Characterization of a double swirl injector in a LOX/LCH4 fueled combustor on Mascotte test bench

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1. Introduction

The work presented in this paper was performed in the framework of the “ISP-1” (In Space Propulsion) project, coordinated by Snecma within the FP7 European program. This research program is aimed to improve the fundamental knowledge and the techniques which are necessary to allow Europe to implement new ambitious space programs involving low cost cryogenic propulsion. Working with liquid oxygen (LOX) and liquid methane (LCH4) as propellants can be an advantage in space applications [1, 2]. This new propellants combination is a candidate for future reusable launch vehicles. After an evaluation of different concepts of injection, considering combustion efficiency and stability, and also the state of the art on this topic, it came out that the best choice for LOX – LCH4 injection study would be a double swirl injector. The critical parameter in such an injector is the LOX post recess length. The influence on flame behavior and combustion stability of injection parameters, such as the flow rates, the fluid mixture ratio and the LOX post recess length, are investigated and discussed in this paper.

2. Materials and methods

The liquid oxygen – liquid methane double swirl injector was designed and manufactured by Onera, in close collaboration with the DLR, Snecma and EADS Astrium, its partners for this activity. This injector was successfully tested on Onera’s cryogenic test rig Mascotte, located in the Palaiseau Center.

The combustor was equipped with large UV-glass windows, allowing to characterize the behavior of the flame for different injector setups. Two identical high-speed intensified cameras (model Photron FASTCAM-ultima APX-i2), operated jointly by Onera and DLR, were used to record OH* and CH* chemiluminescence images simultaneously. A spectrograph from DLR was also used to record the flame emission in a wide range of wavelength.

3. Results

Preliminary cold flow tests were performed with actual propellants, either in the LOX line or in the LCH4 line, alternatively. Spray cone angles were deduced from video images. The interaction between the two sprays was investigated by supplying water in both LOX and fuel lines. Pressure drop data through the double swirl injector were also obtained for each line during these tests. The injection pressure drop was found to be always the same for cold and reacting cases in the LOX line, but not in the LCH4 line.

Several reacting hot fire tests conditions, corresponding to different injection configurations and flow conditions, were defined in order to investigate the flame behavior, and in particular the influence of the LOX post recess length, in established combustion regime. These conditions corresponded to previous CARS experimental result data [3]. Time-averaged OH* chemiluminescence images were calculated from high-speed recordings (see example in Figure 1). Although the vicinity of the injector could not be visualized because of the presence of an ice film on the windows, formed during established combustion regime, a decrease of the flame length induced by an increase of the propellants mixture ratio (*ROF*, defined as the LOX to LCH4 flow rates ratio) was clearly evidenced, except for the longest recessed case. The LOX post recess length was found to influence the flame shape. To understand the effect of the recess, results were compared with the literature [4], [5] for similar operating conditions.

Combustion stability was studied by performing Fourier analysis on the instantaneous OH* chemiluminescence images and pressure signals. A low frequency of around 40 Hz was detected in several cases (see example in figure 2). In particular, the largest recess length investigated resulted in a less stable flame, according to the pressure fluctuation intensities.

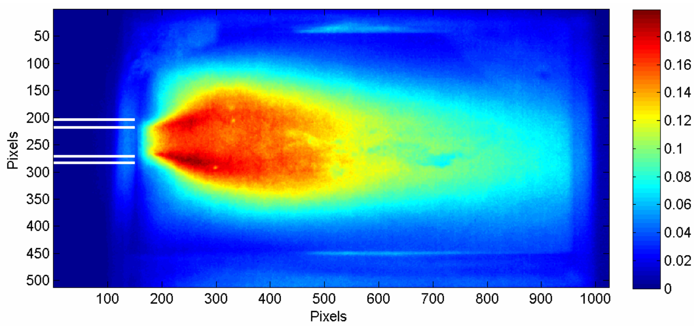

Figure 1: Time-averaged OH chemiluminescence images obtained for the coaxial injection configuration. Field-of-View: 100 mm x 50 mm.*

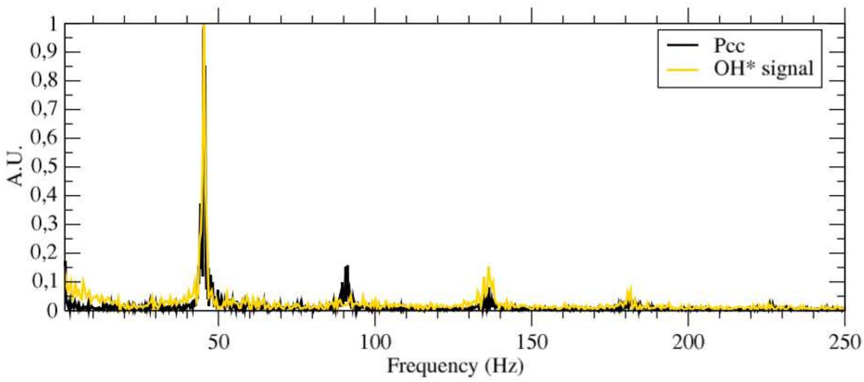

Figure 2: Comparison of normalized FFT spectra performed from the instantaneous OH chemiluminescence images and the combustion chamber pressure signals (Pcc).*

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