Post-buckling and nonlinear thermal stress of laminated composite by CUF

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Advanced composite materials offer high specific stiffness and strength and a nearly zero coefficient of thermal expansion in the fiber direction, making them suitable for extreme thermal environments [1]. When high temperatures are reached, a thermo-elastic linear analysis is no longer sufficient to describe the structural behavior. Furthermore, the thermal load acts as a volume force affecting both the displacement and stress fields.

It is well known that, once a specific value of overtemperature has been reached, it is no longer possible to restrict the structural description to small displacements and rotations. In such cases, the introduction of a nonlinear geometrical relation becomes imperative, particularly for highly flexible structures.

Large deformations result in coupled bending, torsion, shear, and membrane behavior, which in turn leads to high nonlinear phenomena [1,2]. Post-buckling behavior and high deflection description of structures under mechanical field have been vastly investigated [3,4], and analogous considerations must be done for thermal loading.

The study centers on the description of the thermal post-buckling behavior of composite structures with a particular focus on high-displacement levels and consequent stress fields. The governing equations are derived from the Principle of Virtual Displacement (PVD), where the nonlinearities are incorporated through the full Green-Lagrange strain tensor. The structural model is obtained through the Finite Element Method (FEM), where high-order theories are implemented within the Carrera Unified Formulation (CUF) [5]. The nonlinear problem is solved using the Newton-Raphson method combined with the arc-length constraint. The thermal load is applied uniformly across the thickness. Furthermore, it is analyzed through a decoupled approach, where the thermal profile is assumed to be known and is treated as an external load.

The results show the influence of the adopted expansion theory in their accuracy and the necessity of using these models combined with the nonlinear description to accurate predict the displacement and stresses field. Different geometries and materials are evaluated, and the

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importance of the nonlinear terms in the buckling investigation is assessed. Post-buckling configuration is described and secondary buckling deflection are also investigated.

Keywords: Finite element method, nonlinear buckling, nonlinear thermal stress, thermos-elastic analysis, geometrically nonlinear.

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