Paper ID: 88367
student

IAF SPACE PROPULSION SYMPOSIUM (C4)
Interactive Presentations - IAF SPACE PROPULSION SYMPOSIUM (IP)

Author: Mr. matteo crachi
Politecnico di Torino, Italy

Dr. Marco Pizzarelli
Italian Space Agency (ASI), Italy
Prof. Rafaella Sesana
Politecnico di Torino, Italy
Prof. Cristiana Delprete
Politecnico di Torino, Italy

LIFE EVALUATION OF LIQUID ROCKET ENGINE REGENERATIVE COOLING SYSTEM: A COMPARISON OF HARDENING MODELS

Abstract

The thrust chamber of high-performance bipropellant liquid rocket engines is a critical component of reusable launch vehicles. The regenerative cooling system is designed to reduce the temperature of the chamber walls exposed to hot gases and increase the energy of the fuel or oxidizer before injection. In order to guarantee the integrity of the thrust chamber and the reusability of the hardware, thermo-mechanical life prediction is crucial.

Due to low-cycle thermal fatigue during multiple hot firings, the life of regeneratively cooled thrust chambers is directly correlated with their thermal behavior. Therefore, it is of primary importance to implement validated thermal models into the design process. The requirement of reducing the temperature of the walls exposed to hot gases can be met with high-thermal conductivity copper alloys, while the mechanical stiffness of the external jacket is often achieved by using high-strength steel or nickel alloys. The difference in materials and thicknesses between the internal and external walls can be identified as the major source of severe strains, leading to multiple challenges in the design of regeneratively cooled thrust chambers.

It is known that life estimation of this particular hardware suffers from overestimation due to a lack of reliable representative simplified specimen characterization, heat flux prediction, and uncertainties regarding the plasticity model to be implemented in computations. For the aforementioned reasons, thrust chambers are commonly cycled to failure during severe test campaigns, and numerical thermo-mechanical codes are validated based on experimental results.

The aim of the present study is to explore, using a commercial structural finite element method software solver, various hardening models to predict the stress-strain behavior of a regeneratively cooled thrust chamber. Furthermore, the cycling behavior is predicted, and a life estimation is provided. A comparison with experimental results acquired during the Space Shuttle Main Engine sub-scale cylindrical thrust chamber test campaign at NASA former Lewis Research Center (LeRC plug thrust chambers) has been identified as the reference case study. By providing the number of cycles to failure, together with accurate temperature measurements obtained through multiple depth intrusive thermocouples, the LeRC plug chambers provide a rare hardware-representative low-cycle thermal fatigue experiment and a reliable opportunity to implement validated thermal boundary conditions for numerical thermo-mechanical analysis.