AI-Assisted Turbulence Modeling for Rotor–Stator Cavity Flows in Space Turbo-pumps (Co-funded project: CNES- ONERA)

Type of offer :
Ph.D.

Location	
ONERA Département d'Aérodynamique Aéroélasticité Acoustique Meudon	Mathematical & Numerical Modelling Laboratory Applied Mathematics & Statistics Department Conservatoire Nationale Arts et Métiers 2 rue Conté 75003, Paris

Context :
Unsteady flow phenomena within rotor–stator cavities are recognized as critical contributors to detrimental vibrations in space turbopumps. Although various palliative strategies are typically incorporated during the design phase, experimental investigations frequently reveal persistent high-amplitude flow oscillations capable of compromising the structural integrity of turbomachinery components and, in severe cases, the rocket engine as a whole. These cavity flows are characterized by rotating, three-dimensional boundary layers that are inherently unstable and prone to the development of complex flow structures, such as spiral and annular modes. Traditional computational approaches, such as Reynolds-Averaged Navier–Stokes (RANS) simulations, have demonstrated significant limitations in accurately capturing these unsteady dynamics. In contrast, Large Eddy Simulation (LES) has emerged as a more promising methodology, offering improved fidelity in predicting such flow behaviors under variable operating conditions, albeit at a substantially higher computational cost.

Building upon recent simulation efforts [1] and advancements in AI-assisted methodologies for turbulence model development and correction [2], the primary objective of this study is to extend these modeling techniques to the complex flow dynamics present in rotating cavity systems. To achieve this, we employ non-intrusive, ensemble-based variational techniques [3]. This framework utilizes measurements from the mean and variance of flow fields generated by LES to inform the correction and design of AI-based RANS models, aiming to achieve LES-level predictive accuracy at significantly reduced computational cost. A key advantage of this non-intrusive approach lies in its avoidance of direct solver differentiation, which is typically required to compute gradients for model training. Instead, gradient information is approximated through ensembles of forward RANS evaluations, making the approach both computationally efficient and compatible with legacy solvers. This methodology is particularly well-suited for the high-dimensional, nonlinear behavior characteristic of rotating cavity flows. Once the AI-driven turbulence model has been calibrated for the reference configuration, the next phase of the study will focus on strategies for generalizing the model to out-of-sample design conditions. Finally, to facilitate the transition from high-fidelity simulation-based workflows to experimental applications, this study will investigate strategies for reducing the number of required measurement locations and optimizing sensor placement.

Scientific partners: ONERA, CNES and CNAM.

Profile :
The candidate should have a MSc degree or equivalent (engineering diploma) in mechanics or applied mathematics, with experience in scientific computing.

Skills :
Programming experience and expertise in data-driven techniques will be considered very positively.

Duration and start date :
The position is offered for the duration of 36 months, from October 1st, 2026 to September 30th, 2029.
Deadline for applications: 01/03/2026

Required documents :
The applicant should include a CV, and a motivation letter.

Contacts :
Vincent Mons - vincent.mons@onera.fr
Olivier Marquet - olivier.marquet@onera.fr
Taraneh Sayadi - taraneh.sayadi@lecnam.net

References :
[1] MATTHIEU QUEGUINEUR. Stability and control of unsteady phenomena in rotor/stator cavities using Large Eddy Simulation. 2020.
[2] S. B. Cheng *et al.* "Machine learning with data assimilation and uncertainty quantification for dynamical systems: A review," IEEE/CAA J. Autom. Sinica, vol. 10, no. 6, pp. 1361–1387, Jun. 2023. doi: 10.1109/JAS.2023.123537
[3] Vincent Mons, Yifan Du, Tamer Zaki. Ensemble-variational assimilation of statistical data in large-eddy simulation. Physical Review Fluids, 2021, 6 (10), pp.104607.
[4] Raphaël Villiers. Correction de modèles dynamiques à partir d'observations limitées par assimilation de données et apprentissage automatique : application à la modélisation instationnaire de la turbulence. 2025.