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DESIGN OF AN ADDITIVELY MANUFACTURED BIPROPELLANT THRUSTER FOR IN-ORBIT SATELLITE OPERATIONS

Abstract

Within the last decade, the new space propulsion panorama has seen a rapid evolution in the manufacturing field involving liquid rocket engine thrust chambers. Advances in Additive Manufacturing (AM) Selective Laser Melting (SLM) applied to propulsive applications allow to overcome manufacturing limitations and therefore to exploit an almost unlimited design freedom that is guaranteed by this technology. The aim of this work is the description of the development and verification steps involving the design of a liquid rocket engine for small thrust and in-space operations. The thrust assembly is based on bipropellant storable 'green' and self-pressurized propellants. The development includes AM SLM technology involving high-temperature IN718 material. In particular, this work is focused on the CAD model design of the thrust chamber which leverages on part consolidation enabled by the additive manufacturing technique, in order to merge in just one single part many of the features typically achieved by conventional engines with complex assemblies. The assembly includes: combustion chamber characteristics, nozzle dimensioning, regenerative cooling channels integration inside the engine walls, thermal sink implementation, injection head design, interface plate evaluation.

The focus of the work is centred on the design and optimization of regenerative channels within the thrust chamber structure: different options are presented and a mathematical approach for channels parametrization is proposed. The evaluation of the models is performed through a series of samples prints for the different designs proposed. Each print is analysed separately with dedicated Non-Destructive Inspections (NDI) to retrieve insights on the selected design such as: channel internal cleanliness and its dependence on the selected design; internal distances between channels and chambers; channels circularity assessment due to printing criticalities; other geometrical analyses.

This study allows to map the overall additive manufacturing criticalities associated to the proposed thruster design: inclination of surfaces, shapes of the cavities and propellant manifolds are evaluated as well as geometric features of the internal channels. A final selection of the internal regenerative channels layout is performed comparing the results of the channels parametrization. The outputs are feedback to the design of the overall assembly, which is finalized in its AM design phase.

This study is concluded with insights on the approach towards the design of small thrust chambers including complex channel geometries involving selective laser melting technology; an overview of the future steps for the overall print of the thruster is proposed in order to proceed with further mechanical, fluidic and thermal analyses.