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PROPOSITION DE SUJET DE THESE

Intitulé : Development of an Actuator Surface Method applied on a fan under distortion

Référence : **TIS-DAAA-2026-01**
(à rappeler dans toute correspondance)

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Mots clés

Body-force, aeroelasticity, actuator surface, turbomachinery, UHBR, distortion

Profil et compétences recherchées

Fluid mechanics (especially for turbomachinery if possible), aeroelasticity, CFD, good knowledge of the Python language

Présentation du projet doctoral, contexte et objectif

Environmental challenges and international competition urge the aerodynamic sector to obtain significant increase in overall performance in a limited time frame. New engine configurations, like Ultra High Bypass Ratio (UHBR) turbofans or Open Fans configurations, are expected to offer 10 to 20% fuel burn savings, but such systems are challenging to design and to simulate.

They must indeed cope with inflow inhomogeneities at some critical (if not all) operating conditions, which strongly affect their efficiency, the aero-structure stability and the expected lifespan of the system. In addition, unsteady RANS methods are required to simulate these effects, but such CFD tool is cost-prohibitive at the pre-design stage.

In the past ten years, the scientific community focused on a new class of engine modeling method called Body Force Modeling (BFM). Its purpose is to model the effect of the engine blades on the flow through source terms added to the RANS equations and spread along the azimuth, instead of discretizing them in the CFD simulation. Such methods, especially the Hall-Thollet model [1], have proven to be very efficient to simulate UHBR engines under inlet distortion [2], to adapt the compressor design to distorted inlet conditions [3], or even to simulate with great accuracy several compressor stages [4] (see Figure 1), at only 1/100th of the cost of uRANS simulations. First applications to turbomachinery aeroelasticity were investigated recently, especially to evaluate the fan aero-structure stability under a given inlet distortion pattern [5]. Results were found promising, but the BFM inability to accurately predict the local flow phenomena over the blade limited the scope of the method.

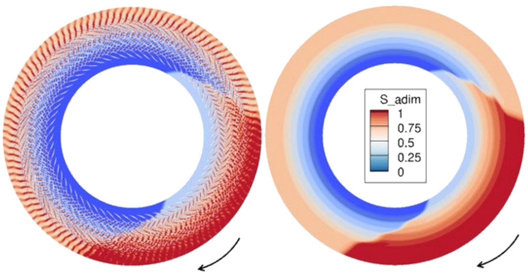
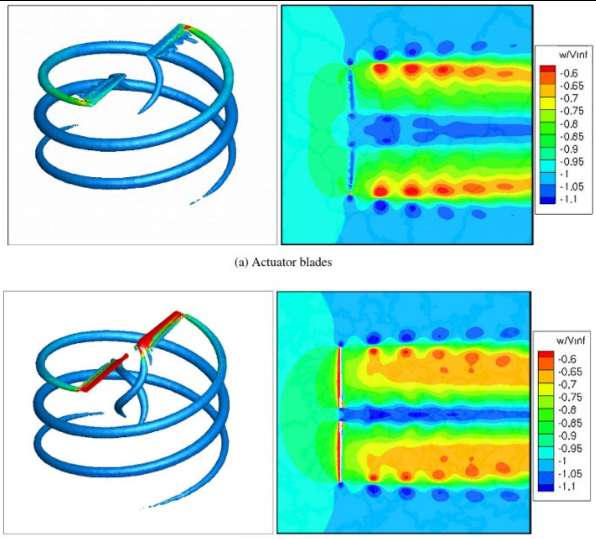


Figure 1 : Simulation of the 3.5 compressor stages of the CREATE turbomachine under inlet distortion. Left: blade-resolved simulation, Right: body-force simulation. (Crea, 2025 [4])

Other scientific communities have worked on BFM-alike methods, especially to simulate wind farms [6] and rotorcrafts [7]. They progressively modified the implementation of their models to locate the source terms where the blade is expected to be, in order to recover most of the local flow phenomena and of the rotor-stator interactions (such as blade wakes, tip vortices). Latest developments allowed spreading the source terms around the blade camber-surface. The authors found that this Actuator Surface Method allowed to correctly capture the unsteady blade aerodynamic loading [7], which is essential to consider aeroelastic applications. Even though such a method is more expensive than basic BFM, it remains 5 times more efficient than uRANS simulations, making it compatible with blade shape and blade structure optimization. However, the models used by these communities are not yet well suited to UHBR and Open Fans.



(b) Overset blades

Figure 2 : Comparison between Actuator Surface (up) and blade-resolved (down) simulations of a wind turbine [8]

The goal of this thesis is therefore to implement a new formulation of the Hall-Thollet model, in order to propose a methodology for a Hall Actuator Surface modeling of axial compressors. Especially, the goal is to determine the correct practice to generate the Actuator Surface mesh, to distribute the sources terms in time near the blade camber surface, and if necessary to calibrate the model.

Once validated, this new tool will be applied to the aerodynamic simulation of a UHBR fan subject to a severe inlet distortion. The objective will be to evaluate the gain in accuracy of this method compared to the conventional BFM approach. The accuracy/cost trade-off will also be undertaken against uRANS simulations, and experimental data will be available to propose a detailed and robust evaluation of the method.

Finally, this new tool will be adapted to perform aeroelastic simulations of this configuration, to predict the aero-structure stability of the fan or even to simulate the dynamic response of the structure to the inlet distortion. Again, high-fidelity and experimental results will be given to the PhD candidate to discuss the reliability of the method for aeroelastic applications.

References :

[1] W. Thollet, *Modélisations simplifiées de turbomachines pour l'analyse par la simulation des installations motrices complexes d'avions/Body force modeling of fan-airframe interactions*, 2017

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[6] Y. Xiaolei and S. Fotis, *A new class of actuator surface models for wind turbine*, 2017

[7] D. Linton *et al*, *Actuator Surface Model with Computational-Fluid-Dynamics-Convected Wake Model for Rotorcraft Applications*, 2021

[8] C.E. Lynch, D.T. Prosser and M.J. Smith, *An efficient actuating blade model for unsteady rotating system wake simulations*, 2013

Collaborations envisagées

A collaboration with LMFA and/or ISAE-Supaero is currently investigated for this thesis

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