Stainless Steel – Alloying Elements

Carbon (C): Iron is alloyed with carbon lo make steel and has the effect of increasing the hardness and strength of iron. Pure iron cannot be hardened or strengthened by heat treatment but the addition of carbon enables a wide range of hardness and strength. In Austenitic and Ferritic stainless steels a high carbon content is undesirable, especially for welding due to the threat of carbide precipitation.

Manganese (Mn): Manganese is added to steel to improve hot working properties and increase strength, toughness and hardenability. Manganese, like nickel, is an Austenite forming element and has been used as a substitute for nickel in the AISI200 Series of Austenitic Stainless Steels, e.g. AISI 202 as a substitute for AISI 304.

Chromium (Cr): Chromium is added to steel to increase resistance to oxidation. This resistance increases as more chromium is added. 'Stainless Steels have a minimum of 10.5% Chromium (traditionally 11 or 12%). This gives a very marked degree of general corrosion resistance when compared to steels with a lower percentage of Chromium. The corrosion resistance is due to the formation of a self-repairing passive layer of Chromium Oxide on the surface of the stainless steel.

Nickel (Ni): Nickel is added in large amounts, over about 8%, to high Chromium stainless steels to form the most important class of corrosion and heat resisting steels. These are the Austenitic stainless steels, typified by 18-8 (304/1.4301), where the tendency of Nickel to form Austenite is responsible for a great toughness (impact strength) and high strength at both high and low temperatures. Nickel also greatly improves resistance to oxidation and corrosion.

Molybdenum (Mo): Molybdenum, when added to chromium-nickel austenitic steels, improves resistance to pitting and crevice corrosion especially in chlorides and sulphur containing environments.

Nitrogen (N): Nitrogen has the effect of increasing the Austenite stability of stainless steels and is, as in the case of Nickel, an Austenite forming element. Yield strength is greatly improved when nitrogen is added to stainless steels as is resistance to pitting corrrosion.

Copper (Cu): Copper is normally present in stainless steel as a residual element. However, it is added to a few alloys to produce precipitation hardening properties or to enhance corrosion resistance particularly in sea water environments and sulphuric acid.

Titanium (Ti): Ttitanium is added for carbide stabilization especially when the material is to be welded. It combines with carbon to form titanium carbides, which are quite stable and hard lo dissolve in steel, which tends to minimise the occurrence of inter-granular corrosion. Adding approximately 0.25 / 0.60% titanium causes the carbon to combine with titanium in preference to chromium, preventing a tie-up of corrosion-resisting chromium as inter-granular carbides and the accompanying loss of corrosion resistance at the grain boundaries. However, the use of titanium has gradually decreased over recent years due to the ability of steelmakers to deliver stainless steels with very low carbon contents that are readily weldable without stabilisation.

Phosphorus (P): Phosphorus is usually added with sulphur, to improve machinability. The Phosphorus present in Austenitic stainless steels increases strength. However, it has a detrimental effect on corrosion resistance and increases the tendency of the material to crack during welding.

Sulphur (S): When added in small amounts Sulphur improves machinability. However, like Phosphorous it has a detrimental effect on corrosion resistance and weldability.

Selenium (Se): Selenium was previously used as an addition to improve machinability.

Niobium / Colombium (Nb): Niobium is added to steel in order to stabilise carbon, and, as such, performs in the same way as described for Titanium. Niobium also has the effect of strengthening steels and alloys for high temperature service.

Silicon (Si): Silicon is used as a deoxidising (killing) agent in the melting of steel and as a result most steels contain a small percentage of Silicon.

Cobalt (Co): Cobalt becomes highly radioactive when exposed to the intense radiation of nuclear reactors, and, as a result, any stainless steel that is in nuclear service will have a Cobalt restriction, usually approximately 0.2% maximum. This problem is emphasized because there is normally a residual Cobalt content in the Nickel used in producing Austenitic stainless steels.

Calcium (Ca): Small additions are used to improve machiniability, without the detrimental effects on other properties caused by Sulphur, Phosphorus & Selenium.

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Affect of Alloying Elements on Properties of Stainless Steel

Property	C	CR	Ni	S	Mn	Si	P	Cu	Mo	Se	Ti or Nb
Corrosion Resistance	-	√	√	X	-	-	√	-	√	-	-
Mechanical Properties	√	√	-	-	√	√	√	√	√	-	√
High Temperature Resistance	-	√	√	X	-	-	-	-	√	-	√
Machinability	X	X	-	√	-	-	√	-	-	√	-
Weldability	X	X	-	X	√	-	X	-	√	-	√
Cold Workability	X	X	√	X	-	-	-	√	-	-	-

Key

√ = **Beneficial**
X = **Detrimental**

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