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In the last decades, new challenges demanded by aerospace, automotive and other engineering fields require the adoption of sophisticated and eventually light-weight structures. For this reason, composite materials, thanks to their outstanding structural performances, in terms of strength and stiffness properties compared to metal alloys, have encountered great success [1]. However, the correct design of composite components generally requires enhanced calculation techniques to account for anisotropy coupling effects, interface phenomena, and 3D stress states. The need for a high level of accuracy and reliability from the structural simulation pushed engineers to use high-performing three-dimensional models, with a high effort in terms of computational cost. In order to cut down this drawback, scientists and researchers have been encouraged to develop lighter one-dimensional (1D) and two-dimensional models, with the goal of maintaining the same level of accuracy when compared to the heavier 3D tools. In addition, particular attention must be given to local phenomena when structures are subjected to large deformation, e.g., large displacements and large rotations. In fact, for an accurate design of structures undergoing extreme loading conditions, a geometrical nonlinear analysis must be carried out.

In many real applications, local phenomena and large cross-sectional deformations occur in particular areas of the structure, for example, in the nearby of external loads or constraint conditions. In such cases, it would be needed to build a model with variable kinematics, namely, capable of refining only the portions of the structure which undergo high deformation or rotation. In this way, the accuracy is still guaranteed, with a drastic decrease in the number of degrees of freedom and, subsequently, of the computational cost. Compatibility conditions have to be guaranteed in the interface zones between different domains, for instance with Lagrange multipliers, see the work by Prager [2].

In the present work, the use of the node-dependent kinematics concept for the geometrical nonlinear analysis of composite one-dimensional structures is proposed. With the present approach, the kinematics can be independent in each element node. Therefore the structural theory changes continuously over the computational domain, describing remarkable cross-section deformation with higher-order kinematics and giving a lower-order kinematic to those portion of the structure which does not require a refinement. In this way, the reliability of the simulation is ensured, keeping a reasonable computational cost. This is possible by

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Carrera unified formulation [3, 4], which allows writing finite element nonlinear equilibrium and incremental equations in compact and recursive form. Compact and thin-walled composite structures are analyzed, with symmetric and unsymmetric loading conditions, to test the present approach when dealing with warping and torsion phenomena. Results show how finite element models with node-dependent behave as well as ones with uniform highly refined kinematic. In particular, zones which undergo remarkable deformations demand high-order theories of structures, whereas a lower-order theory can be employed if no local phenomena occur: this is easily accomplished by node-dependend kinematics analysis.

References

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