Stainless Steels

Stainless Steels are iron-base alloys containing Chromium. Stainless steels usually contain less than 30% Cr and more than 50% Fe. They attain their stainless characteristics because of the formation of an invisible and adherent chromium-rich oxide surface film. This oxide establishes on the surface and heals itself in the presence of oxygen. Some other alloying elements added to enhance specific characteristics include nickel, molybdenum, copper, titanium, aluminum, silicon, niobium, and nitrogen. Carbon is usually present in amounts ranging from less than 0.03% to over 1.0% in certain martensitic grades. Corrosion resistance and mechanical properties are commonly the principal factors in selecting a grade of stainless steel for a given application.

Stainless steels are commonly divided into five groups:

- Martensitic stainless steels
- Ferritic stainless steels
- Austenitic stainless steels
- Duplex (ferritic-austenitic) stainless steels
- Precipitation-hardening stainless steels.

Martensitic stainless steels are essentially alloys of chromium and carbon that possess a martensitic crystal structure in the hardened condition. They are ferromagnetic, hardenable by heat treatments, and are usually less resistant to corrosion than some other grades of stainless steel. Chromium content usually does not exceed 18%, while carbon content may exceed 1.0 %. The chromium and carbon contents are adjusted to ensure a martensitic structure after hardening. Excess carbides may be present to enhance wear resistance or as in the case of knife blades, to maintain cutting edges.

Ferritic stainless steels are chromium-containing alloys with Ferritic, body centered cubic (bcc) crystal structures. Chromium content is typically less than 30%. The ferritic stainless steels are ferromagnetic. They may have good ductility and formability, but high-temperature mechanical properties are relatively inferior to the austenitic stainless steels. Toughness is limited at low temperatures and in heavy sections.

Austenitic stainless steels have a austenitic, face centered cubic (fcc) crystal structure. Austenite is formed through the generous use of austenitizing elements such as nickel, manganese, and nitrogen. Austenitic stainless steels are effectively nonmagnetic in the annealed condition and can be hardened only by cold working. Some ferromagnetism may be noticed due to cold working or welding. They typically have reasonable cryogenic and high temperature strength properties. Chromium content typically is in the range of 16 to 26%; nickel content is commonly less than 35%.

Duplex stainless steels are a mixture of bcc ferrite and fcc austenite crystal structures. The percentage each phase is a dependent on the composition and heat treatment. Most Duplex stainless steels are intended to contain around equal amounts of ferrite and austenite phases in the annealed condition. The primary alloying elements are chromium and nickel. Duplex stainless steels generally have similar corrosion resistance to austenitic alloys except they typically have better stress corrosion cracking resistance. Duplex stainless steels also generally have greater tensile and yield strengths, but poorer toughness than austenitic stainless steels.

Precipitation hardening stainless steels are chromium-nickel alloys. Precipitation-hardening stainless steels may be either austenitic or martensitic in the annealed condition. In most cases, precipitation hardening stainless steels attain high strength by precipitation hardening of the martensitic structure.

Selecting a Stainless Steel

There are a large number of stainless steels produced. Corrosion resistance, physical properties, and mechanical properties are generally among the properties considered when selecting stainless steel for an application. A more detailed list of selection criteria is listed below:

- Corrosion resistance
- Resistance to oxidation and sulfidation
- Toughness
- Cryogenic strength
- Resistance to abrasion and erosion
- Resistance to galling and seizing
- Surface finish
- Magnetic properties
- Retention of cutting edge
- Ambient strength
- Ductility
- Elevated temperature strength
- Suitability for intended cleaning procedures
- Stability of properties in service
- Thermal conductivity
- Electrical resistivity
- Suitability for intended fabrication techniques

Corrosion resistance is commonly the most significant characteristic of a stainless steel, but can also be the most difficult to assess for a specific application. General corrosion resistance is comparatively easy to determine, but real environments are usually more complex. An evaluation of other pertinent variables such as fluid velocity, stagnation, turbulence, galvanic couples, welds, crevices, deposits, impurities, variation in temperature, and variation from planned operating chemistry among others issues need to be factored in to selecting the proper stainless steel for a specific environment.