A special prebraze cleaning process called fluoride ion cleaning was developed to remove complex Ti and Al oxides from superalloys used in gas turbines because conventional cleaning processes like hydrogen cleaning (bright annealing) are unable to remove them for effective brazing.

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Some base metals and components, such as stainless steels and Co- and Ni-base superalloys used in land-based and aerospace turbine blades and vanes, require special methods to prepare the surface prior to brazing. These methods include vacuum cleaning, hydrogen partial pressure cleaning, and fluoride ion cleaning (FIC). Conventional processes such as hydrogen cleaning were effective for a wide range of stainless steels, cobalt- and nickel-base alloys. However, hydrogen is not very effective on alloys containing significant amounts of aluminum and titanium. These two metals severely oxidize to form complex spinels on hardware surfaces that penetrate deeply into existing cracks.

Only cleaning methods using the fluoride-ion technique are currently capable of removing these deeply imbedded oxides. FIC is a process that can prepare gas-turbine components for braze repair by removing oxides present on parts that have been in service. Once the oxides have been removed, the surface and cracks can be braze repaired with excellent results.

What is FIC?
Fluoride ion cleaning, synonymous with hydrogen fluoride (HF) ion cleaning, has been proven to be a highly effective process for the removal of deeply embedded oxides from superalloys containing significant amounts of aluminum and titanium. It was developed by a major jet-engine manufacturer as a cost effective repair process for nickel-base airfoil components such as turbine blades and vanes. Today it is widely used to pre-
pare cobalt- and nickel-base superalloys for braze repair/activated diffusion healing (ADH) on jet engines and industrial gas turbines.

FIC is a vacuum/thermal/chemical process that operates in a pressure and temperature range of 100 torr (133 mbar) to atmospheric and 1750 to 1900°F (955 to 1040°C), respectively, using HF (anhydrous hydrogen fluoride) gas, which must be precisely metered during the process. FIC utilizing HF gas offers a more precise and consistent alternative to other more complex techniques. The process attacks deeply imbedded oxides (surface and cracks) through the following reactions:

\[
6 \text{HF} + \text{Al}_2\text{O}_3 \rightarrow 2 \text{AlF}_3 + 3 \text{H}_2\text{O} \\
4 \text{HF} + \text{TiO}_2 \rightarrow \text{TiF}_4 + 2 \text{H}_2\text{O} \\
6 \text{HF} + \text{Cr}_2\text{O}_3 \rightarrow 2 \text{CrF}_2 + \text{F}_2 + 3 \text{H}_2\text{O}
\]

Vacuum/partial pressure increases effectiveness for removal of oxides from cracks and inside of cooling passages. HF gas is forced into voids and cracks, and lower pressure helps boil off oxides illustrated by the reactions:

\[
6 \text{HF} + 2\text{Al} \rightarrow 2\text{AlF}_3 + 3\text{H}_2 \\
8 \text{HF} + 2\text{Ti} \rightarrow 2\text{TiF}_4 + 4\text{H}_2
\]

The depletion reaction is a function of temperature, concentration of HF, and alloy composition. Surface depletion of Ti and Al also occurs.

FIC is a cost-effective, repeatable process. The generation of HF is independent of the part process temperature and is not a secondary reaction. HF concentration, cleaning time, pressure and temperature are independent process variables. In addition, the process offers reliable off-gas management, and process residuals are neutralized for easy disposal.

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