Modal Analysis of Sailplane and Transport Aircraft Wings Using the Dynamic Stiffness Method

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Abstract

Sailplane and transport aircraft wings are slender and flexible because of their high aspect ratios resulting from large spans and relatively short chords. As a consequence, they are prone to undesirable dynamic and aeroelastic phenomena such as flutter and gust response which must be checked against to ensure structural integrity and safety of the aircraft. In this respect, modal analysis of an aircraft wing plays an important role in the design process. An analysis of this type is a mandatory airworthiness requirement, stringently demanded by the civil aviation authorities. The purpose of this paper is to carry out such an analysis and investigate the modal behaviour of sailplane and transport aircraft wings with cantilever boundary conditions. This is achieved by taking a rigorous recourse to the dynamic stiffness method through the application of the Wittrick-Williams algorithm as the solution technique. In essence, the aircraft wing is idealised as an assemblage of the frequency dependent dynamic stiffness elements of bending-torsion coupled beams, comprising both the mass and stiffness properties of the wing. Once the overall dynamic stiffness matrix of the cantilever wing is formed, the eigenvalue problem is formulated. Next the Wittrick-Williams algorithm which monitors the Sturm sequence property of the dynamic stiffness matrix is invoked to extract the natural frequencies of the wing. Following the eigen-solution procedure, the mode shapes corresponding to each natural frequency are recovered in the usual way by choosing a displacement component at a particular node and then expressing the relative displacement components of the rest of the nodes in terms of the chosen one. Illustrative examples are given for wings of two sailplanes and two transport aircraft of varying degrees of complexity. Natural frequencies and mode shapes are computed and the results are compared and contrasted. A parametric study is undertaken by changing significant wing parameters including the bending and torsional stiffnesses of the wing and their subsequent effects on the natural frequencies and mode shapes are illustrated. The results are critically examined and discussed and some conclusions are drawn.