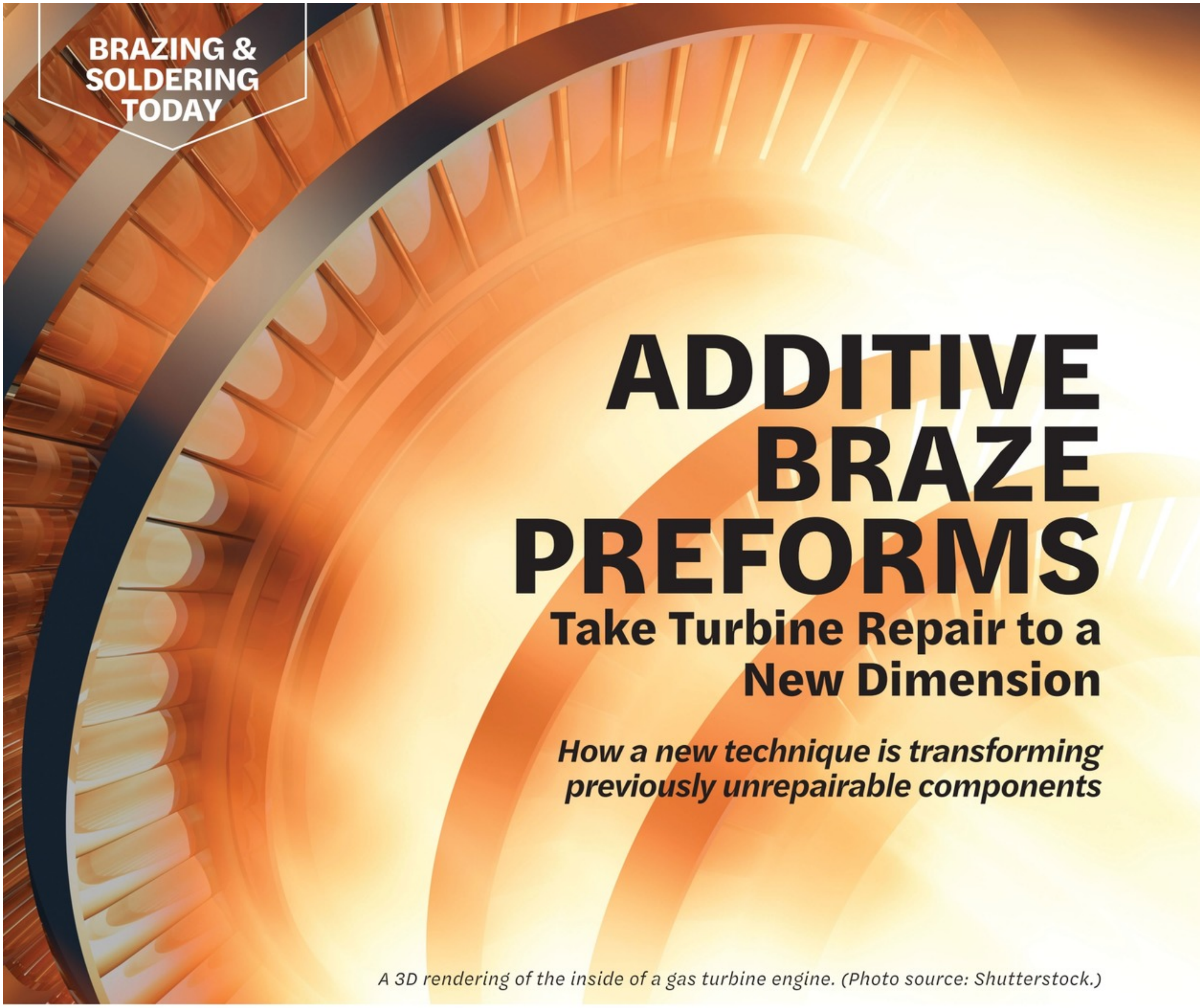


ADDITIVE BRAZE PREFORMS

Take Turbine Repair to a New Dimension

How a new technique is transforming previously unrepairable components

A 3D rendering of the inside of a gas turbine engine. (Photo source: Shutterstock.)

BY SCOTT NELSON AND JUSTIN BOREMAN

Since the development of gas turbine engines, the demand for decreased costs and increased performance has required components that can withstand higher temperatures and longer service lives.

Modern turbine components, such as nozzle guide vanes (NGVs), which are responsible for directing and harnessing the violently expanding gases from fuel combustion, are made of advanced nickel-based superalloys cast using solidification techniques, like single crystallization, and include intricate cooling features. These components are expensive to produce and are removed or repaired when damaged or after exceeding their service limits.

Wide Gap Brazing

Cracks and worn surfaces in low-stress areas have been repaired using wide gap brazing (WGB). This is a technology derived from nickel diffusion and transient liquid phase bonding, but limitations of WGB technologies have prevented many turbine components from being repaired. Due to the high component costs, used components are often stored while waiting for suitable repair development, creating large populations in warehouses and leaving operators and original equipment manufacturers with the cost to store and replace them.

A new WGB technique, developed through a partnership of Rolls-Royce, Indianapolis,Ind., and AIM MRO, Miamiville, Ohio, has brought new life to previously unrepairable turbine components, saving costs and resources.

WGB is commonly used for the maintenance, repair, and overhaul of hot section components in both aerospace and ground-based gas turbine engines. WGB filler materials consist of two primary components: a superalloy powder and a lower-melting braze powder. During a vacuum furnace brazing cycle, the braze powder constituent will melt, and melting point suppressants, such as boron and silicon, will begin to diffuse into both the component and the superalloy powder, causing an isothermal solidification, effectively creating a population of microbrazes between the superalloy powder particles and the component. As the braze cycle continues, the diffusion of the melting point suppressants ensures that a strong, thermally resistant repair is left in place without brittle eutectic intermetallic phases.

WGB methods can repair cracks with widths of up to 0.080 in. (2 mm), a significant increase compared to traditional braze joint clearances. WGB methods can also be used to restore areas worn away by fretting, erosion, and thermal mechanical fatigue.

WGB materials and processes are coordinated to control the filler alloy flow and ensure chemical compatibility. WGB balances constituent powder mixes and furnace time/temperatures to achieve the required material properties and filler flow sufficient to achieve dimensional controls. This powder mixture composition is defined by how much the alloy needs to flow to complete the repair; a crack will need more flowability and a higher percentage of braze, whereas a dimensional restoration repair will need to stay in place and have a higher percentage of superalloy powder. WGB filler materials with both proprietary and commercially available compositions are used by aerospace engine manufacturers and repair facilities internationally. WGB filler materials come in numerous forms, including slurry, paste, paints, powders, flexible sheets, and rigid (sintered) sheets, to ease application.

Rigid sintered sheets are cut into preforms known as braze sintered preforms (BSPs) or presintered preforms (PSPs). Thus far, repair limits have restricted this type of repair to small cracks and minor wear damage, leaving much of the population of damaged turbine vanes unrepairable.

Unrepairable Airfoil Damage

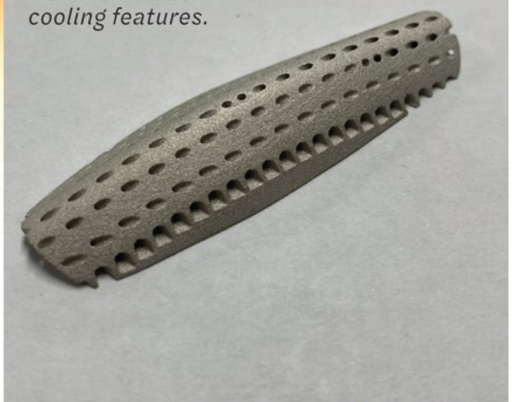
To improve operational efficiency, commercial and military operators continue to push the envelope and run combustor temperatures to the upper end of their specified limits. While this may optimize mission performance, it also results in shorter operational lives for the turbine vanes. Damage can start as a small crack that breaches the pressure side of the airfoil and allows the hot combustion products to enter the internal cooling passage and disrupt the cooling air, which results in oxidation, melting, and physical damage to the airfoil and the internal cooling structure. This type of damage has previously been unrepairable, but PSP developments made by AIM MRO and Rolls-Royce have presented a new opportunity.

The Solution

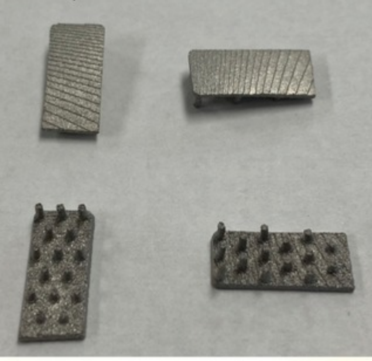
The first application of this novel PSP repair was on a single-crystal turbine NGV from the Rolls-Royce AE3007™ engine that powers many small regional and corporate airframes. This damage presented as a small hole measuring 0.4 to 1.2 in. (10 to 30 mm) in diameter with cracks radiating toward the edges and platforms of the vane; the internal cooling passages were featureless. To repair this damage, a milling tool was used to remove a specific amount of material corresponding to a preset patch preform. These patches, comprising a single-crystal-specific composition, were made using a significantly higher ratio of superalloy to prevent sagging into the internal structures during brazing. WGB paste was also used adjacent to the patch and on the radial cracks before a cover preform was added. After brazing and heat treatment, the airfoil was blended to match the required geometry. The final repaired component was returned to service, extending the usable life for most previously unrepairable parts.

Other parts provided different challenges that required an even more-novel solution. The internal cavity of the AE2100™ turbine NGV component powering the USAF C130J is an equiaxed nickel superalloy component and features sets of submillimeter pins and rails

Leading-edge 3D preform to repair an NGV with modern cooling features.



3D preforms with cooling features designed and produced for the AE2100 NGV repair.



to promote increased heat exchange and turbulate the cooling air. Damage on the airfoil resulted in a significant impact on the internal cooling geometry, leading to a loss of cooling efficiency and the potential of debris damaging components downstream. To repair this damage, AIM MRO used an additive process that produces high-resolution 3D preforms. This involved adding layers of metal powder and binder on top of each other to create the desired shape. With this capability, it was possible to design WGB patches that included complex cooling features integrated into a patch to restore both internal and external features. The 3D preform patch was brazed much like the AE3007 repair method and then blended to final configuration requirements. This method resulted in a repair that successfully met all metrics set by the program, including internal and external geometry, joint integrity, and cooling airflow. Evaluation of the repaired component showed that a controlled braze flow process, result-

An AE2100 NGV with airfoil damage, after brazing, and after blending and coating.

ing in internal air passage with complex geometries, could feasibly be repaired using 3D sintered patches.

Looking Forward

Work is still underway on the development of a new repair focused on the replacement of the leading edge of a damaged turbine vane airfoil. This repair requires complex 3D geometry and integrated cooling holes with internal cooling features. Work also continues on 3D batch and process qualification.

The successes of complex 3D WGB preforms provide opportunities for the future of WGB outside of the current repairs. Possibilities include using patches to alter material properties, repair or change cooling circuits, and manufacture or restore complex airfoils. As the engines get hotter and critical cooling pattern designs require costly processes to produce the components, repair and manufacturing technologies must keep up. The AIM MRO and Rolls-Royce cooperation has shown that 3D processing will provide the needed solutions by utilizing a balance of materials, processes, and 3D technology for both high-temperature turbine component service repair and new component manufacturing innovations. WJ

Acknowledgments

The authors were assisted by Aaron Jones as well as Dr. Ray Xu, global process owner for brazing at Rolls-Royce and an AWS Fellow, who contributed heavily to this work.

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