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PROPOSITION DE POST-DOCTORAT

Title : Two-temperature atomization modeling for liquid methane rocket engines

Starting date : before 31/12/2023	**Application deadline :** 16/03/2023

Duration : 24 months

Keywords : two-phase flows, Large Eddy Simulation, primary atomization, combustion

Profile and skills needed: PhD in two-phase flow simulation, strong background in two-phase flow and combustion modeling.

The choice of liquid methane as propellant for the design of new rocket engines brings some new difficulties compared to hydrogen/oxygen engines. One of them is operating conditions involving methane and oxygen both injected liquid through coaxial injectors. Well-known liquid-gas atomization of liquid oxygen is in this case replaced by less favorable conditions of atomization, that need to design dedicated injectors with new knowledge about the atomization in liquid-liquid conditions.

As experimental observation of atomization of two liquids is far more complex than atomization in liquid-gas conditions, Computational Fluid Dynamics (CFD) simulation appears to be the best tool to improve knowledge of liquid-liquid atomization and injector design. Nevertheless, severe conditions inside these combustion chambers require highly robust and precise numerical models and schemes, in order to accurately simulate cryogenic flames produced by methane/oxygen atomization and combustion.

ONERA developed simulation methods for two-phase flows in CEDRE, its simulation platform for energetics. Assisted atomization was successfully simulated inside a cryogenic flame in gas-liquid conditions (Le Touze et al., Appl. Math. Modeling 2020). With a coupling strategy between a 4-equation diffuse interface model and a dedicated solver for the spray, the strategy is able to retrieve the full dynamics of such a complex flow. However, it is highly sensitive to strong temperature and density gradients, especially in weakly compressible regions of the flow. In order to tackle this difficulty, a 5-equation diffuse interface model is under development in CEDRE, to take into account the subgrid energy difference between the two propellants, instead of the full equilibrium hypothesis made in 4-equations models (Cordesse et al., Flow Turb. Comb. 2020). This new formalism leads to a strong reduction of unwanted acoustics released in strong temperature gradients. It will then bring a higher level of robustness, especially under severe conditions like liquid-liquid injection conditions. Applied to a realistic flow, this new model has already shown promising results but some physical phenomena were not taken into account.

The objective of the proposed postdoctoral study is to involve this 5-equation model in the high-fidelity simulation of a liquid-liquid cryogenic flame of rocket engine. During the first year, the postdoctoral candidate will implement into the 5-equation model an evaporation model designed to deal with two temperatures, and a combustion model. With simple test cases highlighting the robustness of this strategy, this work will be published as a new numerical methodology for reactive two-phase flow simulation. The candidate will work in collaboration with two research engineers experts in two-phase flow modelling, and with a PhD student working on dedicated numerical methods for 5-equation diffuse interface modelling.

During the second year, the complete modelling strategy will be applied to simulate a realistic cryogenic flame in liquid-liquid injection conditions. Results will be compared to experimental measurements recently obtained in same operating conditions on the MASCOTTE test bench at ONERA. Such a comparison will demonstrate the performance of the new numerical framework as well as it will validate the code, but it will also bring significant knowledge about the behavior of such a physical complex flow. This work will be published as a liquid-liquid atomization and combustion study with two-temperature physical modelling.

Collaborations : CNES

ONERA host laboratory : Département Multi-Physique pour l'Énergétique

Location: Palaiseau

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