Alloying Elements

Aluminium **Al**

Aluminium is the strongest and most commonly used deoxidising and denitriding agent. It has therefore a favourable effect on the insensitivity to aging and promotes fine grain formation when added in small amounts

Calcium **Ca**

Calcium is used together with Si in the form of silco-calcium for deoxidation. It increases the scaling resistance of heating conductor materials and aids machinability

Carbon **C**

Carbon is inseparable from steel & is therefore usually not defined as alloying constituent. Carbon is the most important element for the majority of steels and has the strongest influence on their properties. Strength & hardenability increase with increasing C content, while elongation values forming properties, weldability & machinability are reduced.

Chromium **Cr**

Chromium makes steel oil & air hardenable. By lowering the critical cooling rate necessary for the formation of martensite it increases hardenability & thus improves heat treating properties, while at the same time it reduces impact strength. Chromium is a strong carbide former. Its carbides increase edge-holding property & wear resistance. High pressure strength & resistance to high-pressure hydrogen are improved by the addition of chromium. The resistance to scale formation increases with increasing Cr content, while the minimum content of approx 13% Cr dissolved in the matrix is required for making the steel resistant to corrosion. Thermal conductivity and electric conductivity as well as thermal expansion are reduced by Cr.

Cobalt **Co**

Cobalt does not form carbides. It inhibits grain growth at elevated temperatures and improves substantially retention of hardness and high temperature strength. It is therefore used as an alloying constituent in HSS, HWS high temperature and creep resisting materials.

Copper **Cu**

Copper is only added to a few steels , because it builds up below the oxide layer and produces high surface sensitivity in hot forming operations due to penetration into the grain boundary.

Lead **Pb**

Lead is added in amounts of .2% to .5% to free cutting steels, because its very fine suspension like dispersion, permits to obtain short chip lengths and clean cut surfaces and thus guarantees improved machinability. Lead contents within the range indicated above have practically no influence on mechanical properties.

Magnesium **Mg**

Magnesium promotes graphite formation in Cast Iron.

Manganese **Mn**

Manganese has a deoxidising effect. It combines with sulphur to form manganese-sulphides and thus lowers the unfavourable effect of iron sulphides. This is of particular importance for free cutting because it reduces the risk of red shortness. Mn reduces substantially the critical cooling rate and thus increases hardenability. Yield point and strength are increased by the addition of Mn. Steels containing more than 12% Mn in combination with elevated carbon contents are austenitic, because Mn enlarges considerably the y-range. Such steels experience severe strain hardening of surface, when exposed to impact stresses, while the core remains tough. They are therefore highly wear resistant in case of impact stresses.

Alloying Elements

Molybdenum **Mo**

Molybdenum is mostly added together with other alloying elements. By reducing the critical cooling rate, it causes an improvement in hardenability. Mn reduces to a large extent temper brittleness, eg in CrNi & Mn steels & promotes fine-grain formation. It increases yield point & strength. Being a strong carbide former, it improves the cutting efficiency of HSS. Mo belongs to those elements which increases resistance to corrosion & is therefore often used in alloying constituent in highly alloyed Cr steels & austenitic CrNi steels.

Nickel **Ni**

In constructional steels Ni causes an increase of impact strength, even at subzero temperatures & is therefore added to case-hardening steels, heat treatable steels and steels intended for low-temperature service to increase their toughness properties. Ni as single alloying element, even in large percentages, merely slows down corrosion process.

Phosphorus **P**

Phosphorus is mostly considered to be detrimental to steels, because it causes heavy primary segregation. P increases susceptibility to temper brittleness, even in the smallest percentages. In low alloy constructional steels with C contents of approx 0.1% phosphorus causes an increase in strength & resistance to atmospheric corrosion. In austenitic CrNi steels with additions may cause a yield point increase and produce precipitation effects.

Silicon **Si**

Silicon has a deoxidising effect. It promotes graphite precipitation and narrows substantially the y-range. It increases strength and wear resistance. Silicon causes a considerable increase of the elastic limit and is therefore best suited as alloying constituent in spring steels. Owing to its ability to improve substantially the resistance to scaling, Si is added to heat resisting steels. Its contents however limited as it impairs the hot and cold forming properties.

Sulphur **S**

Among all tramp elements sulphur produces the most serious segregations. Iron sulphides leads to red shortness, because the low melting sulphide eutectics surround the grains like a net resulting in a low coherence of the letter and in breaking up the grain boundaries during hot forming. S is added to free cutting steels as its lubrication effect on the cutting edge reduces the friction between the work piece and the tool. S increases susceptibility to welding cracks.

Titanium **Ti**

Owing to its great affinity to oxygen, nitrogen, sulphur & carbon, titanium is strongly deoxidising, denitriding and carbide forming & combines with sulphur. In corrosion resisting steels it is used as carbide former for stabilization to ensure resistance to intergranular corrosion.

Tungsten **W**

Tungsten is a strong carbide former, it improves toughness and inhibits grain growth. It increase high temperature strength & inhibits grain growth. It increases high-temperature strength & retention of hardness as well as wear resistance at elevated temperatures & thus cutting efficiency. It is therefore used predominantly added to HSS, HWS high temperature steels & steels featuring maximum hardness. It impairs scaling resistance.

Vanadium **V**

V refines the primary grain and thus the as cast structure. It is a strong carbide forming element thus causing an increase in wear resistance, edge holding property and high temperature strength. It is therefore a preferred alloying constituent in HSS, HWS and high temperature steels.