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Variable kinematics models for the analysis of thermal stresses in metallic and composite laminates

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The temperature variation acts as an external load on the structures, often leading to failure or unexpected phenomena. Such temperature variations may result from a variety of factors including solar radiation or drag caused by the high velocities to which aerospace structures are frequently subjected [1]. The consequent thermal load acts as a volume force, influencing both the displacement and stress fields within the structure.
The expansion properties of the material must be considered, and the nature of this load must be described by an appropriate kinematic theory that allows the strain field to be described in an accurate form, particularly taking into account the nonzero normal shear deformation. Traditional theories are unable to describe this transverse strain and the resulting stress developed along the plate thickness. The description of the thermo-mechanical problem requires additional terms in the kinematic field beyond those necessary in the modelling of purely mechanical problem [2].
This study employs higher-order theories to describe the displacement field in the thermo-mechanical problem. The Carrera Unified Formulation (CUF), within a Finite Element framework, is employed to implement these theories in a simple and hierarchical form, using the Fundamental Nuclei (FN), whose formulation is independent of the chosen kinematic theory [3]. A new implementation of this theory allows the use of different orders of expansion for each displacement field. This work aims to thoroughly examine the most appropriate kinematic theory for every displacement component to attain a precise analysis of thermal stress throughout the plate thickness. The thermal problem is schematised by a decoupled approach, where the thermal profile is considered as known and treated as an external load.
The study examines the thermal outcomes of various plates with differing boundary conditions, material, lamination and thermal profiles. It is shown that an appropriate high-order

representation of the kinematics of the displacement components is necessary to accurately describe the thermal stress along the plate, and that the choice of the best model depends on the applied thermal profile. Additionally, a comprehensive examination of several kinematic models is conducted to assess their influence and impact on the stress field.

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