Design, Modeling and Testing of an GOX/GCH4 Igniter for Rocket Engine Thrust Chambers.

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The HYPROB program is carried out by CIRA under contract by the Italian Ministry of Research with the main objective to enable and improve National system and technology capabilities on liquid rocket engines (LRE) using propulsion systems for future space applications, with specific regard to LOX/LCH4 technology. As far as the System line devoted to the LOx/LCH4 technology is concerned, a first implementation project has been launched, called HYPROB BREAD, aimed at designing, manufacturing and testing a LRE demonstrator, of 3 ton of thrust, based on a regenerative cooling system using liquid methane as refrigerant. The HYPROB-BREAD project foreseen the design of some breadboards aimed at the investigation of critical design aspects in the development of the complete system. These breadboards and in particular the SSBB is described in [1].

This paper discusses the design of the candidate gaseous oxygen-gaseous methane igniter for a subscale experimental “breadboard” (SSBB) LOX/Methane rocket engine. The igniter architecture takes into account different literature efforts about igniter design as in particular [2].

The igniter is made up of three sections, two inlet ports with flanged interfaces sealed by O-rings for the gaseous oxygen and methane connected to the central igniter body consisting of the chamber and nozzle as shown in Figure 1. The fuel and oxidizer are injected via sonic orifices that are fed at 30 bar pressure in order to maintain a constant mass flow for all the working conditions. A spark torch is used to ignite the propellants. The igniter is equipped with a flange that allows for a flanged joint in such a manner as to avoid stress in case of thermal expansion.

The objective of the simulations is to obtain heat loads for the analysis on the igniter and on the water disk where the jet impinges. The simulations conducted using FLUENT®[3] are for fully reacted flow where the species distribution and temperatures are given at the inlet represented by the chamber section. A 2D axisymmetric grid is generated for the ignition chamber and igniter nozzle and rocket chamber section. This modeling is viable since the heat fluxes along the igniter chamber and nozzle walls and on the rocket chamber wall opposite the igniter outlet are of principle interest. Figure 3 shows a sample pressure distribution and Figure 4 and Figure 5 show heat loads along the igniter wall and engine chamber right hand wall respectively. Since the heat loads on the first chamber module are of the same order of magnitude as those produced by the injector in the combustion chamber at steady state a thermal analysis is conducted.

An axisymmetric FEM model has been considered in this analysis using ANSYS[4]. The interface between the TZM alloy structure and the Inconel 718 structure has been modelled by means of contact sliding elements which leads to a more complex, but more realistic analysis. The use of contact elements avoids the manifestation of thermal stresses. Figure 6 shows the temperature distribution in the TZM alloy igniter structure after 4 seconds. The maximum temperature is 1687 K is satisfactory since it is lower than the maximum allowable value for the TZM alloy. Figure 7 shows the distribution of the Von Mises stresses which indicate that the igniter structure is sound. Figure 9 shows the variation of the main design performance parameters in time using ECOSIMPRO[5]. The results are reasonably good. The main difference between the design values and the results from the ECOSIMPRO model are attributable to the different equilibrium temperature provided by ECOSIMPRO

The results from the various calculations demonstrate that the design methodology employed is satisfactory. The final paper should also include some preliminary experimental results that are foreseen in FAST 2 AVIO facility.

Acknowledgements

This work has been carried out within the Hyprob program, funded by the Italian Ministry of University and Research (MIUR) whose financial support is much appreciated.

References

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2. George A. Repas, Hydrogen Oxygen Torch Igniter, NASA/TM 106493.

3. ANSYS FLUENT 12.0 Theory Guide, 7.4-7.6, Fluent Inc., Canonsburg, Pennsylvania, USA, 2009.

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Nomenclature

CFD = Computational Fluid Dynamics
GCH4 = Gaseous Methane
LOX = Liquid Oxygen
SSBB = Subscale Breadboard

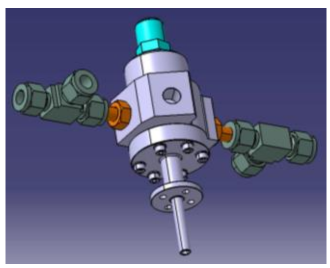

Figure 1 : Igniter stack

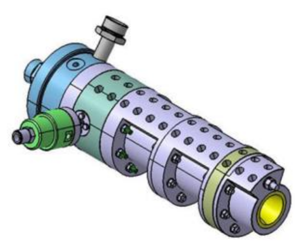

Figure 2: Subscale breadboard

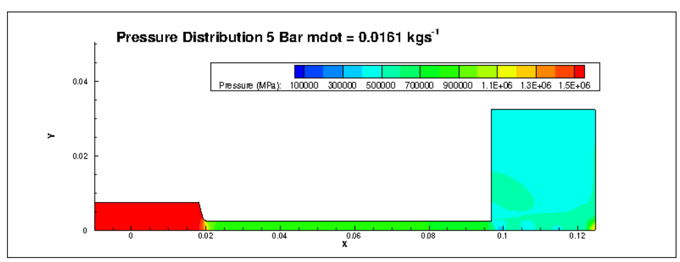

Figure 3: Pressure distribution

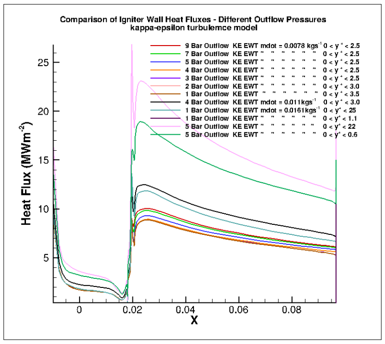

Figure 4: Igniter heat fluxes

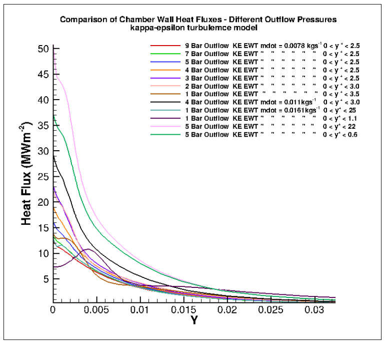

Figure 5: Chamber heat fluxes on right wall

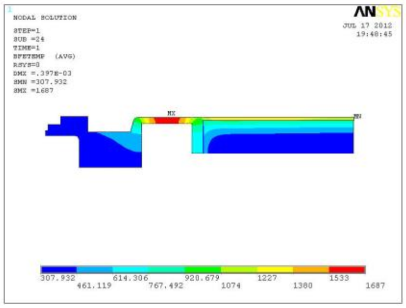

Figure 6 : Temperature after 4 seconds

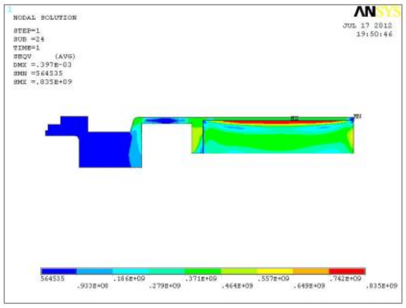

Figure 7 : Von Mises Stresses

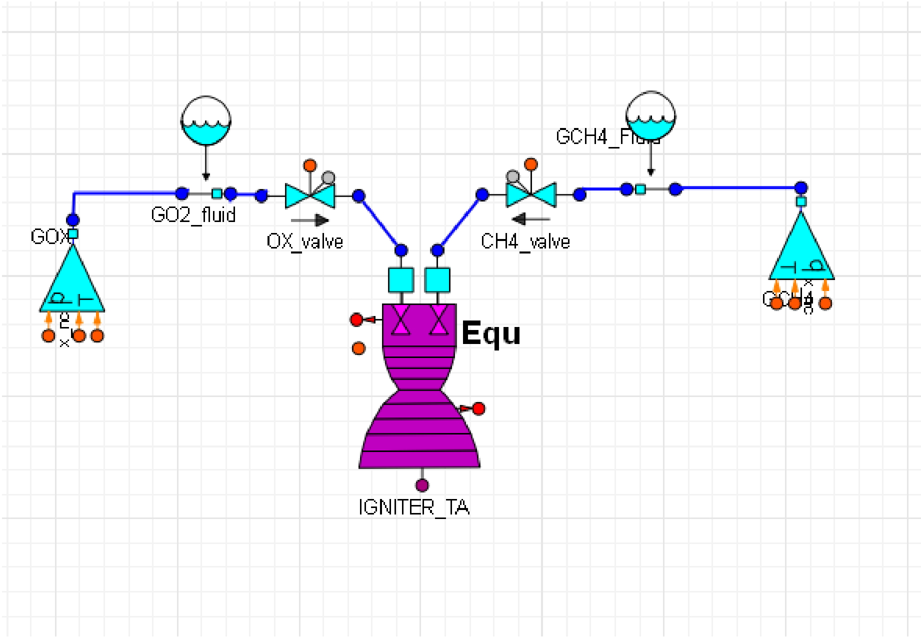

Figure 8 : Ecosimpro Schematics

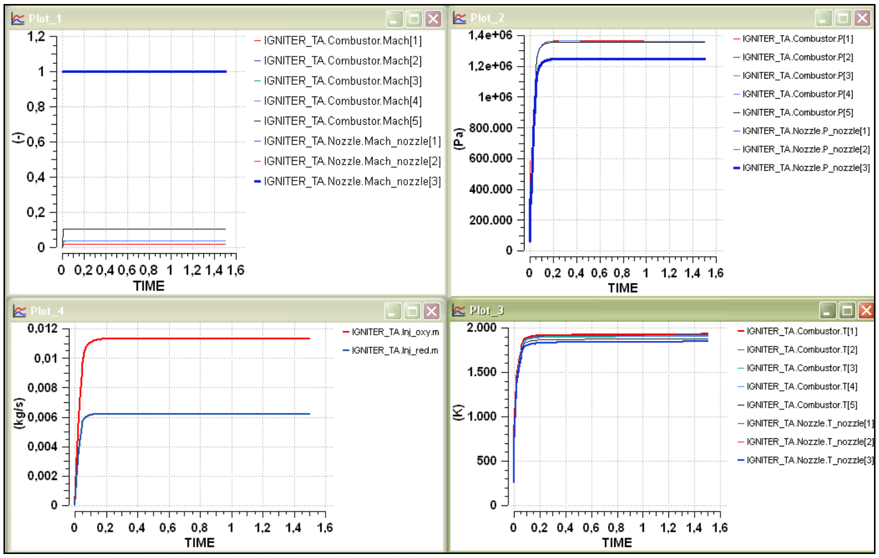

Figure 9 : Igniter temperature, pressure, mach number and injector mass flow rate