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PROPOSITION DE SUJET DE THESE

Intitulé : Aeroelastic Stability Analysis of Turbopumps Axial Balancing System

Référence : **MAS-DAAA-2026-02**
(à rappeler dans toute correspondance)

Début de la thèse : 01/09/2026	Date limite de candidature : 30/06/2026

Mots clés

Turbopump, aeroelasticity, stability

Profil et compétences recherchées

Master degree required, in Fluid Mechanics, Applied Mathematics or relevant field of studies.

Présentation du projet doctoral, contexte et objectif

In aerospace turbo-pumps, turbines rotate at speeds up to 100,000 rpm to deliver propellant to the rocket engine at high flow rates and optimized pressures. At such extreme conditions, mechanical supports like ball bearings alone cannot maintain the rotor's axial position. Instead, part of the propellant is diverted into a cavity behind the rotor, known as a hydrostatic bearing or Axial Balancing System (ABS) to balance forces.

This cavity (red rectangle in Figure 1(a)), bounded by inner and outer valves at the rotor's center and periphery, stabilizes the rotor through pressure equilibrium. However, under certain conditions, the compressible fluid's response to rotor motion can induce vibrations and instabilities. These fluid-structure interactions are critical as they may degrade performance or even cause failure. Understanding them is therefore essential to improving the reliability and performance of spatial turbo-pumps.

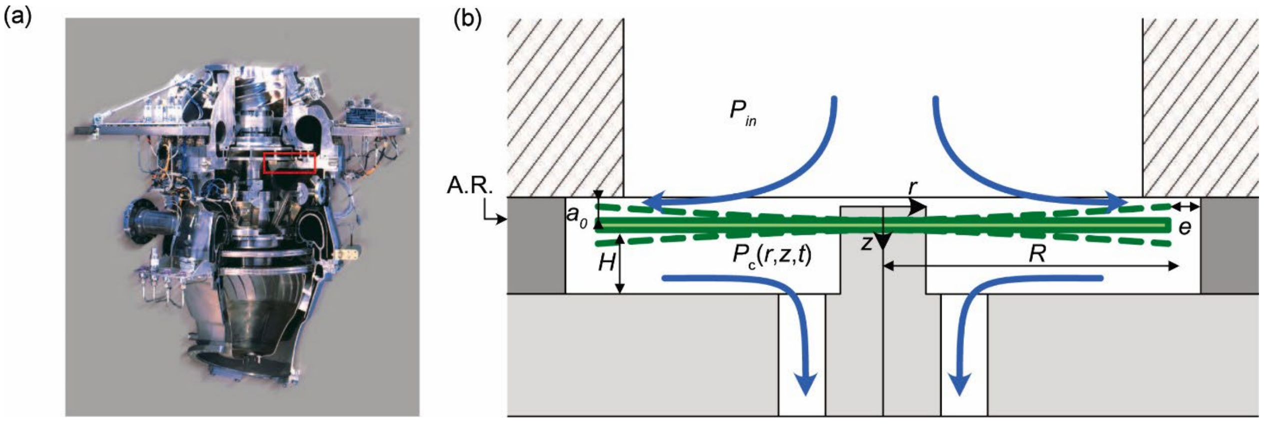

Figure 1(a) Example of Liquid Oxygen turbo-pump with Axial Balancing System framed in red. (b) Simplified model of the Axial Balancing System (not scaled).

To investigate the fundamental mechanisms of these instabilities, a simplified ABS test bench depicted in Figure 1(b) was set up at IRPHE [1]. In this setup, the motion of a disc (green in the sketch) changes the aperture of an inner valve, directly influencing the cavity flow and pressure fluctuations. Adjustment rings (A.R. in the sketch) allow precise tuning of the geometry, making it possible to couple acoustic modes in the cavity with structural modes of the disc. This can generate sustained oscillations, thereby reproducing instability mechanisms observed in real turbo-pumps. This experimental platform provides an ideal reference for validating numerical predictions.

Although fluid-structure coupling in such systems is conceptually understood, there is currently **no accurate method to predict the onset of instability** in ABS configurations. Existing studies [2,3,4] using Arbitrary Lagrangian Eulerian (ALE) frameworks have successfully captured oscillatory behavior and destabilization phenomena in other fluid–structure systems, but a systematic application to ABS geometries and conditions has not yet been undertaken.

This PhD project aims to address this gap by:

1. Developing a numerical framework based on linear stability analysis within the ALE approach to capture fluid-structure instabilities in a compressible, turbulent flow.
2. Providing **predictive insights and confirm destabilization mechanisms.**
3. Investigating the sensitivity of instability onset to key input parameters such as inflow velocity profiles, cavity dimensions, or disc rigidity.
4. Investigate the harmonic response to periodic perturbations.

The numerical predictions will be systematically compared with available experimental data from IRPHE to assess accuracy and refine the model, ultimately leading to a validated numerical tool capable of predicting ABS instabilities.

[1] Brunier-Coulin, Florian, Vandenberghe, Nicolas, Verhille, Gautier, and Le Gal, Patrice. Fluid–structure instabilities in the axial balancing system of a turbo-pump. *Journal of Sound and Vibration*, 538 (2022), 117193.

[2] Pfister, Jean-Lou, Marquet, Olivier, and Carini, Marco. Linear stability analysis of strongly coupled fluid–structure problems with the Arbitrary-Lagrangian–Eulerian method. *Computer Methods in Applied Mechanics and Engineering*, 335 (2019), 663-689.

[3] Pfister, Jean-Lou, Fabbiane, Nicolo, and Olivier, Marquet. Global stability and resolvent analyses of laminar boundary-layer flow interacting with viscoelastic patches. *Journal of Fluid Mechanics*, 937 (2022).

[4] Houtman, Jelle and Timme, Sebastian. Global stability analysis of elastic aircraft in edge-of-the-envelope flow. *Journal of Fluid Mechanics*, 967 (2023).

Collaborations envisagées : This thesis will be co-supervised with CNES and Ariane Group.

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