Abrasive Waterjet Coating Removal: Efficient and Cost-Effective

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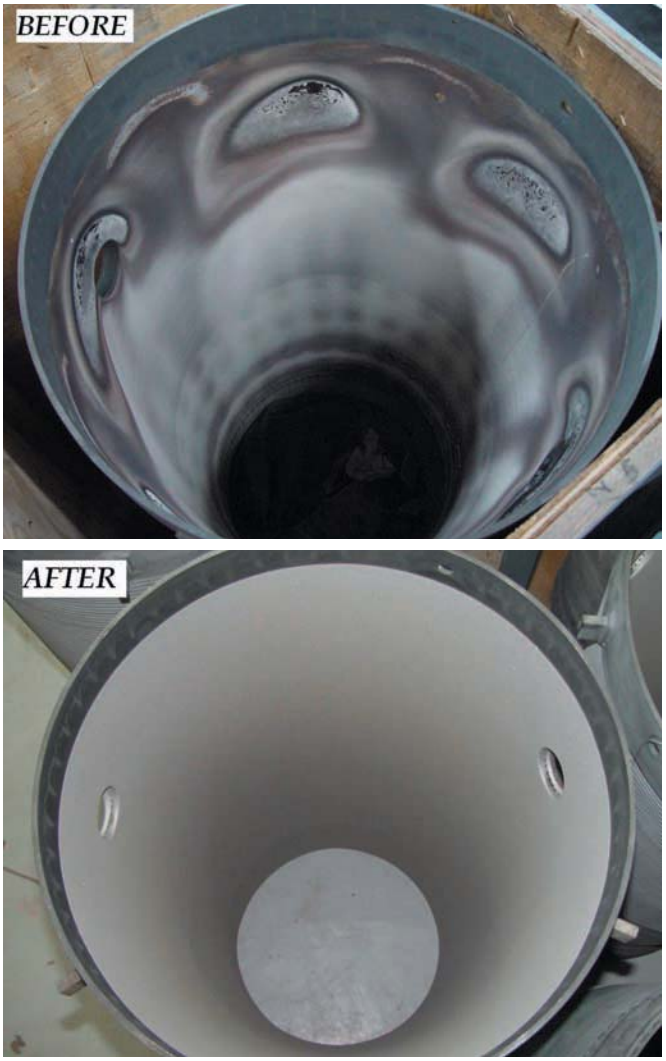
Superalloy components require coating systems to protect the base metal from the harsh operating environments of gas turbines. The tenacious coatings are designed to resist oxidation and corrosion created by the combustion process in the turbine hot gas path. These same coating characteristics make it difficult to remove the coatings after service to refurbish the parts. Most advanced hot gas-path coatings consist of a ceramic thermal barrier coating (TBC) on the outer surface and a bond coat between the TBC and base metal. Typically, acid stripping and grit blasting of the bond coatings from superalloy components can cause metallurgical and dimensional damage.

Acid stripping and grit blasting of 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, while grit blasting can result in uneven material removal and thinning of the base metal. In addition, there are environmental issues that are becoming increasingly important.

By comparison, a precision abrasive waterjet (AWJ) process developed and patented (US 6,905,396) by Huffman Corporation in conjunction with Springfield Manufacturing LLC gently removes the coating without compromising base-metal integrity; there are no intergranular-attack (IGA) or other issues with the process. The AWJ process provides a clean, efficient, repeatable process for removing MCrAlY coatings from hot gas-path components. The environmentally friendly process is gaining momentum as the preferred method to remove coatings from turbine components without damaging them and to lower costs.



The abrasive waterjet (AWJ) process cleans coatings from aerospace and industrial gas turbine parts better than acid stripping and grit blasting, extending useful part life and lowering total cost; liner before AWJ cleaning (top); after AWJ cleaning (bottom).

Acid-Stripping Issues

Problems from acid stripping include IGA and leftover smut that contaminates the interface. Many OEMs and users limit part repairs to one cycle because of IGA. Acid stripping requires masking to avoid removing internal coatings, and then the masking must be removed—an expensive step that adds no value. Also, a poor mask can destroy internals and scrap the part. Acid stripping is a batch lot process, and it is not unusual to find industrial gas turbine parts damaged due to acid variability.

Acid attacks braze material from previous repairs, reducing part life and adding to the total cost of an operation. Brazed joints are often attacked due to the difference in material composition and porosity in the braze. This tends to absorb the acid making it difficult to remove and resulting in acid attack.

Acid stripping also does not evenly or uniformly remove the bond coat. Thus, parts require subsequent hand processing to clean up, adding more labor cost.

Internal cavities and areas such as the highly stressed blade root must be protected from strong acids. Control of the acid bath requires close monitoring because the process is dynamic, and the chemistry of the bath is constantly changing due to the part/acid reactions and losses due to evaporation. There also are environmental issues and costs to factor in.

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Both aerospace and industrial applications are particularly vulnerable since the superalloys used in the parts contain chromium and other heavy elements, which, when they go into solution, become toxic in nature. Personal Exposure Limits have recently been lowered by the U.S. Environmental Protection Agency (EPA) to lessen the probability of long-term health issues due to exposure to such materials. Because of issues associated with the acid stripping process, a grit blast process usually follows.

One result of acid stripping is intergranular attack.

Grit Blasting Issues

Grit blasting using aluminum oxide has drawbacks. It is a manual, unskilled operation, and, while used on a wide scale, it is the least controlled of all repair processes.

Grit blasting can result in uneven material removal and thinning of the base metal. The coating and the base metal are similar in color (gray metallic), which makes it hard to distinguish the coating to be removed from the base metal. A hand-held grit blast operation typically results in uneven removal. Grit-blast guns use coarse grit that breaks down to finer grit during a typical liner blasting operation leaving a dirty residue. The gun is difficult to insert by hand into a liner, for example, and still be able to maintain any consistent tolerance, especially when the color difference between the coating and the base metal is not apparent.

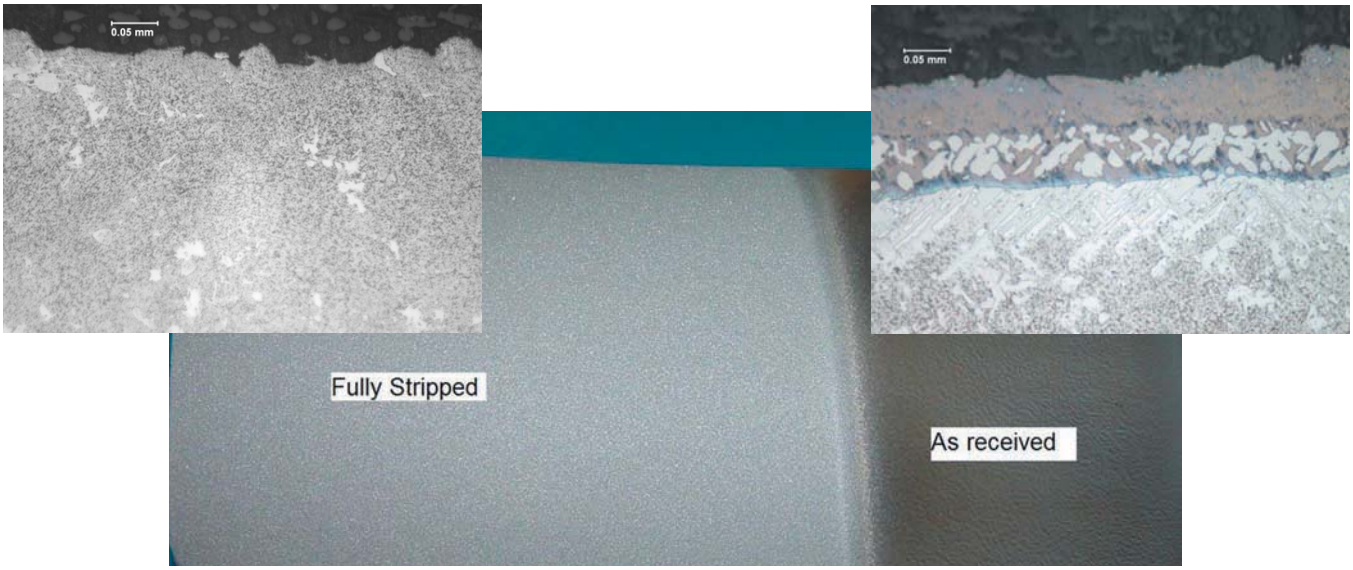
Besides contaminating the surface interface with aluminum oxide, grit blasting results in uneven coating removal and shape distortion. Most turbine manufacturers control the amount of contamination in the interface between the coating and the substrate. Alumina contamination negatively impacts tensile bond integrity. Because of incomplete bond coat removal, and contaminated surfaces, patches and even "sheets" of coatings are known to come off (spall) in initial service, or long before normal warranty service. Sometimes, coatings spall as they are applied causing as high as 40% rework. Worse, many repair processes call for additional grit blasting if residual grit is found during fluorescent particle inspection, which extends the problem.

Abrasive Waterjet Processing Offers a Solution

Precision abrasive waterjet (AWJ) processing is an environmentally friendly process that removes coatings without damaging the turbine component while lowering total costs. A precision five-axis computer numerically controlled (CNC) abrasive waterjet removes the coating in iterative steps. The process functions like a machine tool with material removal rates being controlled by speeds, feeds, pressures, and material flow.

Since coating thicknesses vary, an X-ray fluorescent instrument is used to measure the content of elements in the coating, such as yttrium, which 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 has many advantages. It is a highly controlled mechanical removal process—a surface milling-type process with tight tolerance control. The machine can hold a position tolerance of less than 0.0005 in. The waterjet stream is controlled to a specific distance from the surface, with feed and speed controlled by software that keep the offset normal to the surface over the entire shape of a blade, for example. Coating



Abrasive waterjet cleaning delivers precise results by means of CNC control at a lower total cost using an environmentally friendly (green) process; fully stripped part (left); as-received part (right).

thickness is measured before, during, and after AWJ processing to ensure full removal of the bond coat and diffusion layer, as well as any contamination, corrosion, etc., under the bond coat. The process can remove craze cracking and deep cracks better than fluoride ion cleaning.

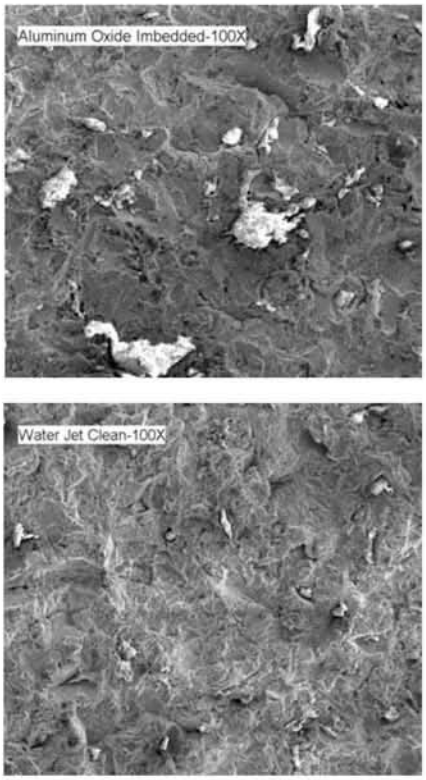
The remaining surface is cleaned of all surface contamination, and in some cases shows the directionally solidified grain structure. Most companies using the method bag the part and send it directly to coating. Process controls are in place to measure part condition before and after cleaning to verify removal over the surfaces where it is desired.

CNC processing single parts reduces the risk of batch-lot errors. Part processing time is much less than for acid stripping and grit blast, and usually at lower total cost. The AWJ process can remove the TBC and bond coat in one process. The cost of grit blasting of TBC and bond coat in some cases may be slightly lower, but at a higher total cost due to lower service life and reduced repair cycles.

The system uses Six Sigma methodology, eliminating the human variable found in hand grit blasting. Run charts can be generated, and all process parameters are controlled by the CNC control system. The high-pressure water prevents entrapment of the abrasive in the material, so the part is much cleaner than a grit-blasted part. Parts can often be coated after waterjet processing without requiring an aggressive grit blast process, which speeds up the repair process.

The process has undergone extensive scrutiny, qualification, and approval by users, independent service providers, and OEMs over the past five years, resulting in increasing use to strip parts including blades (buckets), vanes (nozzles), liners, transition pieces, and shrouds. iTSSe

For more information: Contact Huffman Corporation (www.huffmancorp.com) or Springfield Manufacturing LLC (www.springfieldmfgllc.com).



Surface contamination after grit blasting (top), and a clean surface after abrasive waterjet cleaning (bottom).