

Improved Operation with Modified Gas Turbine Parts

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The overhaul of gas turbines and the repair of gas turbine hot-section components offer excellent opportunities to verify the condition of components. In the past years, many improvements in gas turbine components have been proposed and executed in this way. As a case study for component repair and the improvement of component design, Sulzer Elbar, a company of the Sulzer Turbomachinery Services division, examined and modified a second-stage single vane segment. After 24,000 hours of operation, the modified component showed considerably higher ductility and less corrosion than the original part.

Components, particularly previously repaired components, often exhibit serious problems during the execution of weld repairs. Sulzer Elbar examined several sets of components that had been repaired at overhaul intervals of 24,000 hours each. A metallographic analysis of the vanes showed that the cause of these problems was an irreversible degeneration of the base material. Further analysis revealed that the base material, Inconel® 939, was very sensitive to internal nitridation and oxidation at the high metal temperature that was present in the affected areas of this component. These factors considerably reduce ductility and creep resistance in the affected areas. Both aluminum oxide and titanium nitride (present in the component) are extremely stable and cannot be reduced or removed by any practical treatment. The original design showed high temperature variations between the vanes. Diffusion is temperature-dependant; a metal tempera-

ture in the range of 900 to 950 °C produces an attack of 400 µm depth in 40,000 operating hours. At 850 °C, hardly any attack will be noticed in the same period of time.

Original Component Design

The component was a hollow-cast guide vane. The wall thickness at the trailing edge was about 1 mm. A metallographic sample of the cross section of the trailing edge (Fig. 1) showed that both the inner and outer surfaces were deeply corroded. The degeneration was limited to a large, crescent-shaped area of the trailing edge; at midspan, up to half of the chord length was affected.

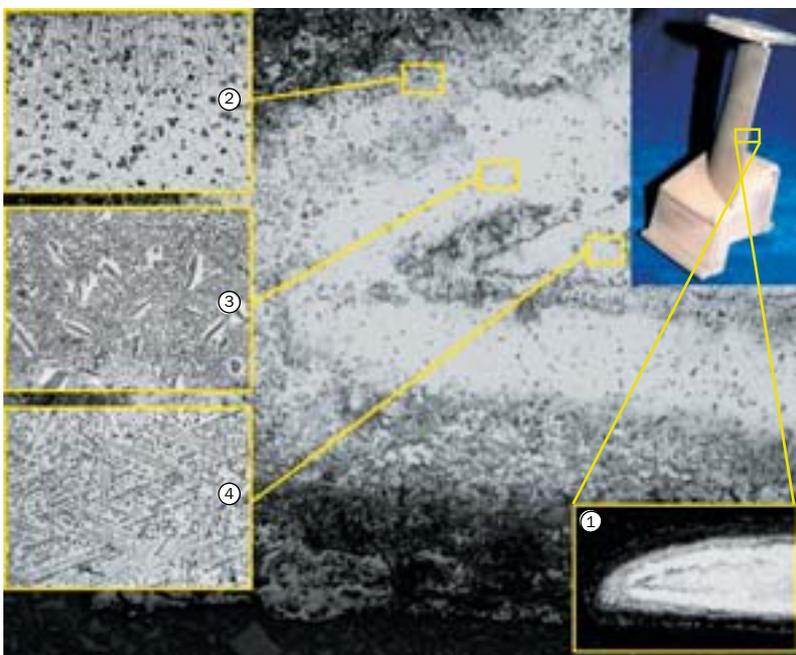
Modifications to the Vane Segment

Such extensive repair was necessary that the recommended course of action was to replace the entire airfoil, rather than just a part of it. A revised design was created, which incorporated the following changes:

- ▶ Wall thickness of the airfoil was increased to 2.0 mm.
- ▶ The cooling air exit openings were separated by relatively wide and long connecting pillars to assure ample temperature homogenization between the walls of the pressure side and suction side.
- ▶ Available cooling air was redistributed for more effective usage in the component.
- ▶ Inconel 738 LC was used as a base material because of its proven long-term stability instead of Inconel 939.
- ▶ A chromium-aluminum diffusion coating was applied to further increase oxidation resistance.

Successful Operation

Neither during the commissioning nor during the next 24,000 hours of operation were any deviations from normal noticed. Power, efficiency, and outlet temperature distribution showed no deviations. Boroscopic inspections at regular intervals revealed no unusual findings. The planned service of the turbine thus took place at the intended regular maintenance interval. After 24,000 operating hours, the modified component exhibited substantially reduced attack except for a few confined and



- ① Cross section through the suction side at the trailing edge (at the pitch diameter)
- ② Oxides
- ③ Nitrides
- ④ σ-Phase

1 Components often exhibit serious problems during the execution of repairs. Close examination at high magnification reveals an irreversible embrittlement by the formation of oxides and nitrides.



2 After 24,000 hours of operation, the modified turbine component supplied by Sulzer Elbar revealed relatively low alloy degeneration, as shown by the formation of the red-brick colored iron oxide.

easily repairable areas where the rate of attack was similar to the original part.

Lower Temperatures and Less Oxidation

Most of the vane surfaces showed a red-brick color (iron oxide) that indicates a moderately low material temperature; at such temperature, alloy degeneration is low (Fig. 2). In the center of the airfoils, light and dark greenish discoloration in varying intensity could be discerned. These colors indicated progressively higher metal tem-

peratures. Contrary to those of the original design, only few of the trailing edges showed indications of elevated metal temperature.

Higher Ductility

One of the most clearly discolored vanes was sectioned for destructive evaluation. The metallurgical inspection revealed the depth and type of the surface attack and degeneration of the base material. The base material was evaluated by checking size and distribution of γ' -phases and carbides (Fig. 3). Continuous segregation of phases (along the grain boundaries and around primary carbides) in the center part of the airfoil, especially the leading edge and the trailing edge, indicated that these components had been operating at up to 925 °C. This type of degeneration can be almost fully restored by heat treatment; therefore, it should not be considered damage as such. In contrast to the original component, no σ -phases had developed; thus the ductility of the base material had remained higher than that of the original component.

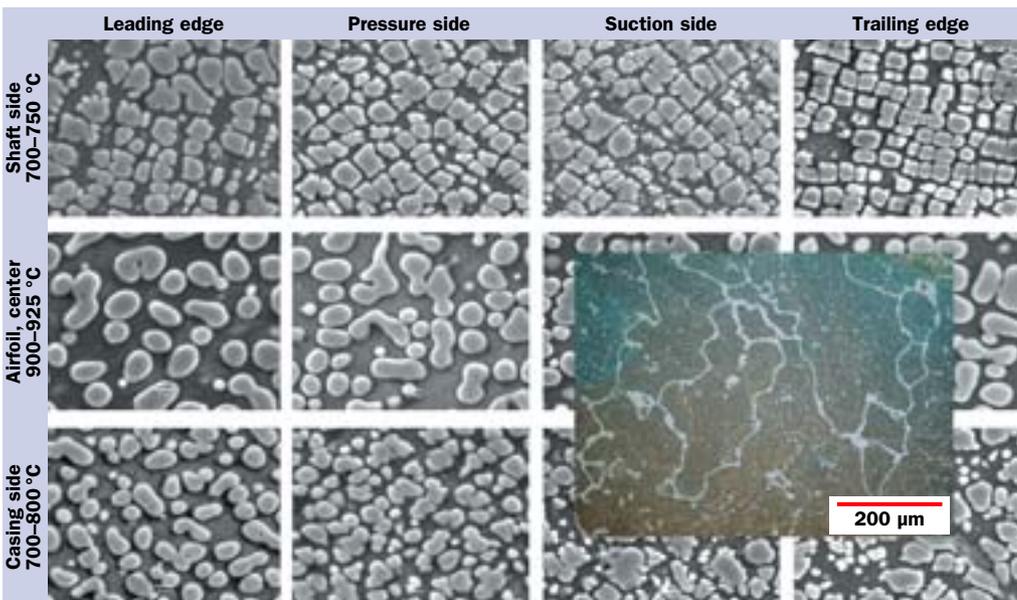
Metal Surface and Coating

The metallographic sample showed that a relatively high rate of attack existed, predominantly on the outer surface. The coating was still intact in those areas that showed little or no discoloration of the airfoil. Here, the original condition of the component can be fully restored by stripping off the old coating and applying a new one.

Lifetime Tripled

The combination of improved cooling air distribution, selection of a different base material, increase in wall thickness, and application of an appropriate coating led to a considerable reduction in degeneration of a second-stage guide vane; the degeneration was confined to more limited areas of the airfoil. After 24,000 hours of operation, the modified component showed a negative change in only a few places when compared with the original vane. The base material condition of the modified component and the depth and shape of the damaged areas was such that this component can be refurbished to a near new condition a number of times. The total expected lifetime of this component was thus tripled to over 72,000 or more equivalent operating hours.

3 The base material of the modified component was stable after 24,000 equivalent hours of operation and showed no signs of irreparable damage.



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