Injector Characterization for a GOX-GCH4 Single Element Combustion Chamber

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Todays' high performance liquid propellant rocket engines are mainly operated with the cryogenic propellant combination LOX/LH2, due to the high specific impulse. The demanding issues in terms of high operational and handling costs of such propellants increased the attention for hydrocarbons in future launch vehicles [1].

In this context, one of the most promising propellant combinations is oxygen/methane. These propellants in fact show, compared to other potential candidates like oxygen/kerosene, a better overall performance from a system point of view [2], higher specific impulse [3], better cooling capability and lower coking attitude [4]. Furthermore, methane can be simply extracted from natural gas, provides a density six times higher than hydrogen when stored in liquid state at typical tank pressure and has no risks for the human health.

The design and the optimization of liquid rocket engines using methane require a detailed knowledge and understanding of the dominating physical phenomena of propellant injection, combustion and heat transfer mechanisms.

Although other propellant combinations have been extensively investigated by different research groups [5, 6], only a limited amount of experimental data is available for oxygen/methane combustion at relevant combustion chamber conditions. Fundamental experimental data are also necessary for the validation of numerical tools. Previous studies have been performed at the MASCOTTE facility at ONERA [7] as well as at the P8 facility at DLR Lampoldshausen [8, 9]. Nevertheless, an extensive experimental and analytical database on oxygen/methane and flame stabilization phenomena has to be established yet.

In the context of the national research program Transregio SFB/TR-40 on "Technological Foundations for the Design of Thermally and Mechanically Highly Loaded Components of Future Space Transportation System", two multi-injector combustion chambers will be designed for gaseous oxygen (GOX) and gaseous methane (GCH4). The high pressure combustion chamber (operating from 4 MPa to 10 MPa) will be equipped with a pattern of seven injectors, while for low pressure ranges (1 MPa to 4 MPa) a combustion chamber with rectangular cross section housing a line of five injector elements will be used. One of the key aspects of this project is to improve the knowledge on heat transfer processes and cooling methods at representative engine-like conditions, focusing on injector–injector and injector–wall interactions.

Classical measurement techniques together with inverse methods will be used to reconstruct the temperature field in the chamber wall material and the heat flux profile. For low pressures these techniques will be supported by an optical access for advanced diagnostics to improve the detailed physical-chemical model. The optical access will be provided via a quartz glass window positioned in the region near the faceplate. The flat window and the rectangular cross section of the hardware will allow the full optical access to the flame interaction, avoiding, compared to a round chamber, the distortion due to the curvatures and the flow disturbances caused by the presence of window corners. Corner effects due the rectangular cross section of the combustion chamber have to be taken into account.

Before the final manufacturing and testing of the aforementioned hardware, a single-element combustion chamber is designed and tested in order to characterize the injector, to establish the heat load to the wall - especially in the area where the window will be placed - and to validate the in-house FEM tool Thermtest [11] for the new propellant combination. The single-element chamber is capacitive cooled and features a total length of 290 mm with a square cross section of 12 x 12 mm, as shown in Fig. 1.

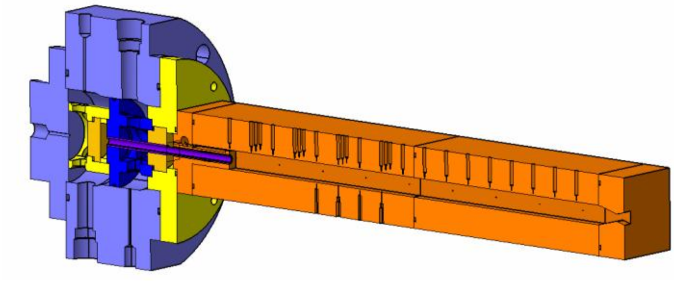

Fig. 1: Single-element combustion chamber

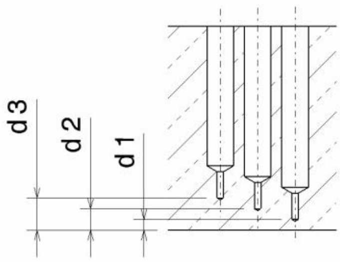

Fig. 2: Thermocouples positioning in the chamber wall

The injector element used is of a shear coaxial type, without any recess or tapering. The total length and the diameter of the injector are kept equal to the final hardware ones.
Surface thermocouples at different axial positions are installed for direct measurement of the local surface temperature inside the combustion chamber, whereas wall thermocouples at different distance *d* from the hot gas wall are used to determine the temperature field in the chamber material. Thus, packages with three wall thermocouples each, with different distances *d* (*d1, d2, d3*) from the hot wall, as depicted in Fig. 2, are also located in axial direction. The axial and radial distribution of the thermocouples allows the determination of the heat flux variation along the axis and the reconstruction of the thermal field in the chamber wall. A number of equally spaced pressure transducers on the side wall provide a measurement of the static pressure distribution *p(x)* along the chamber axis. The static pressure variation gives an indication of the chemical reaction time and the length of the flame zone.
Detailed results and a comprehensive study will be presented in the full paper.

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