PROPOSITION DE POST-DOCTORAT

Intitulé : Data-driven modelling of mean and unsteady flow features in rotating machines

Référence : **PDOC-DAAA-2025-02**
(à rappeler dans toute correspondance)

Début du contrat : Septembre 2025	**Date limite de candidature : Août 2025**

Durée : 24 mois

Mots clés

Data Assimilation, Floquet-Bloch analysis, Machine Learning, Turbomachinery

Profil et compétences recherchés

PhD in fluid dynamics or applied mathematics, skills in numerical simulation for fluid mechanics applications and/or knowledge in stability analysis and/or in optimization techniques would be appreciated.

Présentation du projet post-doctoral, contexte et objectif

Many industrial systems involve rotating machines whose designs may have to be improved in order to meet sustainable development goals. Such industrial systems range from onshore/offshore wind turbines to marine propulsion and turbomachines in general. Enhancing the design of these systems first requires the ability of correctly predicting the involved flows. However, flows in rotating systems are particularly challenging to capture through numerical simulations due to the presence of separation and stall phenomena, among others. From an experimental point view, it is difficult to have access to more than a few pointwise pressure or temperature measurements for such configurations, which thus precludes a full characterization of the flows of interest from experiments alone. In the ANR project MALEAF (MAchine LEArning for Fluid system efficiency), which is led by ENSAM and by the Ecole Navale, ONERA, Sorbonne Université and CNAM, the main goal is to develop data-driven strategies that enable overcoming the limitations of experimental and numerical approaches by combining them, and to obtain accurate reduced-order models that may be useful for the design of rotating machines.

More specifically, in the present postdoctoral project, we aim to obtain Reynolds-Averaged Navier-Stokes (RANS) models that provide reliable predictions of mean flows in rotating systems. To this end, we will rely on combinations of data-assimilation and machine-learning techniques [1,2,3] to learn corrective terms to RANS models from experimental data that will be provided by the Ecole Navale for single blade/airfoil configurations [4]. The use of data-assimilation techniques will first allow us to obtain full flow descriptions from the (limited) experimental data. In a second step, machine-learning tools will be used to obtain predictive models from the data-assimilation results, which may then be applied to other flow configurations. As we will here rely on experimental data, it will be of interest to take into account measurement errors and propagate them in the learning procedure in order to provide the uncertainties in the retrieved models based on a Bayesian framework.

As a further step towards the consideration of actual turbomachines, the so-obtained RANS models will be applied to blade cascade configurations. If needed, additional data from high-fidelity simulations [5] could be considered to ensure the accuracy of the learned RANS models in this case. Beyond mean-flow characteristics, linear mean-flow analyses will be performed to capture important unsteady phenomena that may occur in turbomachines such as rotating stall [5]. Exploiting the periodic aspect of the base/mean flow in the azimuthal direction, we will rely on the Floquet-Bloch formalism to carry out such linear analyses at an affordable computational cost. Nonlinear extensions of such an approach could then be considered.

In summary, this postdoctoral project will contribute to the development of advanced data-driven techniques and mean-flow analyses for the accurate estimation of flows in rotating systems.

[1] Parish and Duraisamy, A paradigm for data-driven predictive modeling using field inversion and machine learning. Journal of Computational Physics 305, 758-774, 2016

[2] Volpiani, Meyer, Franceschini, Dandois, Renac, Martin, Marquet and Sipp, Machine learning-augmented turbulence modeling for RANS simulations of massively separated flows. Physical Review Fluids 6, 064607, 2021

[3] Villiers, Mons, Sipp, Lamballais and Meldi, Enhancing Unsteady Reynolds-Averaged Navier-Stokes modelling from sparse data through sequential data assimilation and machine learning. Flow, Turbulence and Combustion, accepted, 2025

[4] Astolfi, Bot and Leroy, Vortex Induced Vibration Analysis of a Cantilevered Hydrofoil by Laser Vibrometry and TR-PIV. Second International Symposium on Flutter and its Application, 2020

[5] Marty, Castillon and Joseph, Numerical Investigations on the Rotating Stall in an Axial Compressor and Its Control by Flow Injection at Casing. Journal of Turbomachinery 145, 051009, 2023

Collaborations extérieures

ENSAM, Ecole Navale, Sorbonne Université, CNAM

Laboratoire d'accueil à l'ONERA

Département : Aérodynamique, Aéroélasticité, Acoustique

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