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INTEGRAL CHANNEL NOZZLES AND HEAT EXCHANGERS USING ADDITIVE MANUFACTURING DIRECTED ENERGY DEPOSITION NASA HR-1 ALLOY

Abstract

Heat exchangers for use in propulsion applications are critical features within components that contain high pressure propellants used for cooling the walls or heat transfer between fluids for the engine cycle. Examples of engine components where heat exchangers are used include the combustion chamber, regeneratively cooled nozzle, and repressurization systems for the launch vehicles. These components are often thin-wall and contain the high-pressure propellants at cryogenic or elevated temperatures. While the environments that these propulsion components must endure are challenging, the manufacturing to meet these requirements are often long lead times due to specialty processes and unique tooling associated with the combined thin-wall integral channel and large-scale structures. Additive Manufacturing (AM) of heat exchanger components can result in significantly reduced lead times and cost, offering programmatic advantages. While AM is being utilized heavily for heat exchanger components in propulsion applications, almost all these AM components use Laser Powder Bed Fusion (L-PBF). L-PBF offers fine feature resolution, but very limited in the overall size that components can be manufactured. Recent developments are maturing the Laser Powder Directed Energy Deposition (LP-DED) process for integral channel thin-wall applications with the ability to manufacture at diameters greater than 1 m. This paper will highlight some of the regeneratively-cooled nozzles and integral channel heat exchanger demonstrator hardware as well as the characterization of this process using the NASA HR-1 alloy. To properly use LP-DED for heat exchanger applications various aspects are being characterized such as geometry limitations for channel sizes, measurement of surface texture for integral channels and geometric angled surfaces, surface enhancements for internal channels, and evaluation of the NASA HR-1 alloy. NASA HR-1 (Fe-Ni-Cr) is a high strength hydrogen resistant superalloy developed for use in aerospace applications, such heat exchangers. The objective of this paper is to summarize some of the considerations when designing for heat exchangers using the LP-DED process in addition to data relevant for the NASA HR-1 alloy. The characterization of these LP-DED features is critical for heat exchanger fluid flow and can modify performance for enhanced heat transfer or can be a detriment to pressure drop.