Non-linear Engineering Model for the Dynamic Analysis of Semi-rigid Helicopter Rotors

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Abstract

This paper presents a comparison of several approximations to the non-linear dynamics of helicopter blades and the associated aeroelastic loads. The dynamics of the blades is expanded using several approximations and maintains its non-linear character. The ANSAT aircraft is used as an example for demonstrating the method, with the blade dynamics computed at a range of speeds from slow to fast forward flight. A simple aerodynamic model is used while several models for the blade structural deformation and vibration are investigated. The results suggest that the complete expansion of the blade dynamics is the best in terms of accuracy even if some of its terms contribute very little to the overall result. An approximation is therefore suggested using only 10% of the complex dynamic terms. This approximation is proved to be accurate and efficient for the ANSAT aircraft. Due to the reduction in the model complexity and the associated computational time the proposed model is a good compromise for engineering computations during the initial design and assessment of rotor blades.

The aeroelastic analysis of helicopter rotor blades is a complex problem that has so far seen several attempts to approximate its complex physics using simple models suitable for engineering computations especially at the preliminary stages of rotor blade analysis. References [1–3] provide good examples of previous efforts in the area as documented in the international and Russian bibliography. These studies also considered the aero elastic stability of the blades and attempted investigations of the behaviour of the blades under complex aerodynamic loads.

The aerodynamic loads can be calculated in many different ways, ranging from impulse theory, to advanced computational fluid dynamics methods. The method described in this work, is based on classic theory and is modified for nonlinear oscillations and semi-rigid blades. Maintaining, non-linear terms in the equation of blade motion, leads to difficulties if a general solution is needed. It is, however, possible for the analysis to be conducted in terms of the nonlinear equations for different aspects of blade aero elasticity i.e. the strength of the blades, hub and shaft dynamics or blade flutter and divergence.

The paper describes the derivation of the non-linear blade vibration in terms of inertial and aerodynamic forces and moments. Several approximate models are considered and results are presented for the case of the ANSAT aircraft. The aircraft is trimmed at several forward flight speeds and the obtained blade dynamics is computed using the aerodynamic model and the proposed dynamic model.

The results show that keeping all the non-linear terms of the blade dynamics may not be necessary due to the relative size of the contributing terms.

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