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Engineering, Materials & Metallurgical Consulting

WH-76, Mayapuri Industrial Area
Phase-I, New Delhi 110 064, India

T: +91-(0)11-2811-5021
F: +91-(0)11-2811-5021
E: acmecast@acmealloys.com
W: www.acmealloys.com

Stress Relieving of Austenitic Stainless Steels

Austenitic stainless steels have good creep resistance. They can consequently, must be heated to about 900°C (1650°F) to attain adequate stress relief. In some cases, heating to the annealing temperature may be desirable. Holding at a temperature(s) lower than about 870°C (1600°F) results in only partial stress relieving. The most effective stress-relieving results are known to be obtained by slow cooling. Quenching or other rapid cooling, as is normal in annealing of stainless steel, will usually re-introduce residual stress that many engineers, manufacturers and metallurgists are oblivious. Stress relieving is only necessary and not a desideratum, when austenitic stainless-steel parts are subjected to corrosive conditions and service environments conducive to stress corrosion (stress corrosion cracking-SCC) and inter-granular corrosion (IGC) failures.

Selection of Treatment

Selection of an optimum stress-relieving treatment is difficult because heat treatments that provide adequate stress relief can impair corrosion resistance of stainless steels, and contrarily, heat treatments that are not harmful (or detrimental) to corrosion resistance may not provide adequate stress relief. Contrarily, avoiding specifying *any* heat treatment might prove to be harmful. ASME Code hence, neither requires not prohibits stress relief of austenitic stainless steel(s).

Metallurgical characteristics of austenitic stainless steels that may affect the selection of a stress-relieving treatment are discussed below based on range of temperatures:

Heating in the range from 480°C-815°C (900°F-1500°F)

Chromium carbides will precipitate in the grain boundaries of wholly austenitic un-stabilized grades. In partially ferritic cast grades, the carbides will precipitate initially in the discontinued ferrite pools rather than in a continuous grain-boundary network. After prolonged sustained heating such as is necessary for heavier sections, however, the grain boundary carbide precipitation will occur. For cold worked stainless steel, carbide precipitation may occur as low as 425°C (800°F); for types SS 309 and SS310, the upper limit for carbide precipitation may be as high as 900°C (1650°F). In this condition, the steel is susceptible to inter-granular corrosion. By using Titanium and Niobium stabilized grades or extra- low carbon grades, the inter-granular precipitation of chromium carbides can be mitigated and, in many cases can be successfully avoided.

Heating in the range from 540°C-925°C (1000°F-1700°F)

The formation of hard, brittle σ (sigma) phase may result, that can decrease both corrosion resistance and ductility. During the time period necessary for stress relief, σ (sigma) phase will not form in fully austenitic wrought, cast, or welded stainless steel. However, if stainless steel is partially ferritic, the ferrite may eventually undergo phase change transformation to σ (sigma) phase during stress relief. This is not a major impediment in wrought stainless steels because they are completely austenitic; however, some wrought grades- 309, 309 Nb/Cb, 312 and 329-may contain some ferrite in its microstructure. Furthermore, the composition of most austenitic stainless welds and castings is intentionally adjusted so that ferrite present as a deterrent to cracking. The niobium (columbium) containing cast grade ASTM A 743/744 CF-8C usually contains 5-20% ferrite, which is more likely to transform to σ (sigma) phase than the niobium (columbium) free ferrite in the un-stabilized ASTM A 743/744 CF-8 grade.

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Slow cooling an un-stabilized grade (other than extra-low-carbon grade)

Through either of the above temperature ranges, slow cooling may alloy sufficient time for these detrimental effects to take place.

Heating in the range from 815°C- 925°C (1500°F-1700°F)

The coalescence of chromium carbide precipitates or σ (sigma) phase will occur, resulting in a form less harmful to corrosion resistance or mechanical properties.

Heating in the range from 955°C- 1120°C (1750°F-2050°F)

This annealing treatment causes all grain-boundary chromium carbide precipitates to re-dissolve and transforms σ (sigma) phase back to ferrite phase, as well as fully softening the steel. Long heating times (more than an hour) may even dissolve some of the ferrite present and further reduce the probability of σ (sigma) phase reforming upon slow cooling.

Stress relieving to improve the notch toughness

Unlike carbon and alloy steels, austenitic steels are not known to be notch sensitive. Consequently, stress relieving to improve or attempt to enhance notch toughness would be of no benefit. Notch-impact strength may actually be decreased if the steel is stress relieved at a temperature at which chromium carbide is precipitate or σ (sigma) phase forms. This temperature will be different for different alloys and needs to be reviewed before subjecting the part to such treatment. Although titanium, niobium (columbium) stabilized alloys do not require high-temperature annealing to avoid inter-granular corrosion, the stress relieving temperature indeed exerts influence on the general corrosion resistance of these alloys.

General recommendations

In the selection of proper stress-relieving treatment, consideration must be given, hence, to specific material used, fabrication procedures involved, and to the design and operating conditions, service and duty cycles of the equipment or component. Stress relieving is not suggested unless the service environment is known or suspected to cause stress corrosion. If it is necessary to provide stress relieving, due attention must be given to metallurgical factors and their effect on the steel in the intended service. The use of stabilized or extra low carbon grades is an advantage in view of greater latitude allowed in stress relieving.