Heraeus

Significant Service Life Extension for High-Temperature Nickel Alloys

Even specialty Ni-alloys for high-temperature application are limited in their lifetime as they remain prone to corrosion. By coating these alloys with α-Al_2O_3 using aerosol deposition the service life of the system parts can be extended by a factor of 3 to 8 while reducing flaking significantly.

Challenge

In a wide range of industries Ni-alloys are used for high-temperature applications, especially where high creep strength is required. They are characterized by outstanding mechanical resistance and a good corrosion resistance in carburizing and oxidizing atmospheres. These Ni-based alloys are used for example for manufacturing parts of kiln furnace or in chemical plants.

In these applications, specialty alloys are exposed to temperatures between 400 °C and 1400 °C. If these alloys contain at least 0.5 % aluminum, they have a limited ability to protect themselves by forming an Al_2O_3 layer on the surface of the alloy. However at temperatures below 1000 °C metastable phases such as θ- and γ-Al_2O_3 form. Therefore, during ramping up and down of temperature, phase transitions with corresponding volume changes occur. These phase transitions turn the surface layer non-protective as voids are caused that allow corrosion. Furthermore, the aluminum, needed for the formation of the Al_2O_3 layer is not available in unlimited quantities and is quickly exhausted.

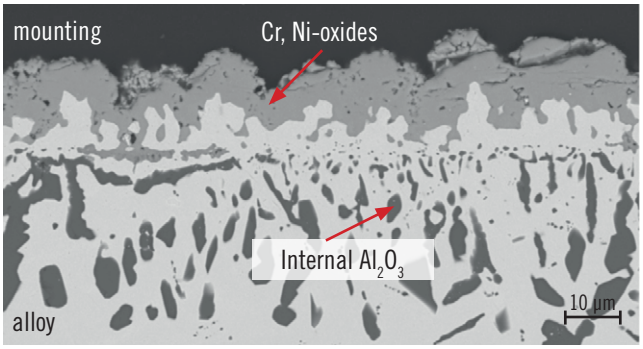
As a result, the service life of the metallic components is limited. The worn parts of the equipment have to be replaced, which leads to downtimes. Another problem that is usually not addressed at all, is the flaking of material surfaces during corrosion. This releases hazardous Cr, Ni dust, which is released into the environment. In addition, these flakes can also contaminate the product in production and cause scrap.

Approach

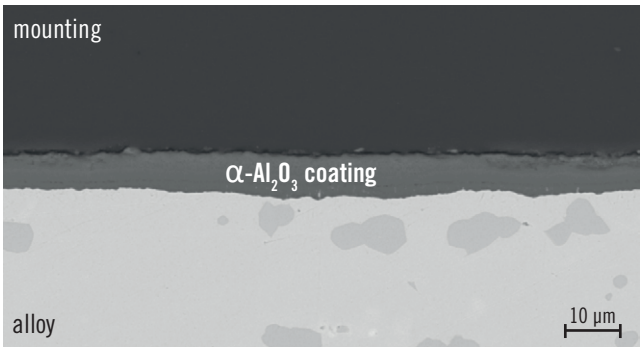
For the study, alloy 602 ($NiCr_{25}FeAlY$) was used, an MCrAlY alloy with an aluminum content of 1.8 - 2.4 %. One of the samples has been coated with a 5 µm α-Al_2O_3 layer at room temperature using aerosol deposition. Both, the coated and the untreated sample, have been exposed to 1000 °C in ambient air for 1000 h.

The scanning microscope cross-section of the untreated sample shows the formation of Cr, Ni-oxides on the alloy surface and Al_2O_3 precipitates in the inner oxidation zone.

The coated sample does not show any micro-structural changes due to the heat treatment, no voids and no precipitates. The lack of oxidation is proof of the protective character of the α-Al_2O_3 layer deposited by aerosol deposition.



Uncoated sample



α-Al_2O_3 coated sample

Results

Longer maintenance intervals
Extension of the service interval by a factor of 3 to 8.

Less scrap
No contamination of the products due to flaking of material surfaces.

Better protection for staff and environment
No toxic Ni- and Cr-Oxides are produced that are harmful to humans and nature.

Conclusion

α-Al_2O_3 applied by aerosol deposition effectively protect Ni-based alloys from high temperature corrosion and flaking.

α-Al_2O_3 applied by aerosol deposition effectively prevents the formation of metastable Al-oxides at any temperature. A reliable protective layer is formed.

The protective layer can be applied to a large number of Ni-based alloys and components.

Interested? Contact us!

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