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THE DEVELOPMENT PROCESS FOR A SINGLE-PART ADDITIVELY MANUFACTURED LIQUID ROCKET ENGINE INJECTOR WITH AS-PRINTED ORIFICES

Abstract

The Liquid Propulsion Laboratory (LPL) presents the research into utilizing additive manufacturing for the design, development, and production of liquid rocket engine injectors. The adoption of additive manufacturing gives engineers more flexibility to design unique geometries into a part that would be otherwise impossible to achieve with traditional subtractive methods. This capability is advantageous for liquid rocket engine injectors, which are typically complex and expensive to produce. LPL's Jessie & James injectors are interchangeable and feature shower head and like-doublet impinging injector element types for the oxidizer & fuel respectively. Utilizing Powder Bed Fusion Direct Metal Laser Sintering (DMLS), the injector consists of a single part and only requires post-machining for threaded ports and sealing surfaces. This enables rapid iteration during development and dramatically reduces the cost per unit, once in production. One of the current challenges with DMLS is the tendency for small features, such as channels and orifices, to shrink during the printing process. Due to the number of factors at play, the shrinkage phenomenon is not trivial to quantify. Diameter reductions of up to 40% have been observed in horizontal orifices with part feature diameters on the order of 0.02". This shrinkage tends to reduce as the diameter is increased and the angle with-respect-to vertical is decreased, becoming insignificant at diameters on the order of 0.08". Since injector stiffness scales with orifice diameter to the fourth power, it is desirable to reduce the uncertainty in orifice shrinkage. This relationship drives the tradeoff between the number of injector elements, which affects the degree of propellant mixing and atomization, and thus injector performance. Lack of shrinkage characterization that results in a diameter reduction of 40% would lead to a deviation from the desired injector stiffness by a factor of 7.7. For this reason, LPL introduces its method to empirically study and quantify the shrinkage experienced using an EOS M 290 DMLS printer for EOS MaragingSteel MS1 Steel & EOS NickelAlloy IN718 metal powders during the development of the Jessie & James injector. In addition, the Jessie & James injector incorporates a design feature that is aimed to increase operation time and reusability. This is done by printing in 10 injection elements positioned perpendicularly around the injector face circumference to direct fuel and thermally protect itself. The development of this film cooling technique looks promising thus far and the results of this additional study will be discussed at length.