frequencies to be taken for identification; D is feasible “shape” of problem. For example, for the one-layer unidirectional composite design parameters comprise only the aspect ratio of plate dimensions and the angle of orthotropy direction; thickness of plate and set of frequencies to be used can be added for the thick multi-layer composite laminates. The optimization problem is being solved using the genetic algorithm with tuned genetic parameters and the package ANSYS; the derivatives are calculated numerically.

In the second step of identification the adequate test specimen is prepared and usual material properties’ identification is performed. In particular case several specimens of one material with different geometry might be necessary, due to unequal influence to natural frequencies of certain identifiable parameter. The results are verified comparing the experimentally measured eigenfrequencies with the numerically obtained using the identified elastic properties. The comparison demonstrates that the eigenfrequencies calculated by the finite element method using the elastic properties obtained during the identification procedure are in good agreement with the experimental results (even with frequencies omitted in identification process). The difference in terms of residuals is in most cases less than 2%.

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