ON THE NON-LINEAR EFFECTS OF THE GIMBAL DESIGN ON THE AEROELASTIC BEHAVIOR OF A TILT ROTOR

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Abstract

The present work describes an on-going effort that focuses on the application of finite-element multibody procedures to the dynamic analysis of tilt rotors. In particular, we are here interested in using the ability offered by the multibody approach [1, 2, 3, 4] to model in detail crucial features of the system, such as the gimbal joint, in order to understand their possible impact on the stability and vibration levels of the aircraft.

In fact, multibody formulations can deal with complex flexible mechanisms of arbitrary topologies: a given mechanism is modelled through an idealization process that identifies the mechanism components from within a large library of elements implemented in the code. Each element provides a basic functional building block, for example a rigid or flexible member, a hinge, a motor, etc. After assembling the various elements, one can construct a virtual prototype of the mechanism with the required level of accuracy. Therefore, using this technology one can model a complex system such as a tilt rotor with a higher level of detail than it is presently possible using conventional industrial tools.

A topological view of the multibody model of the aircraft considered in this study is given in fig. 1. The various mechanical components of the system are associated with the elements found in the library of the code. The model consist of the wing, engine and nacelle and of a detailed representation of the rotor. The rotor itself includes shaft, swashplate, pitch links, constant speed joint, flex-beam, cuff and blade.

At first, a validation has been carefully carried out by comparison with established industrial codes, including NASTRAN and CAMRAD. The validation effort included modal analyses at different rotor speeds in aircraft and helicopter mode, and comparisons of the rotor aerodynamic loads in different flight conditions, including the transition from airplane to helicopter mode. As an example of the data collected, fig. 2 shows the thrust-power curve in airplane mode at different trim conditions. The correlation with CAMRAD is in this case excellent.

Next, a study was conducted on the influence of the possible effects of the geometrical non-linearities related to the hub design on the whirl-flutter stability, the drive train torsional loads, and the overall vibratory level. These details are difficult if not impossible to determine with accuracy with standard non-multibody simulation tools. We consider three models of the

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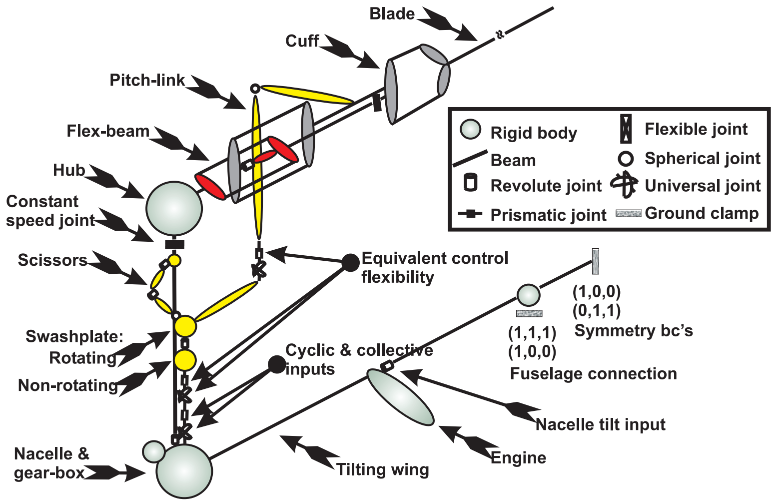

FIGURE 1. Topological representation of the tilt rotor multibody model. One single blade is depicted for clarity.

gimbal mount, which differ on the level of approximation of the constant speed transmission from the shaft to the hub. The first model uses a standard universal joint, and is representative of the level of detail achievable by industrial codes. The second joint is a multibody model of a practical possible hardware implementation of a constant speed joint. Finally, the third joint represents an ideal case that ensures constant speed transmission in all flight conditions. The effects of these various realizations of the gimbal mount on complex aeromechanical instabilities (whirl-flutter), vibration and loads are discussed in detail.

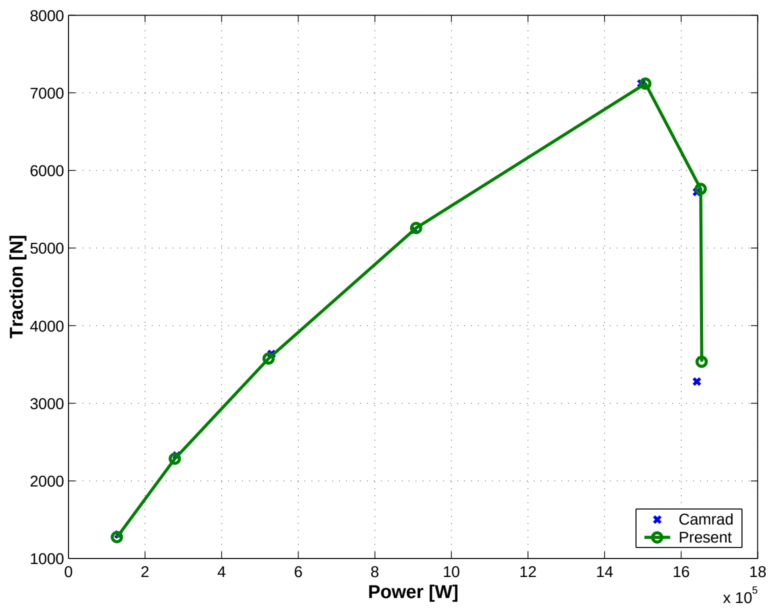

FIGURE 2. Traction-power curve for flight in airplane mode at different trim conditions.

The stability of the system is analyzed using two alternative procedures: using transient simulations and using the implicit Floquet method. A typical result obtained using the Floquet approach is shown in fig. 3, which gives the spectral radius of the transition matrix as a function of the flight speed. One can observe that the details of the gimbal mount have a noticeable effect on the flutter boundaries. These effects are discussed in detail in the full paper.

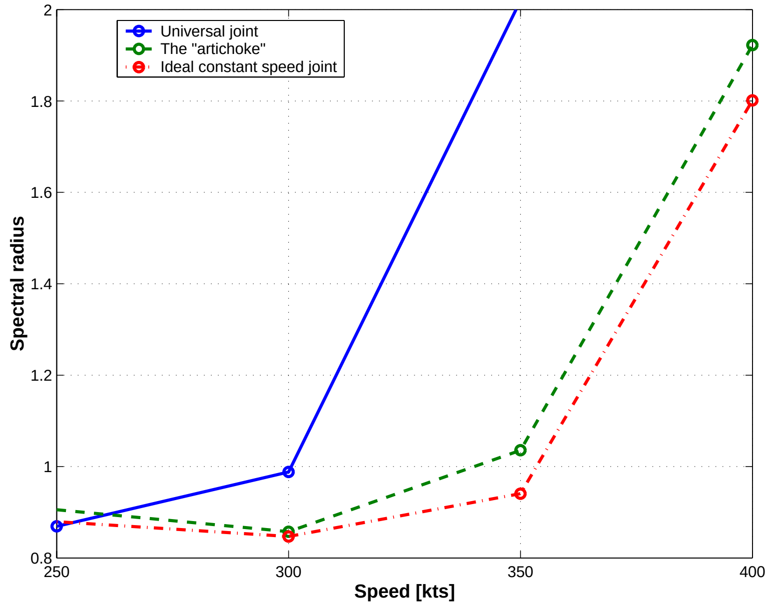

FIGURE 3. Whirl-Flutter, 7500 m of altitude: spectral radius of the transition matrix vs. flight speed for the three joints.

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