

Effects of Alloying Elements in Steel

Steel is basically iron alloyed to carbon with certain additional elements to give the required properties to the finished melt. Listed below is a summary of the effects various alloying elements in steel.

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Carbon

The basic metal, iron, is alloyed with carbon to make steel and has the effect of increasing the hardness and strength by heat treatment but the addition of carbon enables a wide range of hardness and strength.

Manganese

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 A.I.S.I 200 Series of Austenitic stainless steels (e.g. A.I.S.I 202 as a substitute for A.I.S.I 304)

Chromium

Chromium is added to the steel to increase resistance to oxidation. This resistance increases as more chromium is added. 'Stainless Steel' has approximately 11% chromium and a very marked degree of general corrosion resistance when compared with steels with a lower percentage of chromium. When added to low alloy steels, chromium can increase the response to heat treatment, thus improving hardenability and strength.

Nickel

Nickel is added in large amounts, over about 8%, to high chromium stainless steel to form the most important class of corrosion and heat resistant steels. These are the [austenitic](#) stainless steels, typified by 18-8, where the tendency of nickel to form austenite is responsible for a great toughness and high strength at both high and low temperatures. Nickel also improves resistance to oxidation and corrosion. It increases toughness at low temperatures when added in smaller amounts to alloy steels.

Molybdenum

Molybdenum, when added to chromium-nickel austenitic steels, improves resistance to pitting corrosion especially by chlorides and sulphur chemicals. When added to low alloy steels, molybdenum improves high temperature strengths and hardness. When added to chromium steels it greatly diminishes the tendency of steels to decay in service or in heat treatment.

Titanium

The main use of titanium as an alloying element in steel is for carbide stabilisation. It combines with carbon to form titanium carbides, which are quite stable and hard to dissolve in steel, this tends to minimise the occurrence of intergranular corrosion, as with A.I.S.I 321, when adding approximately 0.25%/0.60% titanium, the carbon combines with

the 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.

Phosphorus

Phosphorus is usually added with sulphur to improve machinability in low alloy steels, phosphorus, in small amounts, aids strength and corrosion resistance. Experimental work shows that phosphorus present in [austenitic](#) stainless steels increases strength. Phosphorus additions are known to increase the tendency to cracking during welding.

Sulphur

When added in small amounts sulphur improves machinability but does not cause hot shortness. Hot shortness is reduced by the addition of manganese, which combines with the sulphur to form manganese sulphide. As manganese sulphide has a higher melting point than iron sulphide, which would form if manganese were not present, the weak spots at the grain boundaries are greatly reduced during hot working.

Selenium

Selenium is added to improve machinability.

Niobium (Columbium)

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.

Nitrogen

Nitrogen has the effect of increasing the austenitic 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 austenitic stainless steels.

Silicon

Silicon is used as a deoxidising (killing) agent in the melting of steel, as a result, most steels contain a small percentage of silicon. Silicon contributes to hardening of the ferritic phase in steels and for this reason silicon killed steels are somewhat harder and stiffer than aluminium killed steels.

Cobalt

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 emphasised because there is residual cobalt content in the nickel used in producing these steels.

Tantalum

Chemically similar to niobium and has similar effects.

Copper

Copper is normally present in stainless steels as a residual element. However it is added to a few alloys to produce precipitation hardening properties.

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