Material Matters

Problems With Copper In Cast High Alloy Austenitic Stainless Steels

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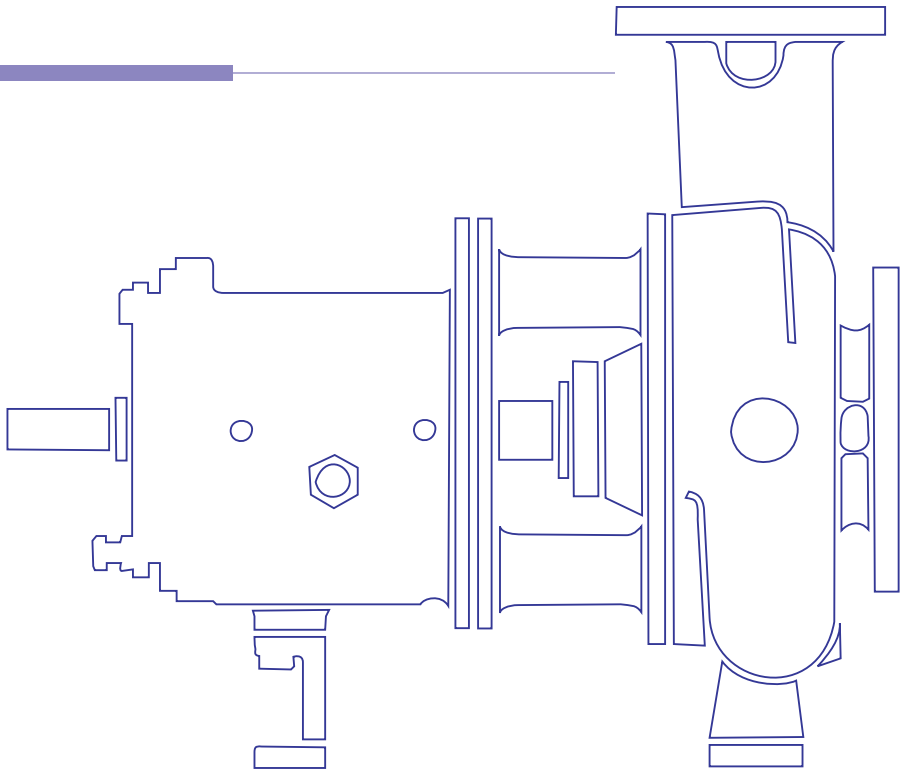

High Alloy Austenitic Stainless Steel

The high alloy austenitic stainless steels are an important group of engineering alloys. They have been used successfully in both cast and wrought forms in a variety of aggressive chemical environments. These alloys are attractive because of their cost advantage over competing nickel-base alloys, and customers often specify them.

Two commonly specified alloys, Alloy 904L (no cast version available in ASTM) and Alloy CN-7M (cast version of Alloy 20) are fully austenitic stainless steels designed for use in various reducing acids such as sulfuric acid, and other aggressive chemical environments. Both alloys contain significant levels of copper intentionally added as an alloying element.

The Problem With Copper in Castings

Alloys like Alloy 20 and 904L were never intended to be cast alloys. It should be recognized that castings are metallurgically more complex than the wrought equivalents, and differences should be expected due to processing.

In castings, segregation during solidification leads to local variations in both chemical composition and microstructure. This results in corrosion resistance and mechanical property differences. During solidification and grain growth, the low melting point elements segregate, or concentrate at inter-dendritic regions and grain boundaries. The wrought products are more homogeneous due to secondary hot working processing, and do not suffer from these segregation effects.

The two major alloying elements, nickel and chromium, exhibit only a slight tendency to segregate. On the other hand, copper, molybdenum, manganese, silicon, sulfur, and phosphorous all significantly segregate to the inter-dendritic and grain boundary regions in cast stainless steels. The large grain size typically found in castings and susceptibility to low melting constituent grain boundary films complicates matters, making these alloys troublesome to cast. Castings with thick sections and complex geometry are particularly susceptible to hot tearing during casting, and weld cracking during repair.

While CN-7M is similar (note chemistry differences) to Alloy 20, there is currently no cast version of 904L available in ASTM. As a wrought product the copper is homogeneously distributed. However, in the cast alloy, the last metal to solidify is rich in copper, which forms grain boundary films.

Recommendations

Be cautious when selecting or specifying high copper containing alloys such as cast 904L or similar alloys, which can produce grain boundary films rich in copper. In certain environments such as electrowinning or electrogalvanizing systems, the copper rich grain boundaries can act as sacrificial anodic regions against the metal grains acting as larger cathode surfaces; resulting in grain boundary loss from being selectively or preferentially attacked. In pumps, this often appears as through wall leakage or corrosion assisted fatigue type cracking failures.

When specifying fully austenitic alloys with low melting point elements such as sulfur, phosphorus, and copper, these elements should be kept to a minimum to eliminate grain boundary weaknesses, and cracking tendencies. Similarly, cast alloys selected for electrolytic services, should also keep these elements to a minimum. Cast alloys such as ASTM A743 Grades CN-3M (Jessop 700 cast equivalent), CN-3MN (AL6XN cast equivalent), or Grade CK-3MCuN (254SMO cast equivalent) are better choices, and recommended for aggressive electrolytic services, since these are low or free of copper additions.

Finally, chemistry control and AOD (Argon-oxygen-decarburization) refining is key to successful production of high copper containing austenitic stainless alloys. This capability is currently being added to the IPG high alloy foundry at our Ashland Operations.