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Title
High-fidelity multidimensional models for stress and dynamic analyses of advanced helicopter blades

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Abstract
The vibrational and stability characteristics are fundamental aspects of the blade's design and manufacturing. Typically, these configurations are large flexible structures requiring adequate modeling techniques to capture their static and dynamic effects accurately. Consequently, knowledge of the response of these structures is a crucial part of the design process of the whole system. Therefore, numerical models developed for rotordynamic analyses should predict the mechanical response accurately under various operational conditions by including as many details as possible. This work presents multidimensional finite element models for the studies of modern helicopter blade configurations, such as straight, swept, double-swept, or blue edge. The adopted mathematical formalism is based on the Carrera Unified Formulation (CUF) [1]. The CUF offers a procedure to obtain low- and high-fidelity one-dimensional (1D), two-dimensional (2D), and three-dimensional (3D) finite element models hierarchically and automatically. In this work, Lagrange (LE) polynomials are considered for developing different kinematic models, exploiting the unique feature of having only pure displacements as unknowns. This property allows connecting beam, plate, shell, and solid elements at node levels without requiring complicated mathematical formulations. Hamilton's Principle is used to derive the governing equations, which are solved by the Finite Element Method (FEM). The CUF theory includes all rotation effects, namely the Coriolis term, spin softening, and geometrical stiffening. Several numerical simulations have been performed, considering various realistic blade configurations with different material and boundary conditions. In addition, a Global/Local (G\L) technique is adopted to carry out accurate stress analysis and obtain a reduction in computational costs along with an increase in accuracy. This G\L method was first proposed in [2], in which a 2D global analysis is carried out through commercial FEM software, while the refined local analysis is performed on a critical region of the complete structure by employing CUF-based high-order models. Displacements and rotations are retrieved from the global analysis and employed as boundary conditions in the local model. Thus, the 3D stress states are obtained with high accuracy. The numerical simulations focus on static, dynamic, and failure analyses performed on blade structures. The solutions have been verified and validated with ones available in the literature or obtained using commercial software.

References
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