PhD offer at ISAE-SUPAERO

Location: ISAE SUPAERO & AIRBUS, Toulouse, France

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Keywords : Body force modeling, Aeroacoustics, propeller noise

PHD DESCRIPTION

Title: **INPRO – Propeller and installation effects modeling with a body force approach**

Proposed duration and period: 36 months, 2021-2024

Context

Recently, in order to tackle environmental challenges, new aircraft designs have been proposed by AIRBUS. Propellers propulsive architectures are particularly studied as they offer significant advantages to reach ambitious decreases in energy consumption, as illustrated in Figure 1. The absence of nacelle allows a larger rotor diameter as compared to a turbofan engine, which increases the propulsive efficiency. However, even if propellers have been used since the beginning of aviation, challenges in term of integration arise, and aircraft and engine manufacturers are exploring several architectures. One of these challenges is the interaction of the propeller wake with the aircraft, which impacts the aerodynamic performance. It is also a major source of noise, which cannot be treated with conventional acoustic liners because of the absence of the nacelle. Therefore, efficient simulation methods are needed to assess the aerodynamic and aeroacoustic performance of installed propeller configurations. At ISAE-SUPAERO, we have been developing for several years a body force modeling approach, which allows to reduce the computational cost of integrated turbomachinery configurations. In this model, the blades are replaced by volumic source term that reproduce the work and losses generated by the blade rows.

In this context, we propose a PhD entitled "Propeller and installation effects modeling with a body force approach" at ISAE-SUPAERO. The study will be performed in close collaboration with AIRBUS, and though the PhD will take place at ISAE, regular interactions with AIRBUS are expected. The overall goal of this PhD is to extend body force models to propellers, targeting installed configurations, and assess the accuracy of the method in such configurations, both for aerodynamic and aeroacoustic performance predictions. The validation and the noise modeling will be supported by Large Eddy Simulations performed in a companion PostDoc study.

Figure 1 : Example of a concept studied at AIRBUS

Objectives and work	**Research questions** The body force modeling (BFM) approach aims at modeling turbomachinery blade rows by source terms corresponding to volumic force fields that reproduce the flow turning (work exchange) and losses (entropy rise) generated by the blades [1,2]. This allows to reduce the simulation cost by (i) reducing the mesh size and (ii) allowing the use of a steady approach even for flows with distortion effects. Using geometrical input, the force field is modeled as a function of flow variables, which allows it to respond to operating point variations and inflow/outflow distortions. A calibration using limited input from standard blade computations can be performed to improve the accuracy of the model. In the literature, the BFM approach has been developed and validated for fans and compressors, but its application to propeller has not been demonstrated yet. This is thus the first research objective of the present study. A second challenge is to extend the method to generate unsteady loads for noise source modeling. While the BFM approach is inherently steady, it has been extended in the literature to predict multiple-tone noise due to shocks propagating upstream in fan configurations [3]. A second research objective is thus to propose a somewhat similar approach, in order to model turbulent rotating wakes so that their impact on a downstream aircraft surface can be assessed. **Research program:** 1. *Isolated propeller blade simulations*. To support the body force model development for propellers, classical blade simulations will first be performed. 2. *Body force modeling for propeller blade*s. Existing models will be assessed for isolated propeller blades, and model improvement will be proposed. Particular emphasis will be put on the loss modeling terms. 3. *Implementation of the model*. The proposed BFM models will be integrated in the new CFD code developed by Airbus and the DLR (CODA). Attention will be paid to the source term formulation with respect to the Discontinuous Galerkin approach used in CODA. 4. *Unsteady modeling*. Rotating wake models will be developed and assessed for installed propeller configurations. For isolated blades, the LES results, generated with our in-house code IC3 [4] within the companion post-doc study, will be used to support the modeling approach. LES results for the installed configuration will serve as a reference for validation. 5. *Noise modeling*. Finally, the unsteady loads generated by the interaction of the rotating wakes with a fixed aircraft surface will be used to propose a noise model that will be validated against LES results. **References** [1] Gong, Y. Y., Tan, C. S., Gordon, K. A. et Greitzer, E. M., 1999. A Computational Model for Short-Wavelength Stall Inception and Development in Multistage Compressors. Journal of Turbomachinery, 121(4). [2] Thollet W., Dufour G., Carbonneau X. and Blanc F., 2016. Body-force modeling for aerodynamic analysis of air intake–fan interactions. *International Journal of Numerical Methods for Heat & Fluid Flow*, 26(7). [3] Defoe, J. J., and Spakovszky, Z. S., 2012. Shock Propagation and MPT Noise From a Transonic Rotor in Nonuniform Flow. *Journal of Turbomachinery*, 135(1). [4] Lamouroux, R., Gressier J., and Grondin G., 2016. A High-Order Compact Limiter Based on Spatially Weighted Projections for the Spectral Volume and the Spectral Differences Method. *Journal of Scientific Computing*, 67(1).

REQUIRED APPLICANT PROFILE AND SKILLS	
Required profile and skills	The PhD candidate will have a master level, with a strong background in fluid mechanics, CFD, and turbomachinery or propeller aerodynamics. Curiosity and problem-solving skills will be necessary to tackle this research work. In particular, a desire to test model variations and to perform analyses of flow physics is needed. Programming skills (C++, python, etc.) will be appreciated. English and/or French is mandatory.