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Use of higher-order Legendre polynomials for multilayered plate elements with node-dependent kinematics

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Abstract

In the present work, higher-order Legendre polynomials are adopted as shape functions of p-version plate finite elements (FEs) and used in combination with node-dependent kinematics (NDK) to construct computationally efficient global-local FE models for the analysis of multilayered plates. The use of higher-order Legendre polynomials enables the elements to accommodate the complex structural deformations with a fewer number of variables in the FE model. Derived from Carrera Unified Formulation (CUF), NDK can integrate plate kinematics based on Equivalent Single Layer (ESL) models and Layer-wise (LW) models to obtain global-local models using no *ad hoc* coupling. The combination of Legendre-type shape functions and NDK shows excellent rates of convergence, which can lead to FE models with high accuracy in the refined local area with a reduction in the computational efforts. The capabilities of the proposed approach are investigated through various numerical examples by comparing the solution accuracy versus the computational expenses.

Keywords: laminated plate, Carrera Unified Formulation, Legendre polynomials, node-dependent kinematics, finite element

1. Introduction

Composite laminated structures have attracted significant attention in the engineering field in the recent decades due to their outstanding structural efficiency. Due to the complex arrangement of these materials, conventional simulation tools soon reach their limits, which has boosted the demands for structural analysis methods to capture their mechanical responses accurately.

Towards the accurate analysis of thin-walled laminated structures, a variety of 2D theories have been proposed and extensively implemented in numerical models. Classical Plate Theory (CPT) [1] is the simplest 2D model, which is based on Kirchoff-Loves hypothesis. First-order Shear Deformation Theory (FSDT) [2] takes the transverse shear effects into account but can only approximate the shear stresses through the thickness of a plate as constants. A series of Higher-Order Theories (HOT) [3, 4, 5] have been suggested to improve the solution accuracy. Following this line, Carrera Unified Formulation [6] was introduced to derive refined plate and shell models for the analysis of laminated thin-walled structures. Various theories can be integrated to formulate refined kinematics based on either Equivalent Single Layer (ESL) or Layer-wise (LW) approach through the arbitrary sets of thickness functions. By making use of the so-called Fundamental Nucleus (FN), the corresponding governing equations can be derived in a unified and compact form [7]. In the CUF framework, a variety of 2D models constructed with different kinematic assumptions were introduced in the last years by Cinefra and Valvano [8], Cinefra et al. [9, 10, 11] and Carrera et al.[12].