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DEVELOPMENT OF A REGENERATIVELY COOLED NOZZLE EXTENSION BY ADDITIVE MANUFACTURING FOR THE THRUST CHAMBER OF A CRYOGENIC LIQUID ROCKET ENGINE

Abstract

During the last decade, the additive manufacturing of metal alloys has demonstrated a growing trend in reliability and production quality, finding a solid application in the aeronautical industry. The easy realization complex geometries with a reduced need of additional machining, the rapid prototyping and, especially, the increase of machine minimum building volume have demonstrated to be valuable advantages in the development of cryogenic liquid rocket engines. Indeed, the availability of flexible space launchers capable of greater payloads with multi-orbital injection represents a strategic solution in a constantly growing satellites market. In this context, AVIO is developing the upper stage of VEGA-E launcher with a new LOX-Methane cryogenic engine by exploiting additive manufacturing technology, using Powder Bed Fusion (PBF) technique with large build volume machines. The current largest size commercial PBF machines allow for the manufacturing of the main combustion chamber, the injector head and sub-systems like the components of the turbopumps whereas the Regeneratively Cooled Nozzle Extension (RCNE) cannot be realized by PBF because of its dimensions. The RCNE is a key component for rocket engine designed for orbital transfers since it allows for the correct combustion gases expansion, by high area ratio, for thrust maximization as well as the heat recovering by the fuel used as coolant inside its cooling channels. Therefore, besides the protection of the walls subjected to hot gases, the turbopumps are powered by heated fuel, so closing the expander cycle of the M10 engine. Like the main combustion chamber, the RCNE is characterized by a complex internal geometry but developed in a very large dimension nozzle, which requires approximately 1 cubic meter of build volume. Currently, the reliability of very large PBF machine has not been demonstrated yet, being far to be suitable for the manufacturing of RCNEs, also considering the high costs and complexity associated with the management of such great amount of powder for one single print. Therefore, the most promising additive manufacturing alternative is represented by Direct Energy Deposition (DED) equipped with optimized powder nozzle for thin walls realization. The DED technique allows for large build volume since, differently from PBF, it does not require an inert build chamber neither a complex optical system. By means of this technology AVIO began the development of M10 RCNE starting by simple representative geometrical mockups and material characterization, to gradually improve the complexity for the target realization of a full-scale nozzle extension.