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Comparison of LOX/Methane and LOX/Hydrogen cryogenic spray combustion with simultaneous optical diagnostics

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ONERA and CNES are working together to support the preparation of the next generation of engines for reusable launchers that will be propelled by liquid oxygen (LOX) and methane (CH₄). The present experimental study, carried out on the MASCOTTE bench of ONERA, aims showing the peculiarities of the cryogenic LOX/gaseous methane combustion compared to gaseous hydrogen (H₂) combustion [1], under similar conditions based on the Mascotte A-10 operating point, with a pressure of 10 bar in the combustion chamber [2].

Three optical diagnostics were implemented simultaneously: either Doppler phase interferometry (PDI) combined with high-speed shadowgraphy or OH* chemiluminescence coupled with high-speed shadowgraphy. First, the jet flame is visualized with a large field of view to determine the droplets locations as well as the front flame location. This first phase is essential to prepare the PDI measurement points in order to collect a maximum of droplets during the short duration of the stationary phase of the flow, which is about 30 s.

During the second phase, dedicated to PDI measurements, temporal and spatial resolutions of the shadowgraphy were increased, up to the frequency of 23 kHz, to follow the jet atomization near the injector exit. Image doublets have been made to follow droplets and liquid structures, in order to evaluate their velocity by the image correlation algorithm FOLKI-SPIV [3], which can then be compared to those obtained by PDI. The PDI validation rates are analysed depending on the measurement volume location and compared for the two types of LOX/CH₄ and LOX/H₂ flames. The PDI validation rates seem to be lower for the LOX/CH₄ flame than for the LOX/H₂ flame, at the same locations. Indeed, the shadowgraphs illustrate the higher optical density of methane with respect to hydrogen as atomizing gas. By superimposing PDI measurement locations on the OH* chemiluminescence and shadowgraphy time-averaged images, the locations where the PDI validation rates are found the highest in the front flame, evidenced by the Abel transform of the OH* chemiluminescence images. At the closest locations from the injector, the number of measured droplets is sometimes low, because of a weak validation rate and a short acquisition time in stationary conditions. Thus, interpolation of the drop size distribution was carried out using different mathematical functions based on the Log-normal law, the Weibull distribution, the Gamma law and the maximum entropy formalism (MEF) [4], [5] in order to identify the shape of the experimental drop-size distribution for future comparison with numerical simulations.

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