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WHIRL FLUTTER ANALYSIS OF A WIND TUNNEL MODEL USING MULTIDISCIPLINARY SIMULATION AND MULTIBODY DYNAMICS

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Abstract

Whirl flutter is a dynamic instability known mostly from tilt-rotors and prop-airplanes. For a tilt-rotor or prop-airplane, from one side the gyroscopic effect of the rotating rotor/propeller causes the coupling of the elastic modes of the propeller-nacelle system and produces the so-called whirl modes and from the other side the originated unsteady aerodynamic forces/moments due to the whirl modes change the damping of the system. With the reduction of the damping, the whole system can reach a zero or negative damping resulting in an oscillation of the system with constant or increasing amplitude, respectively.

Classical analysis of whirl flutter is limited to a system with reduced degrees of freedom. However, going beyond this classical approach allows considering more physical effects. In this work a multidisciplinary simulation of the whirl flutter phenomenon is introduced. Different simulation codes are used to create the model and to simulate the physical effects. A FEM code is used to model the elasticity of the wing and nacelle. A propeller comprehensive code is utilized to consider the propeller induced velocity field. The full model is then implemented within a multibody simulation tool, which allows performing the dynamic stability analysis. The method introduced in this paper can be used for the whirl flutter investigation of any configuration. Fig. 1 shows the modeling procedure schematically.

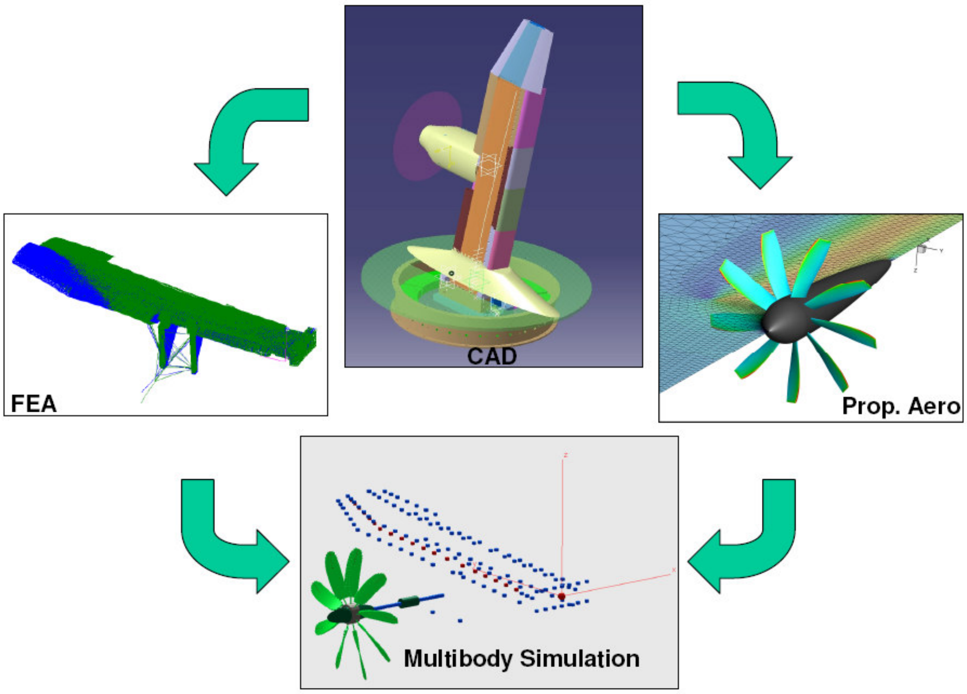

Fig.1 Multidisciplinary simulation of the Whirl Flutter phenomenon

For this work, SIMPACK (**SI**mulation of **M**ultibody systems **PACK**age) as a multibody simulation tool was selected. This tool has shown considerable ability to model and analyze linear and non-linear systems during different DLR (German Aerospace Center)-projects [1], [2], and allows using modular models to build a complete detailed system and analyzing it in both frequency and time domain. SIMPACK was originally developed by DLR and is now further developed and commercially distributed by SIMPACK AG. ANSYS is used to model the elastic parts. The outputs of the modal analysis with ANSYS for the dynamically reduced model are used to define the elasticity of the parts inside SIMPACK. Aerodynamics of the propeller model inside SIMPACK is based on the strip theory and quasi steady aerodynamics corrected with the consideration of the propeller induced velocity field. This induced velocity field is calculated using the propeller design code PROPPY (developed by Dr. Martin Hepperle). Aerodynamic of the wing is modelled in one case based on the strip theory and quasi steady aerodynamics and in the other case based on the unsteady aerodynamics using Wagner function. This simulation procedure and whirl flutter analysis was performed as an example for a wind tunnel model, which is a scaled model of the wing of a transport airplane with the ability of short take-off and landing. Because of the heavy weight of the propeller-nacelle comparing to the wing, the whirl flutter effects of this model will be similar to those of a tiltrotor configuration. This wind tunnel model was designed within the project "Buergernahes Flugzeug" [3] under the cooperation of the different research institutes of DLR, University of Braunschweig and Leichtwerk AG.

1. INTRODUCTION

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1.1. Whirl Flutter

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1.2. Whirl Flutter Modelling Approaches

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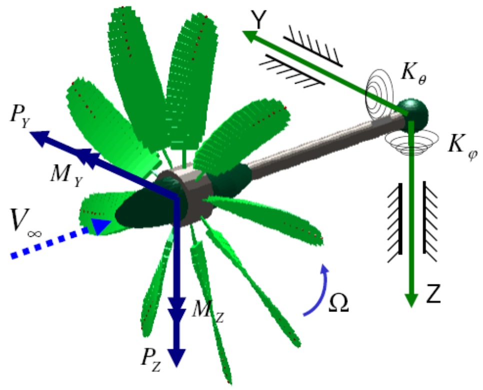

FIG. 2 Simplified whirl flutter model

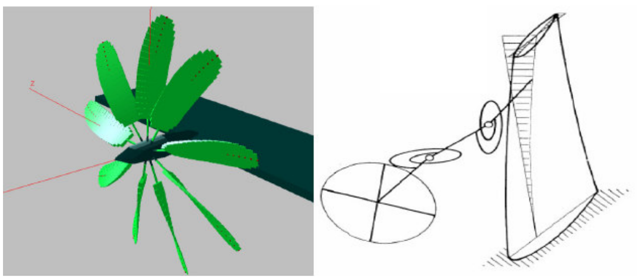

FIG. 3 Whirl flutter model with elastic wing

1.3. Simulation tools

- SIMPACK (**SI**mulation of **M**ultibody systems **PACK**age) software package is used to simulate, analyse and design all types of mechanical systems

2. WIND TUNNEL MODEL AND AEROELASTIC MODELLING APPROACH

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2.1. Wind Tunnel model

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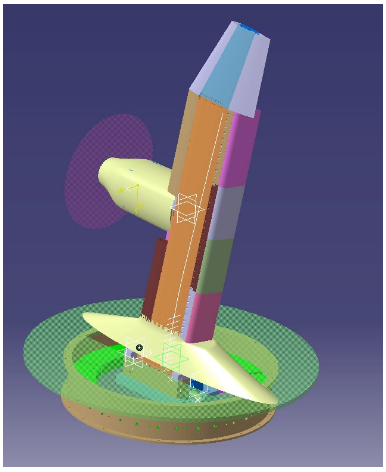

FIG. 4 CAD Model of the wing-nacelle-propeller

2.2. Modelling of the Wing

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2.2.1. Wing Structure

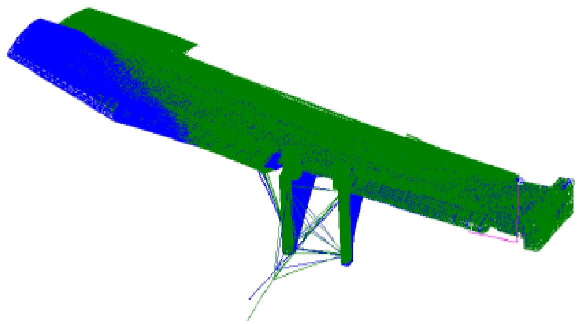

FIG. 5 ANSYS model of the wing with elastic motor shaft

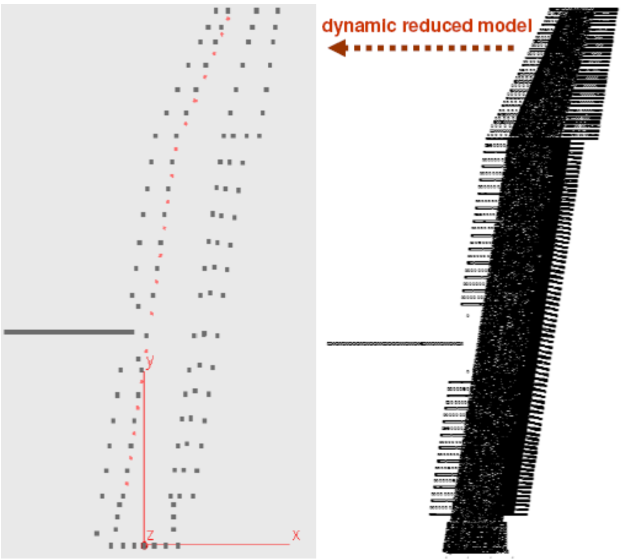

FIG. 6 Nodes of the left: Dynamic reduced model, right: original FEM model

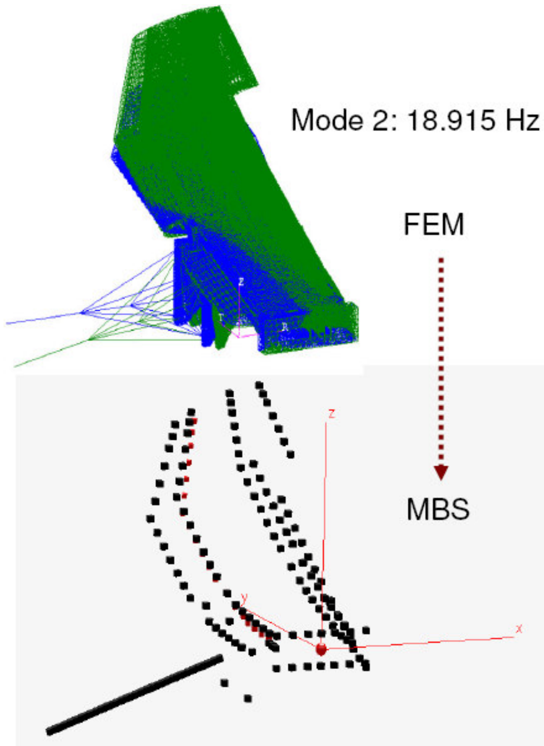

FIG. 7 Dynamic equivalency of the FEM model and MBS model

2.2.2. Wing Aerodynamics

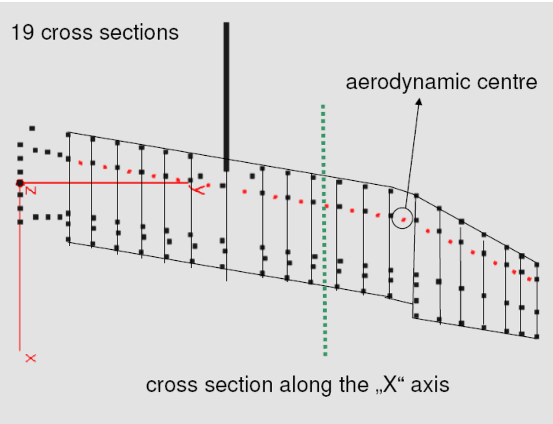

FIG. 8 Wing aerodynamic sections

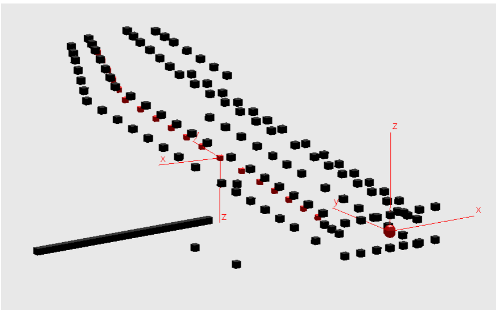

FIG. 9 Aerodynamic marker for calculation of air loads

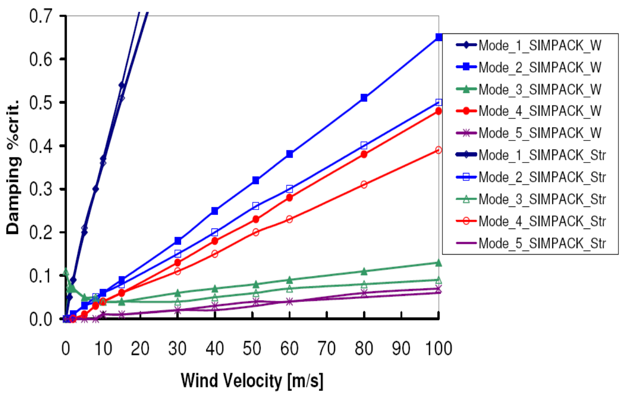

FIG. 10 Comparison of unsteady aerodynamics based on the Wagner approximation and quasi steady aerodynamic based on the strip theory

2.3. Modelling of the Propeller

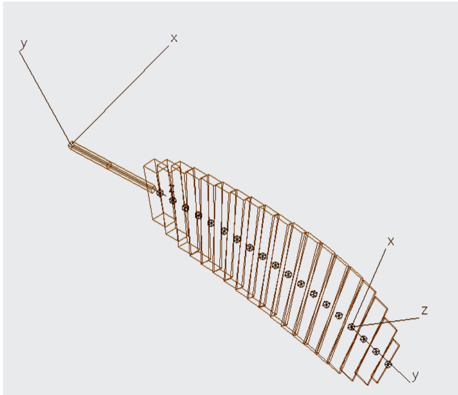

FIG. 11 MBS-model: Propeller blade sections

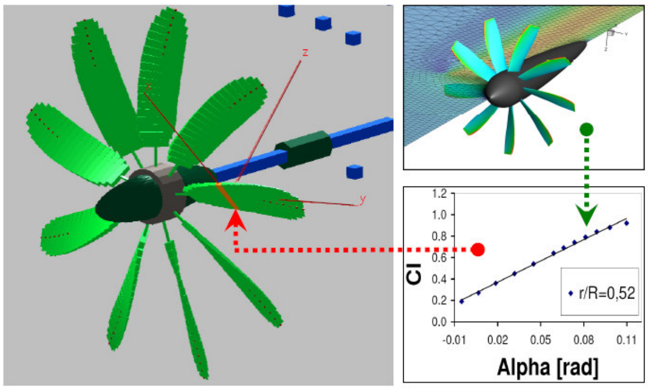

FIG. 12 Modeling of the MBS propeller-aerodynamics using the propeller design code PROPPY

3. WHIRL FLUTTER ANALYSIS

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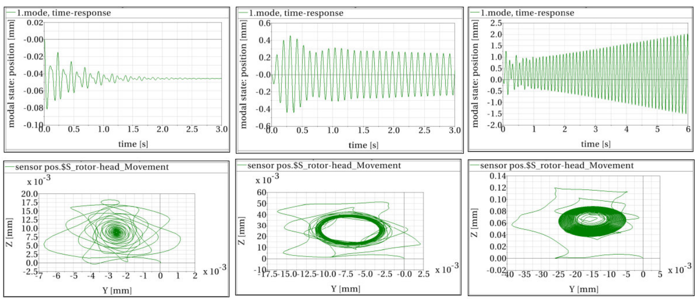

FIG. 13 Displacement of the rotor head (lower) and propeller-wing in 1.modal coordinate (upper)

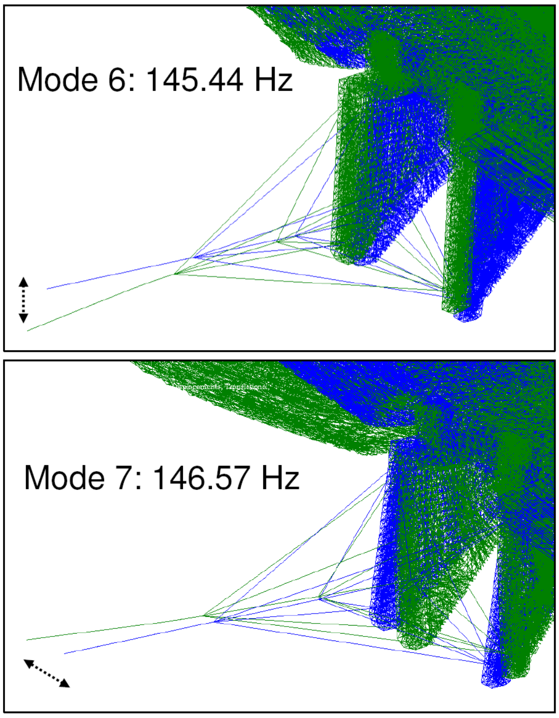

FIG. 14 Mode shapes with the local pitching and yawing of the nacelle

3.1. Dynamic Analysis of the Substructure Propeller-Nacelle

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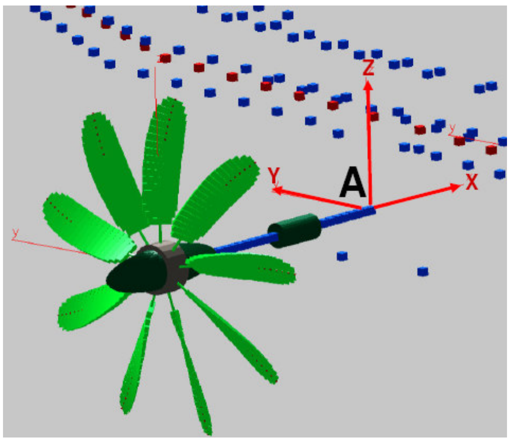

FIG. 15 Local coordinates definition for analyzing the whirl modes of the propeller

4. CONCLUSION

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ACKNOWLEDGMENT

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