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MULTI-MATERIAL LASER POWDER BED FUSION OF LIQUID ROCKET NOZZLE WITH REGENERATIVE COOLING CHANNEL WALL

Abstract

Rocket engines generate high temperatures for extended durations. The nozzles, particularly, require implementation of a cooling strategy to keep the temperatures within material limits. Regenerative cooling is a preferred and effective method. A conventional rocket nozzle features cooling passages positioned close to the inner nozzle wall. These coolant passages are machined into the inner liner, then closed off with an outer jacket attached using techniques such as brazing. This manufacturing process is time consuming and expensive.

Additive Manufacturing (AM), a prototyping technology dating back to the mid-1980s, has evolved into a versatile method for producing high-precision products. Notably, it has found applications in the manufacturing of engines, heat exchangers, and structural components. AM technologies such as wire arc additive manufacturing (WAAM) and laser wire direct closeout (LWDC) have been used for closing off the coolant channels. Laser powder bed fusion (LPBF) has been employed to print the channel wall nozzle with a complex geometry directly.

This study reviews current technologies for fabricating nozzles with channel wall cooling and compares their advantages and disadvantages. To improve cooling efficiency, materials with high thermal conductivity, such as copper alloys, are good candidates for the channel wall. However, copper alloys lack the strength to maintain the structural integrity of the overall rocket nozzle. Fabricating a channel-wall nozzle as a multi-material component may be a solution. This would use copper alloys for the inner nozzle with the hot-wall channels, and for the outer, load-bearing structure, a suitable high-strength material, probably an iron or nickel-base alloy. AM techniques have advanced with the development of multi-material additive manufacturing (MMAM), which can create multi-material components with novel functionalities and offering enhanced performance compared to single material AM processes.

In this study, a multi-material channel wall nozzle was fabricated from CuCr1Zr copper alloy and 1.2709 maraging steel using multi-material laser powder bed fusion in a single printing operation, demonstrating the feasibility of multi-material AM. This study suggests a novel one-step-solution for fabrication of the next generation of dual-material channel-wall nozzles for liquid propellant rockets.