Cost-Effective Repairs for Turbine Vanes with Vacuum Brazing

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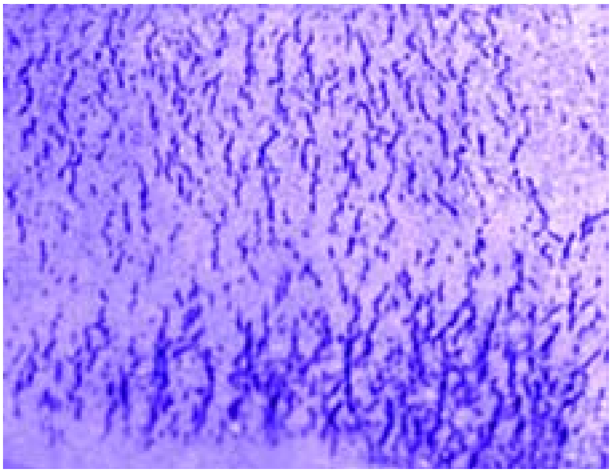
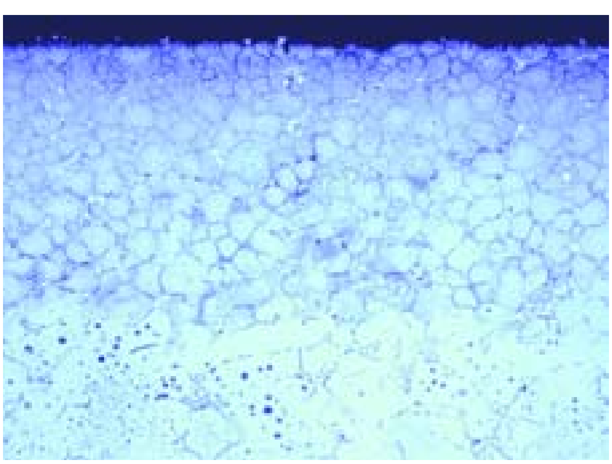
Gas turbine component damage can take many forms. Craze cracking (Fig. 1), large thermal mechanical fatigue fractures, erosion, and oxidation attack are common and are generally repaired by welding. The weld repair process is often tedious, requires highly skilled technicians, and can cause additional cracking and deformation—drawbacks that sometimes make weld repair expensive and time-consuming.
For situations where large amounts of material must be restored, a simpler and more cost-effective solution exists: the application of melting-point-suppressing materials, or braze. Sulzer Hickham has developed a new vacuum brazing process for the crack repair and surface restoration of cobalt-based superalloy components in industrial gas turbines.



1 Craze cracking, a typical form of damage occurring in IGT vanes (enlarged 40×).

Brazing, a method of joining metals and other materials by applying heat and a filler, is an alternative to welding. Although welding is a favored repair method for land-based components (especially for local restoration), when large areas must be restored due to erosion, craze cracking, etc., welding can have technical and commercial limitations. Brazing can offer a good solution in these instances.

2 Microstructure of the braze alloy specially formulated by Sulzer Hickham for use in its vacuum braze repair process (enlarged 100×).



Overcoming the Limitations of Ordinary Brazing

Most brazing alloys for high-temperature/stress applications have boron or silicon added to a material with a composition similar to that of the original component material. Boron and silicon reduce the melting temperature by several hundred degrees. Boron and silicon are therefore known as melting-point-suppressing materials. Once the braze liquefies, the boron or silicon diffuse into the base material. Unfortunately, the resulting material often lacks the ductility or oxidation/corrosion resistance of the base alloy. Improvements in Sulzer Hickham's brazing process have overcome many of these problems by the addition of a powdered form of the base alloy itself.

Furthermore, oxide scales and other impurities that form during service on the surface of a material will lower the quality and performance of a braze process by impeding the wettability (the ability to flow) and diffusion of the braze. Therefore, these surface contaminates must be completely removed prior to application.

Sulzer Hickham has introduced a brazing technology that has overcome the negative qualities of earlier brazing processes such as the consequences of insufficient cleaning and the inability to perform subsequent repairs on the components after the first braze repair. This new technology is based on a unique cleaning process combined with a brazing material that has a similar composition and properties to the cobalt-based material. The repair result displays better properties than those obtained using weld fillers. Additionally, this technology allows for the repair of parts previously considered irreparable using traditional processes.

Development of the Materials and Process

A proprietary cobalt-based alloy braze filler (Fig. 2) was specially formulated by Sulzer Hickham to complement most common cobalt-based alloys used in stationary turbine materials, e.g., FSX 414, ECY 768, and X 45. The braze material can be applied by brush, in tape form, or by spraying. After applying the braze material, an ultrahigh vacuum ($<10^{-4}$ torr) brazing cycle is performed. The heat treatment is designed to ensure that the melting point after

3 Microstructure of a simulated repair weld following stress relief heat treatment (enlarged 50×, unetched).

diffusion is well over 1200 °C (2200 °F), which ensures that it is higher than the firing temperature of the turbine. This adaptation makes vacuum brazing suitable for high-temperature components and improves the subsequent weldability of the components.

As part of the initial qualification, hundreds of specimens were processed and tested. Evaluation included examination of the material's microstructure, as well as hardness, impact and tensile strength, and weldability testing. Hardness traverses were conducted on brazed ECY 768 cross sec-

Typical compositions of common cobalt-based alloys (wt. %, balance Cobalt)

	X 45	FSX 414	ECY 768	L 605	H 188
Carbon	0.25	0.25	0.6	0.1	0.1
Nickel	10	10	10	10	22
Chromium	25.5	29	22	20	22
Iron		1		<3	<3
Tantalum			3.5		
Tungsten	7.0	7.5	7	15	14.5

tions before (diffusion heat-treated) and after aging (fully heat-treated). Once fully heat-treated, no significant hardness difference was found between the braze filler, interdiffusion zone, and base material. A typical hardness range for ECY 768 is 24–34 HRC in the fully heat-treated condition, and the braze material fell well within those values.

The impact toughness of the braze filler was determined by applying braze to one side of an ECY 768 plate, machining specimens, and testing, unnotched at room temperature. Impact loading was applied to the brazed surface. Each of the specimens with braze filler applied outperformed the base alloy reference samples.

Stress rupture properties, a significant factor in any repair, were evaluated by fabricating test specimens of half base alloy and half braze filler. Two base materials were used: ECY 768 and FSX 414. Rupture strength and ductility were found to be comparable to or better than those of most of the common base alloy materials.

The weldability tests consisted of applying several weld beads over areas that had been brazed. Weld parameters, technique, and welding filler alloy were the same as those used during a typical weld repair (Fig. 3). The weldments were inspected by various methods immediately following welding and after stress-relieving heat treatment. The welds, braze, and base material had no defects in either condition.

Metallographic examination of the repaired areas of actual components showed that all cracking had been completely penetrated by the braze material. Also, the built-up material was free of inclusions and other impurities. Porosity levels were similar to those in the base alloy itself. For more critical applications, hot isostatic pressing can eliminate porosity in the braze material.

Successful Results

Over the last four years, countless numbers of turbine components have been successfully refurbished using this technique (Fig. 4), and the process has proven to be a sensible addition to Sulzer Hickham's service portfolio. Most importantly, Sulzer Hickham's customers have been delighted by the improvements in delivery, quality, and cost value resulting from this new process development. ◄

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4 Before and after images of a vacuum braze repair performed by Sulzer Hickham. Gas turbine nozzle prior to repair (left) and the same gas turbine nozzle after repair (right).