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Large-deflection and post-buckling analyses of laminated composite beams by Carrera Unified Formulation

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Abstract: The Carrera Unified Formulation (CUF) was recently extended to deal with the geometric nonlinear analysis of solid cross-section and thin-walled metallic beams [1]. The promising results provided enough confidence for exploring the capabilities of that methodology when dealing with large displacements and post-buckling response of composite laminated beams, which is the subject of the present work. Accordingly, by employing CUF, governing nonlinear equations of low- to higher-order beam theories for laminated beams are expressed in this paper as degenerated cases of the three-dimensional elasticity equilibrium via an appropriate index notation. In detail, although the provided equations are valid for any one-dimensional structural theory in a unified sense, layer-wise kinematics are employed in this paper through the use of Lagrange polynomial expansions of the primary mechanical variables. The principle of virtual work and a finite element approximation are used to formulate the governing equations in a *total Lagrangian* manner, whereas a Newton-Raphson linearization scheme along with a path-following method based on the arc-length constraint is employed to solve the geometrically nonlinear problem. Several numerical assessments are proposed, including post-buckling of symmetric cross-ply beams and large displacement analysis of asymmetric laminates under flexural and compression loadings.

Keywords: Carrera unified formulation; Composite beams; Higher-order theories; Geometrical nonlinearities; Post-buckling; Path-following methods.

1 Introduction

During the last decades, composite laminates have been widely used for the design of advanced structural components. Even today, thanks to the new aircraft programs such as the Airbus A350XWB, aerospace industry continues to belong to the forerunners of composites application, manufacturing, and verification. As a natural consequence, contextually, research engineers and scientists have developed a large number of theories for describing the *rheological* behavior of composite structures and for substituting those obsolete models that were originally devised for metallic components. Interested readers can find more details about the modeling and linear mechanics of composite laminates for plate/shell and beam structures in

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