HIGH-FIDELITY ONE-DIMENSIONAL MODELS FOR TAPERED STRUCTURES ANALYSES

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The design of aircraft structures requires the use of advanced structural models able to provide accurate results also when complex configurations are considered. Wing boxes are a well-known example of these structures, they have a thin skin, transversal and longitudinal reinforcements and in the most of the cases they are tapered, the cross-section is therefore not constant. The solution of the structural problems becomes even more complex when advanced materials, e.g. composite materials, are considered. For these reasons the finite element method, FEM, is widely used the structural analysis. In particular three-dimensional, 3D, elements appear to be very accurate in the evaluation of displacements, stresses and strains fields of complex structures. Despite these advantages, the 3D models require a huge computational cost, the development of reduced structural models able to provide reliable results is, therefore, mandatory. One- and two-dimensional elements can be used to simplify the computational model but they are limited by their kinematic approximations that restrict the use of these model only in those case in which the fundamental assumptions are respected. The introduction of refined kinematic approximations could extend the range of applicability of the classical structural models, in this case accurate results can be achieved also when one- and two-dimensional elements are used.

The present work proposes the use of advanced one-dimensional FE models based on the Carrera Unified Formulation (CUF) for the analysis of tapered structures. These models introduce a cross-sectional expansion able to describe complex displacement fields. The kinematic approximation can be refined in according to the accuracy required in the analysis. In this particular case, the Lagrange functions are used in the expansions. The use of refined kinematic permits to describe with high-fidelity the geometry of the model, in fact, the solution is not referred to the nodes on the beam axis but is evaluated in the nodes placed on

the cross-section. These models, in contrast with the classical beam elements, only have displacements as degrees of freedom, these elements ca be arbitrary oriented in the space and easily connected each other. These features of these model make them suitable for the analysis of complex structure as the thin-walled tapered beams. Each structural component can be modeled with an independent beam element and then joined by imposing the displacement compatibility at the shared nodes. This work focuses on the studies of reinforced thin-walled structure. Initially, simple cases of reinforced rectangular thin-walled structure are considered. Afterwards, a tapered panel is introduced. Static analyses are performed to verify the accuracy of the shear stress results inside the panel. The dynamic behavior was also analyzed. The work continues with an analysis of a single-bay and multi-bay tapered wing-box. Both static and dynamic analyses are performed. Isotropic aluminum alloy is used for the cases presented, but the work also explores, in some cases, the use of composite materials because their use is increasingly important in the aerospace field. The results have been compared with those from commercial FEM codes. Classical solid model and a beam-shell model are used as comparison. The research demonstrates that the advanced FE model used can provide accurate analyses and 3D-like results. Tapered reinforced thin-walled structures can, therefore, be easily studied considering an high-fidelity geometrical description.