Removing Turbine Component Coatings Without Damage

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Superalloy components require coating systems to protect base metals from the extraordinary operating environments of gas turbines. These tenacious coatings are designed to resist the oxidation and corrosion created by the combustion process in the turbine hot gas path. But these coatings also resist removal when they become depleted during operation.

Most modern hot gas path coatings consist of a ceramic thermal barrier coating (TBC) on the outer surface and a "bond" coat between this TBC and the base metal. Typically, acid stripping and grit blasting of these bond coatings from superalloy components can cause both metallurgical and dimensional damage.

Acid stripping and grit blasting of molybdenum, chrome, aluminum and yitterbium (MCrAlY) bond coatings from vanes, blades, shrouds, liners and transition pieces are destructive processes. Exposure to acid can result in stress corrosion cracking, pitting and alloy depletion. Grit blasting can result in uneven material removal and thinning of the base metal. Then there are the environmental issues that are becoming increasingly important.

A precision abrasive waterjet (AWJ) process can be more cost-effective than traditional acid stripping and grit blasting and the process gently removes the coating without compromising the base metal integrity. There is no inter-granular attack with the AWJ process. It's a clean and efficient method to remove MCrAlY coatings from hot gas path components and the process can be repeated.

Acid Stripping and Grit Blasting

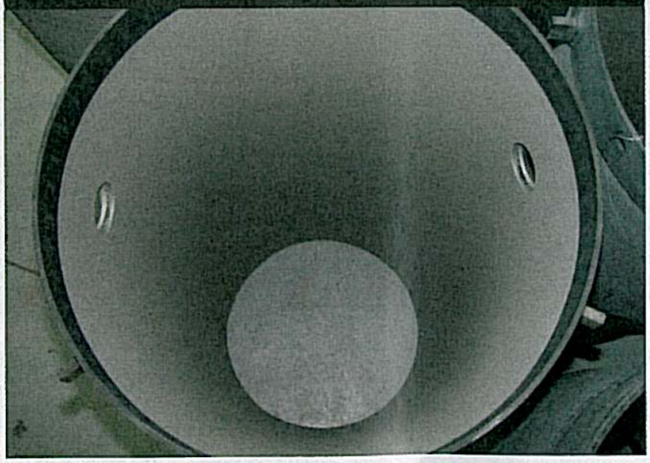
One of the problems with acid stripping is intergranular attack (IGA). Many original equipment manufacturers (OEMs) and users limit part repairs to one cycle because of IGA. Acid stripping can also leave smut that can contaminate the interface. Acid requires masking to avoid removing the internal coatings and subsequent unmasking. A poor mask can destroy internals and the part may have to be scrapped. Because acid stripping is a batch-lot process, sometimes a whole group of industrial gas turbine (IGT) parts are damaged because of acid variability.

Acid attacks braze from previous repairs, reducing part life and the number of repair cycles, which can add to total operational costs. Braze metal in brazed joints can be attacked due to the difference in material composition and porosity. Braze tends to absorb the acid, making it difficult to remove, and then acid attack occurs. When acid stripping does not evenly or uniformly remove the bond coat, parts require subsequent hand-processing to clean up, adding more labor cost.

Control of the acid bath requires close monitoring. The process is "dynamic" and the chemistry of the bath is constantly changing due to the part/acid reactions and losses due to evaporation. Internal cavities and areas such as the highly stressed blade root must be protected from strong acids.

FIGURE 1 BEFORE

FIGURE 1 AFTER COATINGS REMOVED WITH THE AWJ PROCESS.



Environmental issues must also be factored in. In some applications, superalloys contain materials such as chromium and similar heavy elements, materials that become toxic when put into solution. Personal exposure limits have recently been lowered by the Environmental Protection Agency to lessen the probability of long-term health issues due to exposure to such materials.

Because of shortcomings in the acid stripping process, a grit blast process follows, which also has drawbacks.

Grit blasting is a hand-held operation, often carried out by the plant's least-trained personnel, and is the least-controlled of all repair processes, yet in many cases the most pervasively used. The coating and the base metal are both gray metallic in coloring, which makes it hard to distinguish the coating to be removed from the base metal. As a result, grit blasting can result in uneven material removal and thinning of the base metal.

Grit-blast guns use coarse grit that breaks down to finer grit during a typical liner blasting, leaving a dirty residue. The gun may be hard to insert by hand into a liner, for example, while still being able to hold any consistent tolerance, especially when the color difference between the coating and the base metal is not apparent.

The results of grit blasting can be uneven removal and distortion of geometry, plus surface contamination with aluminum oxide (ALOX). Alumina contamination negatively affects the tensile bond integrity.

Most turbine manufacturers control the amount of contamination in the interface between the coating and the substrate. Because of incomplete bond coat removal, and contaminated surfaces, patches and even sheets of coatings have come off in initial service, or long before normal warranty outages. Sometimes coatings come off as they are applied, causing a rework level as high as 40 percent. Worse, many repair processes call for additional grit blasting if residual grit is found at fluorescent particle inspection, and more grit perpetuates the problem.

An Alternate Process

Precision abrasive waterjet processing (AWJ) is an environmentally friendly process that removes coatings without damaging the turbine component, which can lower costs.

A five-axis computer numerically controlled (CNC) AWJ removes the coating in iterative steps. The process behaves like a machine tool, with material removal rates controlled by speeds, feeds, pressures and material flow.

Since coating thicknesses naturally vary, an X-ray fluorescent device reports elements like Yttrium that decline in intensity as the base metal is approached. With this type of process control, it is sometimes possible to realize additional repair cycles in some components due to minimal damage to the substrate.

The CNC process offers certain advantages. It is a controlled mechanical removal process, like a surface milling process with tight tolerance control. It doesn't put chrome into solution, like acid. The machine can hold positional tolerance to less than .0005 inch. The waterjet stream is controlled to a specific distance from the surface, with feed and speed controlled by software that, for example, keeps the offset normal over the entire form of a blade. Coating thickness is measured before and after the AWJ to insure full removal of the bond coating and diffusion layer, as well as any contamination or corrosion and under the bond coat.

The process can remove craze cracking and deep cracks better than fluoride ion cleaning. The remaining surface is also cleaned of all surface contamination and in some cases shows directionally solidified (DS) grain structure and DS etching.

Many companies using this method then bag the part and send it directly to coating. Grit blasting re-contaminates the surface and destroys the bond interface. Process controls are in place to measure before and after conditions to verify removal over the surfaces where it is desired. Because of the CNC processing, single part flow occurs that beneficially reduces risk of batch-lot errors. Actual part processing time is much less than acid and grit blast, at usually lower total costs.

The AWJ process can remove the TBC and bond coat in one process. While grit blasting of TBC and bond coating in some cases may be slightly lower in cost, when lower service life and reduced repair cycles are factored in, a higher total expense may result. pe