Material Selection for Corrosive Environments

Metallic materials and their alloys have significant and widespread uses in engineering applications and their selection and use requires careful evaluation of their properties and suitability. The best reference source for determining the suitability of a material for an application would be the manufactures literature and handbooks. Several factors such as compatibility, strength, formability, corrosion resistance, cost, availability, etc. are to be considered prior to specifying the material of for a given application. What follows is a brief compilation of the salient features of some ferrous and non-ferrous alloys available for different heat transfer applications.

AUSTENITIC STAINLESS STEEL

The designation for austenitic stainless steel is 304 (UNS S30400) and 304L (UNS S30403). They are variations of the Chromium-Nickel (18Cr-8Ni) steels. The important features of these alloys are that they have good resistance to corrosion, easy to fabricate, have the ability to maintain clean surfaces and are available in a wide range of product forms. They are frequently used in applications for the food, beverage, sanitary and cryogenic pressure containing vessels.

The "L" grades of stainless steel, e.g. 304L 316L, are preferred for applications used in the as-welded condition as the low carbon extends the time to precipitate a harmful level of chromium containing carbides that contribute to intergranular corrosion and cracking (hot brittleness). 304L is susceptible to stress corrosion cracking due to low Ni content and generally 100 ppm chloride is considered to be the limit for 18-8 alloys for corrosion from pitting. Also, the 18-8 alloys are not recommended for marine environments. Cold working of this material increases its strength and decreases its elongation value.

The other variation of the 18Cr-8Ni steels is obtained by the addition of 2 to 3% Molybdenum (Mo) as alloying element and is designated as 316 (UNS S31600) and 316L (UNS S31603). It has better corrosion resistance, strength, and ease of fabrication compared to 304 grades and widely used in the food, pharmaceutical, and chemical industries. The addition of Mo gives better pitting corrosion resistance and generally considered to be resistant to about 2000 to 5000 ppm chloride concentrations.

The low carbon levels enhance resistance to intergranular corrosion and significantly reduce or even eliminate the risk of cracking after welding. 316 stainless steel is theoretically less resistant to nitric acid due to the higher Mo content but in practice both 304/304L and 316/316L hold up very well to both hot and cold nitric acid.

DUPLEX STAINLESS STEEL

Duplex stainless steels are a combination of Ferritic-Austenitic steels balanced almost equally in the solution annealed condition. They are designated as Duplex 1803 (UNS S31803) and Duplex 2205 (UNS S32205). It should be noted that all 2205 is 1803 but not vice versa. It combines the advantages of stress corrosion cracking resistance of the ferritic phase and the formability of austenitic phase. Due to the high Cr, N, and Mo content it has good resistance to pitting, uniform corrosion, and the continuous ferrite phase increases the resistance to stress corrosion cracking (SCC). It is not suitable for temperatures over 600°F due to the potential for embrittlement from precipitation of the phases. The bending and forming processes are difficult due to its high strength.

AL6XN

AL6XN is the trade name for a Super-Austenitic steel from Allegheny Ludlum Corporation and designated as UNS N08367. It has about 24% Ni, 6.3% Mo which gives good resistance to SCC. The Cr content provides corrosion resistance in neutral or oxidizing environments and the Cr, Mo, and Nitrogen (N) provides excellent pitting resistance. It has better resistance to intergranular corrosion due to it low carbon content.

CARPENTER ALLOY 20 CB-3

This alloy is also a type of Super-Austenitic steel however it is not truly stainless as the alloying is greater than 50% and not a Ni alloy as the Ni content is less than 50%. It is designated as UNS N08020 and is the trade name from Carpenter Technology. It is generally referred as Ni-Cr-Mo stainless steel and very suitable for sulfuric acid applications.

HASTELLOY

Hastelloy is the trade name for a family of Nickel alloys from Haynes International and are designated as C276 (UNS N10276) and C22 (UNS N06022). The C276 is a Ni-Mo-Cr alloy that has excellent resistance to pitting and SCC and is suitable for chemical service in the as-welded condition as it resists formation of grain boundary precipates in the heat affected zone HAZ. It has a tendency to work harden. The C-22 is Ni-Mo-Cr-W alloy with Tungsten (W) added as alloying element and has improved properties compared to C276.

COPPER-NICKEL ALLOYS

The common Copper-Nickel alloys are designated as 90-10 Cu-Ni (UNS C70600) and Cu-Ni 70-30 (UNS C71500). They have excellent resistance to uniform corrosion. These alloys release Cu ions and the structure of oxide layer formed gives excellent resistance to bio fouling and are used widely in marine environments. When used as heat exchanger tube materials, the may show erosion corrosion limiting the velocity of the fluid and the oxide film thickening may decrease the overall heat transfer.

TITANIUM

The commonly used form of Titanium (Ti) is Titanium Grade 2, which is designated as UNS R50400. It has a stable oxide film and it very useful in chlorine environments as oxidizing nature of Chlorine (Cl) passivates Ti. However under highly reducing environments, the oxide film may break down and it should be avoided for Hydro Fluoric Acid as it causes rapid general corrosion.

INCONEL

The common Inconel alloys are designated as Alloy 600 (UNS N06600) and Alloy 635 (UNS N06625). The have about 72% Ni and are almost immune to SCC from chlorides. They are used in application that require resistance to corrosion and heat such as for seawater, exhaust gases, and organic acids. The Cr content provides the resistance in oxidizing environments and the Ni content provides the resistance in reducing environments. It is not age hardening alloy and suffers slight oxidation under alternating conditions.

TANTALUM

Tantalum is identified as UNS R50200. It equals glass in resistance to acids and it is impervious to liquid metals up to 1650°F. The only media that can affect it are fluorine, hydrofluoric acid, sulfur trioxide (including fuming sulfuric acid), concentrated strong alkalis, and certain molten salts. They have a strong tendency to seize, tear and gall and the operations are normally performed cold.