High Temperature Corrosion

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High-temperature materials are used in many critical components. Hydrogen reformers or ethylene pyrolysis furnace systems used in chemical and petrochemical processes, the interior of jet engines, and fossil-fired steam boilers, all use high temperature, high performance materials.

The need for these materials has to do with corrosion. At elevated temperatures, high temperature corrosion reactions occur at an alarming rate in unprotected materials or conventional materials such as carbon steel. To reduce the occurrence of oxidation, and other corrosion processes such as carburization, sulfidation, halogen corrosion, salt corrosion and hot corrosion, engineers continue to develop materials that can withstand extreme temperatures, without compromising mechanical properties.

A variety of material classes are used in high-temperature applications. Alloy and stainless steels, and more complex alloys based on nickel or cobalt, are most commonly used. Ceramic materials such as alumina and zirconia are finding more applications for temperatures above 870° C. Various composite materials, such as oxide dispersion strengthened alloys and carbon-carbon composites, are now available for specific high-temperature applications, usually where strength is the primary goal. Intermetallic compounds, such as aluminides and silicides, have very high yield strengths and considerable oxidation resistance at high temperatures.
With high creep strength materials such as ceramics and, to a much lesser extent, intermetallic compounds, issues of material brittleness may come into play. It is possible through the use of suitable materials-by-design considerations to reduce the brittleness. For example, the ductility and formability of nickel aluminide intermetallics can be improved by additions of boron at the part-per-million level. Due to the formation of chromium and microalloy element carbides during casting, heat resistant cast stainless steels containing at least 0.3 - 0.4 weight percent carbon also offer a good combination of high-temperature creep strength with reasonable reduction of ductility through aging.

In cases where a given material exhibits the requisite high-temperature mechanical properties such as creep or fatigue strength, but cannot withstand corrosive attack of the environment, various metallurgical and ceramic coatings, such as diffusion and thermal spray coatings, applied to the surface of the material may provide the necessary high-temperature corrosion protection.

Careful attention must be given to the specific chemistry of the high-temperature environment when selecting a protective coating system. For example, aluminide diffusion coatings provide excellent resistance to oxidation and sulfidation in gas turbine environments. However, the presence of salt deposits, typically called hot corrosion, may reduce the effectiveness of the aluminide coating in this service. It is possible to incorporate other elements, such as silicon and chromium, into the diffusion coating, which will greatly enhance its hot corrosion serviceability.

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