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Static and dynamic analyses of laminated plates using a layerwise theory and a radial basis function finite element method

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Abstract: A layerwise shear deformation theory for composite laminated plates is discretized using a radial basis function finite element method (RBFEM). The RBFEM is the radial basis function (RBF) method in weak-form and is a partially mesh free method. Therefore, elements of complex shapes can be easily constructed. Compact-support Wendland function is used in the RBFEM. A layerwise theory based on a linear expansion of Mindlin's first-order shear deformation theory in thickness direction is employed for static and dynamic analysis. The combination of the RBFEM with the layerwise theory allows an accurate and very flexible prediction of the field variables. Laminated composite and sandwich plates were analyzed. The RBFEM solutions were compared with various models in literatures and showed very good agreements with exact and other high accurate results in literatures based on similar layerwise theories. The analysis of composite plates based on the layerwise theory indicates that the RBFEM is an effective method for high accuracy analysis of large-scale problems.

Keywords: composite; sandwich plates; layerwise theory; radial basis functions; finite element method.

1. Introduction

Composite and sandwich plates are one of the most significant applications of composite materials in industry. As a result, various approximate theories have been developed in an effort to properly assess their mechanical behavior under static and dynamic loads [1-3]. Numerous displacement-based laminate theories have been proposed to describe the kinematics of laminated composite plates. Based on the assumed variation of the displacement field through the laminate thickness, these theories can be divided into two broad classes: the equivalent single-layer theories and the layerwise theories [4, 5]. For laminated composite plates, the former theory amounts to replacing the heterogeneous laminate with a statically equivalent (in the integral sense), single, homogeneous layer. Therefore, the simplicity and low computational cost is evident, while the accuracy is declined especially in sandwich applications, the difference between the material properties of layers makes it difficult for such theories to fully accommodate the bending behavior. The layerwise theory, introduced in the 1980s [6-13], assumes separate displacements within each material layer, thus provides much more accurate approximation in kinematics. A very recent and comprehensive review of such theories in the analysis of multilayered plates and shells has been presented by Carrera [14]. This work adopts a layerwise theory [1, 15] based on an expansion of Mindlin's first-order shear deformation theory in each layer. The in-plane displacements are assumed to be piecewise linear through thickness and continuous at layer's interface, and the transverse displacements are constant through the thickness. Also the theory directly produces very accurate transverse shear stress, although constant, in each layer.

The finite differences (FDM) and finite elements (FEM) are the most commonly used spacial discretization techniques thus far. Such low order schemes typically use low order basis functions and the accuracy is improved

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