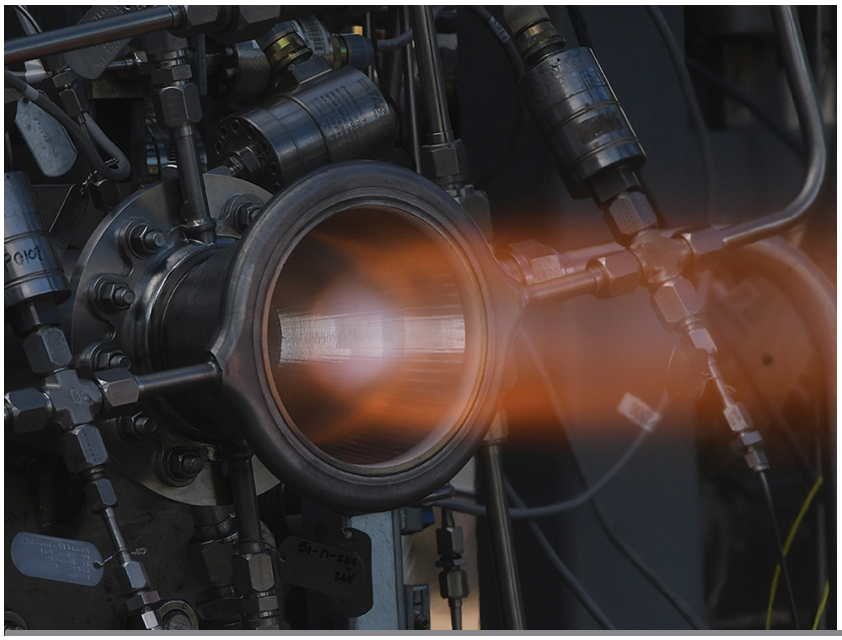


National Aeronautics and Space Administration

TECHNOLOGY SOLUTION

Manufacturing

Cladding and Freeform Deposition for Coolant Channel Closeout

A better way to manufacture combustion chambers and nozzles

Low-cost, large-scale liquid rocket engines with regeneratively cooled nozzles will enable reliable and reduced-cost access to space. Coolant, contained under high pressure, circulates through a bank of channels within the nozzle to properly cool the nozzle walls to withstand high temperatures and prevent failure. It has been a challenge to affordably manufacture and close out the intricate nozzle channels. As such, NASA developed a robust and simplified additive manufacturing technology to build the nozzle liner outer jacket to close out the channels within and contain the high-pressure coolant. The new Laser Wire Direct Closeout (LWDC) capability reduces the time to fabricate the nozzle and allows for real-time inspection during the build. One variation enables a bimetallic part (copper/super-alloy, e.g.) to help optimize material where it is needed. The manufacturing process has been demonstrated on a series of different alloys. Hot-fire testing is complete—the parts were exposed to extreme combustion chamber temperatures and pressure conditions for 1,000+ seconds. Micro-graph examination of the hot-fired test article has verified that the coolant channel closeout bonds are reliable and that there is very little deformation to the coolant channels. The picture above was taken during the hot-fire testing of a nozzle.

BENEFITS

- Proven (via hot-fire testing) to produce a reliable bond with little deformation to the channels
- Enabling bimetallic parts such as copper-inconel and other alloy combinations
- Applicable to many metals including: superalloys, stainless steel alloys, aluminum-alloys, and bimetallic (including copper-based) alloys
- Real-time inspective with visible and infrared methods
- Reduced build time from several months to several weeks
- Filler-free: no filler is needed in the cooling channels during fabrication

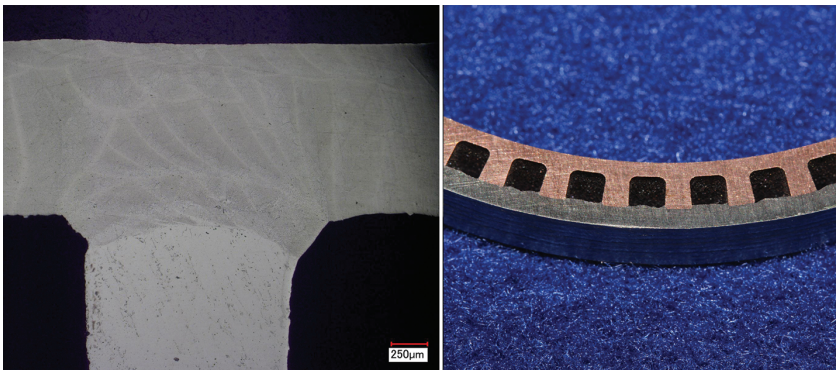
APPLICATIONS

The technology has several potential applications:

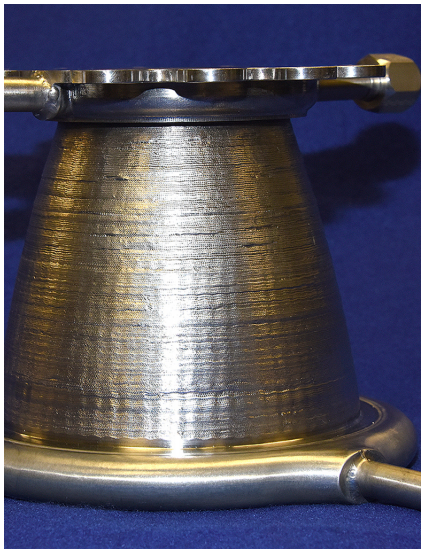
- Aerospace Propulsion: Rocket engine combustion chambers, nozzles
- Oil and Gas: Heat exchangers
- Nuclear Power: Heat exchangers

THE TECHNOLOGY

LWDC technology enables an improved channel wall nozzle with an outer liner that is fused to the inner liner to contain the coolant. It is an additive manufacturing technology that builds upon large-scale cladding techniques that have been used for many years in the oil and gas industry and in the repair industry for aerospace components. LWDC leverages wire freeform laser deposition to create features in place and to seal the coolant channels. It enables bimetallic components such as an internal copper liner with a superalloy jacket. LWDC begins when a fabricated liner made from one material, Material #1, is cladded with an interim Material #2 that sets up the base structure for channel slotting. A robotic and wire-based fused additive welding system creates a freeform shell on the outside of the liner. Building up from the base, the rotating weld head spools a bead of wire, closing out the coolant channels as the laser traverses circumferentially around the slotted liner. This creates a joint at the interface of the two materials that is reliable and repeatable. The LWDC wire and laser process is continued for each layer until the slotted liner is fully closed out without the need for any filler internal to the coolant channels. The micrograph on the left shows the quality of the bond at the interface of the channel edge and the closeout layer; on the right is a copper channel closed out with stainless.



The micrograph on the left shows the quality of the bond at the interface of the channel edge and the closeout layer; on the right is a copper channel closed out with stainless.



A scaled rocket nozzle made with the NASA process to close out the channels.

PUBLICATIONS

Patent No: 10,471,542; 9,835,114

Gradl, P. Rapid Fabrication Techniques for Liquid Rocket Channel Wall Nozzles. AIAA-2016-4771

Gradl, P.R., Brandsmeier, et.al. Manufacturing Process Developments for Large Scale Regeneratively-cooled Channel Wall Rocket Nozzles. JANNAF 9th Liquid Propulsion Subcommittee, Dec. 5-9, 2016.

Patent Pending Gradl, P., Greene, S., et.al. Hot-fire Testing and Large-scale Deposition Manufacturing Development Supporting Liquid Rocket Engine Channel Wall Nozzle Fabrication, JANNAF 10th Liquid Propulsion Subcommittee, May 21-24, 2018.

technology.nasa.gov

NASA's Technology Transfer Program pursues the widest possible applications of agency technology to benefit US citizens. Through partnerships and licensing agreements with industry, the program ensures that NASA's investments in pioneering research find secondary uses that benefit the economy, create jobs, and improve quality of life.

MFS-33232-2, MFS-33232-1, MFS-TOPS-81

More Information

National Aeronautics and Space Administration

Agency Licensing Concierge

Marshall Space Flight Center

Huntsville, AL 35812
202-358-7432
Agency-Patent-Licensing@mail.nasa.gov

www.nasa.gov

NP-2017-09-2457-HQ