Identification of orthotropic material properties using displacement field measurements

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ABSTRACT

One of the main challenges in composite design and development is to be able to compute the damage state at any point of a composite structure during a complex loading, especially to predict their in-service global mechanical behavior. In this context, knowledge of the spatial distribution of the material elastic properties provides a quantitative estimation of the damage level and localization.

The association of kinematic fields and finite element model updating method (FEMU) constitutes an interesting way for such identification, especially in view of structural analysis and industrial requirements. Indeed, such iterative technique relies on a numerical framework, is able to explore complex shapes and loads and is based on kinematic fields surface measurement without any assumption on volume distribution [1,2].

If many studies have been devoted to the context of isotropic materials [3], the paper aims to extend the method to the determination of the macroscopic anisotropic elastic properties of composite materials. Compared to existing works, the approach is characterized by an important number of comparison points, which confers a great spatial precision and allows in the future the extension of such methodology to heterogeneous materials.

To implement the FEMU technique, a specific algorithm in Python language following the flowchart in Fig.1 has been established. A particular attention has been paid to the matching of the kinematic fields grid and numerical one through the determination of neighboring points and interpolation functions. The cost function minimization is based on the Levenberg-Marquardt algorithm.

The procedure have been applied for the identification of orthotropic carbon-epoxy laminated composites (four elastic properties and orthotropic principal angle) for aviation industry by means of kinematic fields obtained under tensile tests. An open-hole geometry is used to generate an heterogeneous strain field localized near the hole that allows to stimulate the whole strain components [4]. The displacement field measurements on the specimen surface are simulated with Abaqus finite element code as by experimental stereo-image correlation measurements.

The capability of the procedure is validated for different configurations of the laminated composite (plies stacking and orientation, components properties) through a comparison with the Kirchhoff-Love theory. Stability and convergence of the algorithm are checked for each considered parameters.

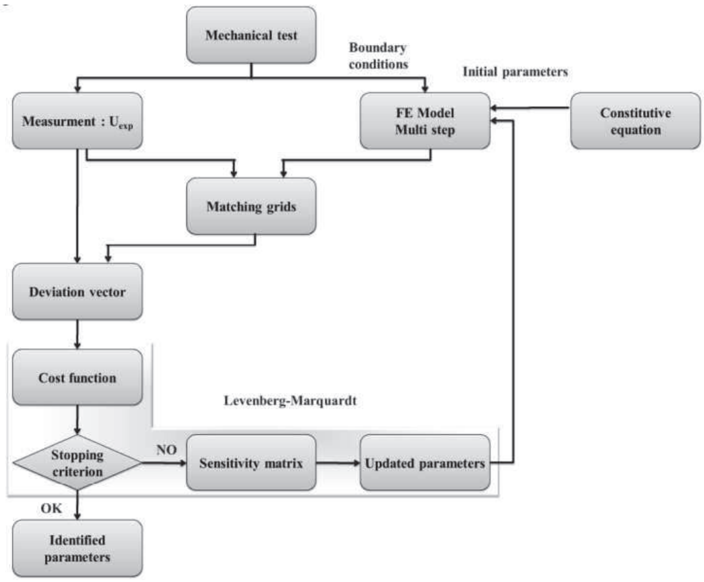

Figure 1: Identification procedure based on FEMU technique [3].

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