# A COMPARATIVE STUDY OF SHAPE-SENSING STRATEGIES FOR COMPOSITE MULTILAYERED STRUCTURES: SENSITIVITY TO INPUT UNCERTAINTIES

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## ABSTRACT

Shape sensing is the real-time reconstruction of the structural deformed shape from in-situ strain measurements. This inverse problem has important implications for the monitoring of structural integrity. Particularly, the knowledge of the structural displacements enables the real-time reconstruction of strains and stresses at every material point of the structure and eventually the application of failure criteria. Within this framework, one of the most attractive application is the monitoring of composite structures which may experience delamination and impact damages that can affect their load carrying capabilities.

A robust and efficient algorithm for the full-field reconstruction of the displacement field is the so-called inverse Finite Element Method (iFEM) [1,2], which is based on the First-order Shear Deformation Theory (FSDT) for plates and shell structures. iFEM uses a least-squares variational principle, which is discretized by $C^0$-continuous inverse elements. Particularly, the variational statement enforces experimentally measured strains to be least-square compatible with those interpolated within the inverse elements. Because only strain–displacement relations are used in the formulation, both static and dynamic response can be reconstructed without any a priori knowledge of material, inertial, loading, or damping structural properties.

In this paper, iFEM is compared with the so-called modal method [3] with particular focus on the shape sensing of multilayered composite structures. In the modal method the displacement field is approximated by using a subset of mode shapes and proper weights. These are determined by using strain-displacement relationships and measured surface strains. Both methods are general enough to accommodate complex structural topologies and boundary conditions and allow the evaluation of the three-dimensional displacement field over the whole computational domain. However, the modal method requires precise knowledge of the material properties.

The theoretical frameworks of the two different strategies are firstly reviewed. Then, numerical tests are conducted on a multilayered CFRP (Carbon-Fiber Reinforced Plastic) stiffened plate, subjected to different static and dynamic loadings. For both methods, the sensitivity of the solutions is examined with respect to inherent measurements errors in the input strains. For the modal method the influence of uncertainty in the material properties is also examined.

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