Multi-scale description of textural atomization of liquid oxygen in liquid rocket engine cryogenic flames

Doctorant·e
GEIGER Leonardo

Direction de thèse
DUMOUCHEL CHRISTOPHE (Directeur·trice de thèse)
BLAISOT JEAN-BERNARD (Co-directeur·trice de thèse)

Date de la soutenance
09/12/2024 à 14:00

Lieu de la soutenance
CORIA - Rouen

Rapporteurs de la thèse
MACHICOANE NATHANAEL Universite Grenoble Alpes
RIMBERT NICOLAS Université de Lorraine

Membres du jurys
BLAISOT JEAN-BERNARD, , Université de Rouen Normandie (URN)
DUMOUCHEL CHRISTOPHE, , Université de Rouen Normandie (URN)
FDIDA Nicolas, , Office National d'Etudes&recherches Aéro
HALTER FABIEN, , Université d'Orléans
MACHICOANE NATHANAEL, , Universite Grenoble Alpes
MENARD THIBAUT, , Université de Rouen Normandie (URN)
RIMBERT NICOLAS, , Université de Lorraine
THERON MARIE, , Centre National des Etudes Spatiales

Abstract

The development of rocket engines to equip future launchers requires a better understanding of the complex physical phenomena that govern their operation. In the case of liquid-propelled rocket engines, the growing demand for engines that can be reliably reignited in space means that the transient phases such as start-up and shutdown must be better understood. These transient phases usually include subcritical injection regimes. Oxygen is injected in liquid state into the combustion chamber and undergoes a series of mechanisms: dense jet atomization, fragmentation of liquid ligaments, droplet evaporation, and turbulent combustion. Under these conditions, the combustion process is mainly driven by the atomization of the liquid oxygen, which must be accurately reproduced by simulation to better understand its role in the onset of combustion instabilities. Before using simulation as an autonomous tool to study the atomization process, it is necessary to ensure its level of accuracy. This requires conducting experimental test campaigns on test benches capable of reproducing conditions representative of rocket engines, such as the MASCOTTE test-bench at ONERA or the MARACA test-bench at CORIA. The goal of these studies is to characterize the atomization process and provide experimental data that can be used to develop and validate numerical models. The experimental study of primary atomization of liquid oxygen, in particular, relies on flow visualization techniques that depict the liquid structures involved in the process. The primary atomization process observed in liquid rocket engines can be categorized as textural or structural, depending on the scale at which the atomization takes place. Textural atomization processes are characterized by thin ligaments being peeled from the jet, while structural atomization is related with the breakup of the liquid bulk. Visualizations resulting from experimental test campaigns show very complex two-phase flows involving textural liquid systems that are difficult to characterize due to the wide range of spatial and temporal scales involved. To this day, no techniques are available to describe quantitatively the liquid ligaments involved in the textural atomization processes observed experimentally. In this thesis, a methodology is developed to characterize the textural primary atomization processes observed in the two-phase-flow conditions representative of those encountered in liquid rocket engines. Based on a multi-scale method developed at CORIA, this analysis provides a quantitative characterization of the size, shape and number of the textural liquid structures involved in the textural atomization process in its entire spatial scale range. This characterization provides information for the development of numerical primary atomization models. Additionally, the application of the methodology to liquid systems depicted by visualizations extracted from numerical simulations allow to validate the simulation results in terms of the correct reproduction of the liquid structures that participate in the textural atomization process.