Abstract

This work explores the possibilities in terms of structural design offered by the advent of composite materials. Through aeroelastic tailoring, it is possible to design high aspect ratio wings with greater aeroelastic performance. The bending-torsion coupling given by oriented fibers or stiffeners can be optimized to counter aeroelastic phenomena such as flutter and divergence.

The first part of this work presents the derivation of a beam finite element with bending-torsion coupling formulation for static and dynamic analysis of wing structures with oriented fibers or stiffeners. Then the finite model is extended to nonlinear vibration analysis of pre-deformed structure through a perturbation approach. The models have been validated with a series of experimental vibration tests and by comparison of numerical and experimental results present in the literature.

The objective of the finite element model is to obtain a versatile tool for static and dynamic analysis of beam structures with bending-torsion coupling, but also for more complex analyses which requires a larger number of calculations and where these elements can be beneficial in terms of computational cost. At this scope, the presented element has been implemented in an optimization algorithm to compute the optimal curvilinear stiffeners path for beam structures. Another application for the finite element is divergence analysis, where the beam finite element structural model can be coupled with an aerodynamic model to find the equilibrium configuration of the wing structure under the aerodynamic load or the divergence condition.

Besides the study of finite elements for the simulation of beam structures with bending-torsion coupling, this thesis presents extensive work on additive manufacturing simulation. Additive manufacturing is increasingly important in the aerospace industry and could be adopted for the production of curvilinear stiffeners for box-beam structures. These geometries can be used to expand the aeroelastic design domain, and requires innovative manufacturing technologies. However, accurate

process simulations are needed to reduce the costs of low quality or failed parts generally associated to additive manufacturing. At this scope, an algorithm for additive manufacturing process simulation has been validated with industrial computed tomography and used to simulate the production of a stiffened panel and a calibrating artifact.