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BRAZE REPAIR REACHES NEW HEIGHTS

Want to know the latest, most innovative methods for extending the life of gas turbine engine components? Read on.

BY ZENGMEI KOENIGSMANN

The evolution in gas turbine engine design, component design and the materials used to produce today’s engines has resulted in ever more reliable, fuel efficient and higher thrust power systems for aircraft. Advancements in today’s jet engines also have spawned the parallel development of new repairs to restore the critical turbine engine components in these high performance systems.

In the gas turbine engine — an extreme environment that subject components to very high temperatures for extended periods — all parts are carefully monitored for routine or unplanned wear during operation and scheduled maintenance events.

Federal Aviation Administration (FAA) approved repairs are an alternative to replacing components when the life cycle of the part allows it — i.e., many components in the hot section or gas path of a turbine engine may be repaired for a specific number of times during maintenance events before FAA guidelines require the part to be replaced.

From an operator cost perspective — whether a commercial or military aircraft operator — refurbishing or repairing engine components can significantly reduce part replacement costs and return savings to the maintenance operation.

Successful implementation of a new repair, however, requires a multi-disciplinary understanding of the materials, design and processing technologies that are critical to the proper functioning of the part. A detailed understanding of metallurgical and physical properties of the component alloys during the repair is essential.

Using this approach, a new braze repair was developed for the life extension of advanced turbine engine parts that are made of Ni-based single crystal alloys. The repair developed by Chromalloy was approved by the FAA in 2005 and utilized by a commercial airline for five years.

A review of the data from five years of engine service performance of the repaired high pressure turbine part by the airline shows the braze repair to be extremely effective.

Longer Life at Constant Stress
Chromalloy, a turbine engine services provider, has offered airlines and military aircraft operators advanced repairs for hot section engine components for several decades. The company’s new component repairs paralleled new engine development and similarly evolved over the years to include today’s materials and superalloys. In addition to repairs, Chromalloy also serves the industry with advanced thermal barrier coatings and with the manufacture of new replacement parts for many of the aircraft engines on today’s commercial jetliners.

High temperature vacuum diffusion braze, a metal joining method operating in at least 1 ×10-4 torr or 0.1 micron level vacuum environment and at a temperature of above 2000 degrees F, is a common industry practice used to repair cracks and surface erosion of engine-run high pressure turbine parts, as it introduces less thermal stress and distortion as compared to welding methods.

This technique uses a component alloy based filler material, which contains a rapidly diffusing melting point depressant such as boron. Upon brazing at an adequate high temperature for the duration time, the braze filler first melts and then solidifies isothermally through the boron diffusion from the liquid braze alloy into the adjacent solid component alloy. Fully isothermal solidified braze joints exhibit similar properties to the component base alloy. It has been well established for their superior strength and creep resistance at high temperatures. The material creep resistance is the resistance to a time dependent permanent deformation or distortion induced by a stress at a temperature close to the material melting temperature.

These alloys are used extensively in the manufacture of today’s advanced jet engines, particularly in the high pressure turbine parts. Because there are no grain boundaries in the single crystal alloy, the strength properties of these single crystal alloys primarily depend on the alloy microstructure characteristics such as primary gamma prime precipitates size and their volume fraction.

An optimal microstructure is therefore very critical for single crystal alloys, and it is normally produced by carefully controlled processing technologies that are critical to the proper functioning of the part. A detailed understanding of metallurgical and physical properties of the component alloys during the repair is essential.

Figure 1 Creep properties in the Larson-Miller plot for four types of thermal processed PWA 1484 equivalent samples. The original alloy is presented as condition-0; the samples processed with the new Ni braze repair are presented as condition-1; the samples processed with traditional braze repairs are as conditions-2 &-3. Δt, ΔT or Δσ indicate the differences in time, temperature or stress. At high temperature and low stress state, comparing with condition-0, condition-1 has a significant advantage while conditions-2 & -3 exhibit debits.
heat treatments. However, this unique nature of these alloys presents challenges during diffusion braze repairing of the single crystal alloy parts. The heat treatments for producing a good joint often result in an irreversible microstructure alteration in the single crystal alloys thus in turn modifies the original alloy properties. This alloy microstructure alteration primarily reduces the alloy creep resistance significantly, which cannot be easily recovered by any further possible treatments. During the testing, it was found that the commonly practiced braze thermal treatments employed in traditional Ni brazes induce such alloy microstructure alterations and therefore result in irreversible creep property degradations in Ni-based single crystal alloy parts.

For repairing Ni-based single crystal alloy components, such as PWA 1484 alloy components, a new braze repair was developed that not only provides a good brazed joint property but also preserves the part alloy properties. As illustrated in Figure 1, the PWA 1484 equivalent alloy sample creep properties in four types of thermal possess conditions — i.e., the original alloy condition, the new braze repair and the traditional brazed repairs, are compared in a Larson-Miller plot. At a high temperature and low stress state that is close to the engine operation condition, the new braze repair has a significant advantage over the two types of current braze repairs. The new braze repaired alloy is stronger at a constant temperature or can experience higher temperature and has a longer life at a constant stress. A high melting temperature filler with a good wetting and bonding properties verified by metallurgical assessments was also defined for this repair in order to increase the high temperature capability of one repaired part.

Metallurgical evaluations confirmed the part alloy properties are preserved based on the similarity of the part alloy microstructures of the prior to and after the braze repair (See Figure 2).

Good Engine Service Performance

The first application of the developed braze repair was to the PW2000 high pressure turbine first stage duct segments that are made of Ni-based single crystal PWA 1484 alloy. More than 200 engine sets of the PW2000 HPT first stage duct segments have been successfully refurbished since 2005 with this new braze repair that goes beyond the engine manual repairs. The manufacturer does not offer a braze repair. One commercial airline utilized the repairs — and the engine service experience reports from the operating airlines showed positive feedback on the repair. Detailed evaluations on the repaired and engine service duct segments were performed on two engine sets. After the engine service, the distress shown on the repaired segments is better than that of seen on the OEM segments. The Chromalloy repaired segments were more durable with a low level distress (i.e., 1 or 2) than the OEM segments after about 5000 engine cycles (see Figure 3). In addition to the new braze repair, a Chromalloy advanced abradable thermal barrier coating system was also included in the repair package for this segment. The application of the TBC further warrants the brazed joint integrity and may also slow down the component alloy degradation rate during engine operation. Figure 4 shows that with a sufficient thermal barrier coating protection, the original braze sealed micro-cracks remain closed after the engine service. Overall, the new braze repair has been proven to be effective on the component life extension by providing a good brazed joint and at the same time preserving the original component alloy properties.

A Viable Alternative

Aircraft operators routinely examine their engine serviced component evaluations: (a) An engine serviced segment that was previously repaired by the new braze process; and (b) Cross section plane at the center gas path shows a previous brazed crack remains closed during the engine service.

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Two Engine Sets. After the engine service, the distress shown on the repaired segments is better than that of seen on the OEM segments. The Chromalloy repaired segments were more durable with a low level distress (i.e., 1 or 2) than the OEM segments after about 5000 engine cycles (see Figure 3). In addition to the new braze repair, a Chromalloy advanced abradable thermal barrier coating system was also included in the repair package for this segment. The application of the TBC further warrants the brazed joint integrity and may also slow down the component alloy degradation rate during engine operation. Figure 4 shows that with a sufficient thermal barrier coating protection, the original braze sealed micro-cracks remain closed after the engine service. Overall, the new braze repair has been proven to be effective on the component life extension by providing a good brazed joint and at the same time preserving the original component alloy properties.

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Chromalloy® repairs extend the life of your gas turbine engine and reduce operating expenses. We partner with our customers to develop and deliver innovative repair solutions for your entire engine that combine proprietary repair processes and leading-edge equipment, with the world’s most advanced technology in coatings and manufacturing. This adds value and longevity to your components. And it’s the reason we’re trusted by the world’s leading airlines and armed forces for safety, precision and reliability. It’s innovation that makes an impact — and it’s only from Chromalloy.

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