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LIQUID ROCKET ENGINE DESIGN FOR ADDITIVE MANUFACTURING

Abstract

This paper describes the entire process of additive manufacturing for a liquid rocket engine capable of producing 10 kN of thrust. The engine is being developed at the Liquid Propulsion Laboratory at the University of Southern California. Two engines will provide the thrust to launch a reusable flight vehicle that is developed by the Kyushu Institute of Technology in Japan. The engine is 400 mm in height with the max inner diameter of 156 mm. Propellants are LOX and Kerosene

A development, qualification, and two flight engines will be designed and 3D printed out of Inconel 718. Each engine will be cooled using regenerative and film cooling. The engine is split into three parts: the nozzle, the chamber with film cooling orifices, and the pintle injector. The pintle is designed so that it can be removed easily and replaced with another design. This allows for multiple pintles to be printed and switched for testing to achieve the highest performance.

Several constraints arise from using additive manufacturing. The engine is split into three parts due to the restricted maximum build height of the 3D printer. Another aspect that was considered is minimizing the need of post machining. Machining is expensive and can cause permanent damage to the engine by clogging regenerative channels. To avoid this, a flange design is used on the fuel inlet. Another constraint is avoiding overhangs in the printing direction. An overhang will not print correctly and could destroy the entire print. To print smooth walls, the maximum angle that can be printed is 45-degrees. The engine design is modified to meet these requirements for additive manufacturing.

After the printing, the Inconel 718 does not have sufficient materials properties to withstand environment in the combustion chamber. To improve these properties, the engine is subjected to a heat treatment process with a specific temperature profile. The next step in manufacturing process is to machine holes and threads for oxidizer and fuel inlet. In the case of the development engine, there are many sensors on the engine to measure pressure and temperature in different locations that will need holes machined. From these sensors, the engine will be improved on the next iteration, the qualification engine. The last step in the manufacturing process is to polish rough surfaces for better flow properties.

The development engine will be hot-fire tested in March 2018.