(Doctoral thesis in 3 years)

FSI-Blades - **F**luid-**S**tructure **I**nteractions for Flexible Blades

Aero-Structural study of rotors with flexible blades Modeling and control

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Summary:

A rotor with flexible blades is the place of many phenomena coupled between the dynamics of the structure and the aerodynamics. The structural properties of a flexible blade determine the main bending and torsion modes. For certain operating points (i.e. rotation and advance speeds of the rotor), these modes can come into coalescence by the presence of the coupling with the fluid surrounding them and lead to a flutter type instability. In this case, large amplitude movements appear, and the aerodynamic performance is greatly degraded. This phenomenon can under certain conditions lead to the destruction of the rotor. It is therefore essential to understand and control this phenomenon. This problem is general to rotors. However, it takes on an even more significant scope in the context of flexible blades.

The thesis work will consist of adopting a structured approach, starting from the analysis, understanding, and modeling of the behavior of a flexible rotor blade for different operating points. Experimental and numerical means will be developed and used to help analyze these phenomena. The use of analytical models, developed in parallel by another study (Thesis of A. Chambon), as well as reduced order models (Polythecnic University of Valencia), will allow the implementation of control strategies, with a view to delay unstable phenomena.

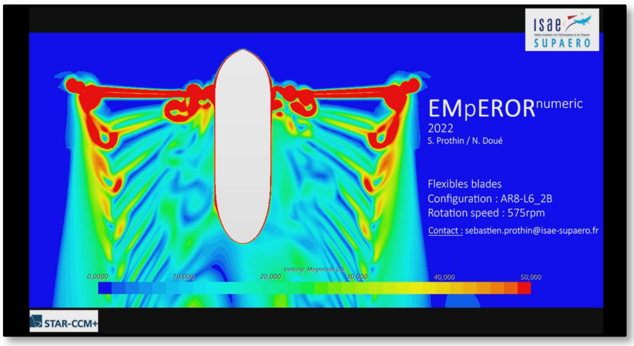
From an experimental point of view, the tests will be carried out within the Department of Aerodynamics, Energetics and Propulsion of ISAE-SUPAERO, on an existing rotor test bench. This test bench makes it possible to carry out global measurements (performance, forces), local measurements embedded in the blades (network of accelerometers, pressure), as well as structural measurements of dynamic deformations by cameras and rotating vibrometer. These measurements can thus be used to complete the analysis of the results of computations in strong coupling, but also as a forcing in a weakly coupled computation.

Regarding the numerical point of view, the Department of Aerodynamics and Propulsion (DAEP) of ISAE-SUPAERO, develops and uses fluid-structure interaction codes, combining Navier-Stokes type computations for the fluid, with finite element type resolutions for the dynamic part of the structure. Similar developments are currently being performed at the University Institute CMT, from UPV. The experimental databases will allow a validation of these computations as well as a fine modeling of the phenomena.

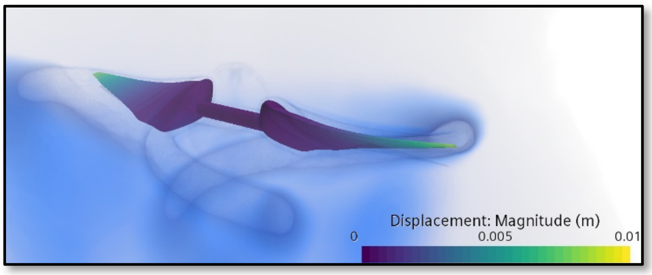
Finally, several reductions of the model complexity will be explored in the context of simulation of rotating aerodynamic structures. From 2D equivalent CFD models, in which the effect of the structure can be modeled as an equivalent mass and stiffness to the implementation of an Artificial Neural Network for predicting Blade Element Momentum Theory unsteady Aerodynamics and their coupling to composite materials structures. These methods will allow the use of the current computations to the structural optimization and aeroelastic passive and active control in industrial time scales.

The challenge of this thesis will be the in-depth understanding of aeroelastic phenomena as well as a model reduction intended both for the design of adaptive rotor blades and the development of optimal control means.

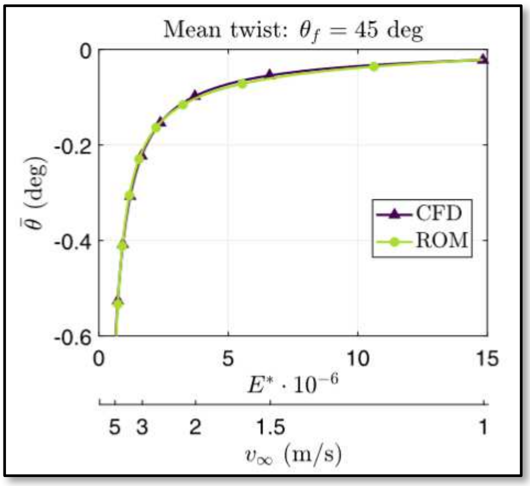
Experimental test bench EMpEROR
S. Prothin, 2021



Coupled Aero-Structure computation*s*
on the EMpEROR configuration
N. Doué, 2022



Coupled Aeroelastic Simulation of a simplified two blade propeller
CMT, UPV, 2023



Comparison between ROM and CFD computations of the aeroelastic deformation of a composite material beam with fibers oriented at 45 deg
CMT, UPV, 2022