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PROPOSITION DE SUJET DE THESE

Intitulé : Optimal control of transitional high-speed flows over complex surfaces for reusable transportation vehicles

Référence : MFE-DMPE-2025-10
(à rappeler dans toute correspondance)

Début de la thèse : Octobre 2025 | **Date limite de candidature :** Mars 2025

Mots clés

Flow control – laminar-turbulent transition – hypersonic flows

Profil et compétences recherchées

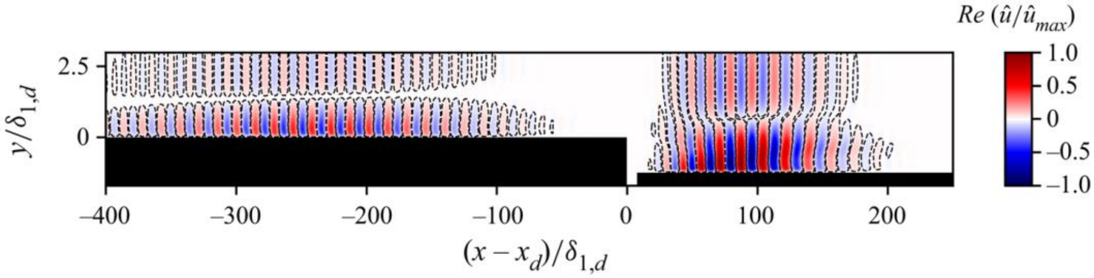
The successful candidate will be a graduate student (holding a Master of Science degree) with a strong background in fluid mechanics. Previous applied experience with computational fluid dynamics will be essential, and interest for machine learning and optimization technics will be beneficial.

Présentation du projet doctoral, contexte et objectif

For reusable transportation vehicles to become a practical option, controlling the state of the boundary layer is key to make it technically viable in combination with safety, economy and ecology. Indeed, laminar and turbulent boundary layers at high speeds trigger drastically different heat and momentum transfer rates, which largely impact the possible designs and related optimizations. The wide range of flow regimes typical of reusable launch and re-entry vehicles introduces specifically the need to optimize the outer mold line and the use of thermal protection systems (TPS) related to drag and heat transfer reduction. For this reason, laminar-turbulent transition is an active area of research with various elements to be addressed as laid out in the recent white paper on the subject [1].

The skin of these transportation vehicles can exhibit non-uniform surfaces, resulting either from manufacturing imperfections or from accumulated degradation during consecutive missions. It is important to determine what surface quality and what tolerances can be allowed from the outer mold line as well as at interface junctions in order to avoid overheats and hot spots due to transition onset. In an attempt to provide a solid basis for setting up practical engineering correlations or tools to determine these allowable tolerances and deformations for a go/no-go decision, the current project will focus on studying the flow around protuberances such as steps and gaps and how they relate to transition. Experimental data sets will be available to compare computations carried out during the project with recent relevant measurements [2,3]. Moreover, the possibility to stabilize the flow in the wake of such obstacles will be explored numerically, by means of optimization through ensemble-variational methods.

The numerical tools to be employed during this project have all been developed and validated in different areas of computational fluid dynamics. The focus will not be on tool development, but on tool integration and exploitation, allowing the successful candidate to focus on flow control by means of optimization techniques outlined previously. The candidate will need to become familiar, however, with the high-performance computing (HPC) environment surrounding expensive numerical simulations, and be proficient in a scripting language that enables tool-integration within complex workflows (either Python or Bash).



Harmonic response developing over a backward-facing step. Figure taken from [4].

[1] Sandham, Neil, and Jeroen Van den Eynde. "Outcome of high-speed boundary layer transition workshop at HiSST 2022." *CEAS Space Journal* 15, no. 6 (2023): 989-991.

[2] Ivison, William, Chris Hambidge, Matthew McGilvray, Jim Merrifield, and Johan Steelant. "Experimental investigation of the effect of steps and gaps on hypersonic vehicles." (2022).

[3] Ivison, W., C. J. Hambidge, M. McGilvray, A. Flinton, J. Merrifield, and J. Steelant. "Heat flux augmentation caused by surface imperfections in turbulent boundary layers." (2024).

[4] Rouviere, Adrien, Lucas Pascal, Fabien Méry, Ehouarn Simon, and Serge Gratton. "Neural prediction model for transition onset of a boundary layer in presence of two-dimensional surface defects." *Flow* 3 (2023): E20.

Collaborations envisagées

The student will be based at ONERA-Toulouse for most of the project, with planned visits to the partner laboratory in Paris (CNAM) and the possibility of a stay abroad.

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