INVESTIGATION OF STRUCTURAL MODELLING METHODS OF HIGH ASPECT RATIO WINGS

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ABSTRACT

High aspect ratio wings can lead to significant fuel savings due to reduction in induced drag, but also suffer from increased bending moments and resulting increase in structural weight. Typically such designs have little or no sweep and therefore the beneficial gust alleviation due to bending-torsion coupling inherent in sweptback designs is absent. They are also notoriously prone to nonlinear aeroelastic instabilities, and these nonlinear effects are usually not well understood therefore the wing is stiffened to avoid such instabilities, with the penalty of further significant weight increases. A number of high aspect ratio wing configurations are currently being considered, and both Airbus and Boeing have published their own concept. The main advantage of a high aspect ratio wing design is aerodynamic; the higher aspect ratio leads to lower lift induced drag. Typically, such designs have zero, or very little sweep, and consequently have a lower cruise speed so that wave drag is not encountered. The move away from linear behavior means that a non-conventional approach needs to be taken for the structural analysis, in order to deal with geometric structural nonlinearities, and also the nonlinear aerodynamics and flight mechanics behavior. Most approaches have used nonlinear beam models coupled to aerodynamic models ranging from strip theory to unsteady vortex lattice method and CFD.

In this research two structural modelling approaches, based on the Finite Element Method and on Multibody Simulation, are compared to investigate the structural dynamics and aeroelastic behavior of high aspect ratio wings which can show geometric nonlinearities due to large displacements and rotations. The first approach is based on the nonlinear Finite Element Method. In this work, an integrated procedure

for the nonlinear aeroelastic trim of the free-flying aircraft based on the nonlinear static FE analysis available in NX Nastran is developed. The procedure uses a nonlinear structural formulation and a linear aerodynamic method. The aerodynamics is based on the Doublet Lattice Method available in NX Nastran. The second approach uses multi-body simulation software LMS Virtual.Lab Motion to model a flexible wing with arbitrary large elastic displacements. It is based on the discretization of the wing by a series of rigid bodies, to which inertial properties are assigned, interconnected by beam force elements, representing the stiffness distribution. Since the multibody formulation allows arbitrarily large rigid body motion, each wing section can undergo large displacements and rotations and the ensuing internal forces are determined based on this displacement field.

The methods are compared on both stick and wing-box aeroelastic models for static trim analysis and multi-body method is also compare to linear finite element model for a gust response analysis. The results show good results for the multi-body method will still computationally efficient.

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