A One-piece Liquid Rocket Thrust Chamber Assembly

Rapid additive manufacturing of a lightweight chamber for regeneratively-cooled liquid rocket engines

NASA is developing a lightweight one-piece regeneratively-cooled thrust chamber assembly (TCA) for liquid rocket engines. Liquid rocket engines create thrust through the expansion of combusted propellants within the TCA. Standard manufacturing of TCAs involves individually building the injector, main combustion chamber and nozzle, and then bolting or welding the components together at the joints. However, potential seal failures in these complex joints can cause catastrophic explosions, as in the tragedy of the Space Shuttle Challenger. NASA researchers are eliminating complex joints by manufacturing a 1-piece TCA utilizing 3D printing and large-scale additive manufacturing technologies to directly deposit the nozzle onto the combustion chamber. And, by replacing a traditional solid metal jacket with a composite overwrap for support, the overall weight is reduced by over 40%. Developed under the Rapid Analysis and Manufacturing Propulsion Technology (RAMPT) project, NASA seeks public-private partnerships to develop specialized large-scale additive manufacturing vendors and accelerate reliable spaceflight hardware to the US supply chain.

BENEFITS

- Reduced manufacturing complexity: Solid one-piece construction ultimately means no joints, no welds
- Reduced weight by 40% compared to current combustion chambers: the use of multi-materials and a composite overwrap optimizes performance and reduces weight
- Increased safety and reliability: eliminating joints reduces potential leak sources
- Reduced thermal stresses: the manufacturing technique minimizes the coefficient of thermal expansion mismatch between varying materials
- Improved metal/composite bond: engineered surface features on the outside of the metallic chamber enable bonding to and thermal isolation from the composite overwrap

APPLICATIONS

The technology has several potential applications:

- Aerospace: Regeneratively cooled liquid rocket engines for booster engines and upper stage engines
THE TECHNOLOGY

The one-piece multi-metallic composite overwrap thrust chamber assembly is centrally composed of an additively manufactured integral-channeled copper combustion chamber. The central chamber is being manufactured using a GRCop42 or GRCop84 copper-alloy additive manufacturing technology previously developed by NASA. A bimetallic joint (interface) is then built onto the nozzle end of the chamber using bimetallic additive manufacturing techniques. The result is a strong bond between the chamber and the interface with proper diffusion at the nozzle end of the copper-alloy. The bimetallic interface serves as the foundation of a freeform regen nozzle. A blown powder-based directed energy deposition process (DED) is used to build the regen nozzle with integral channels for coolant flow. The coolant circuits are closed with an integral manifold added using a radial cladding operation. To complete the TCA, the entire assembly including the combustion chamber and regen nozzle is wrapped with a composite overwrap capable of sustaining the required pressure and temperature loads.

NASA has performed hot-fire testing of the chamber/overwrap assembly shown in black in this picture.

PUBLICATIONS

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