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Influence of alloy components on steel properties

Coal (C)
it is a steel component crucial for mechanical properties. The more coal is in the steel the higher is its tensile strength, yield point, and hardness, while impact resistance, elongation, and contraction are reduced. Higher content of coal decreases weldability but improves hardenability. In tool steels, and particularly in high-speed steels the content of coal must exceed 1 % because only with this percentage the alloy additives (vanadium; tungsten; cobalt) will be used in a correct way.
The existence of more than 0.03 % of coal in stainless and acid-resistant steels makes those steels more susceptible to intercrystalline corrosion.

Chromium (Cr)
in low-alloy and low-carbon steels, it increases their strength and hardness and improves their impact resistance, too. It is an essential additive for toughening and tool steels, where it increases hardenability, hardening depth and leads to high hardness. Due to applying mild hardening tools do not deform, they are less susceptible to cracking and are more resistant to wear.

Nickel (Ni)
from among all the alloy additives, it most favorably influences improved strength and hardness maintaining high impact resistance at the same time. It does not create carbides. It significantly reduces the nil ductility transition temperature of steel. It has an influence on the good hardenability of steel, particularly when accompanied by chromium and molybdenum.
In hot work tool steels, nickel increases ductility and hardenability. In steels containing from 3 to 9% of nickel, it assures high impact resistance and good plastic properties even in very low temperatures.
As an austenite forming element nickel is widely applied in the production of corrosion-resistant steels, acid-resistant steels, heat resistant, and heat and creep resistant steels.

Manganese (Mn)
it increases hardness and strength but reduces plastic properties. The characteristic feature of the manganese steels is a higher limit of elasticity and higher wear resistance. Manganese in the tool steels increases their hardenability, but at the same time, it affects higher susceptibility to overheating. It may partly replace nickel in corrosion-resistant steels.

Silicon (Si)
silicon is applied in the metallurgical process as a deoxidizer. The existence of silicon increases the strength and hardness of steel. The steels containing silicon have a higher yield point and limit of elasticity accompanied by higher resistance to dynamic forces after toughening treatment, therefore silicon is widely applied for spring steels and vehicle spring steels.
When used in tool steels together with carbide formers silicon increases plastic properties after hardening and restricts drop in hardness after tempering.
When combined with chromium and molybdenum it increases the heat and creeps resistance of steel. Silicon steels are also used as materials having special magnetic and electric properties.

Molybdenum (Mo)
it intensely increases the hardenability of steel, much more than chromium or tungsten. It significantly reduces the brittleness of steel occurred for high-temperature tempering. Carbide forming property and the related phenomenon of secondary hardness increasing steel wear resistance obtained at tempering time are used in tool steels. In martensitic, ferritic, and austenitic steels it increases corrosion resistance.

Tungsten (W)
it is a carbide former, but much less effective than molybdenum, chromium, or nickel. An additive of tungsten makes the steel very resistant to tempering thus steel keeps its mechanical properties obtained during the process of hardening at temperatures up to about 600 °C. The existence of very hard and durable tungsten carbides makes steels resistant to wear and tear, providing tool steels with high cutting ability and resistance of a blade to wearing.

Cobalt (Co)
it is an austenite forming element, it does not form any carbides, it increases the critical cooling speed thus decreasing the hardenability of steel. It is mostly used in high alloyed tool steels. It increases melting temperature and prevents steels from overheating during the hardening process, thus enabling to use of higher hardening temperatures and increasing saturation of the solution with alloy carbides which in turn increases resistance to tempering action of high temperatures. The tools made of steels containing cobalt are very durable and resistant to wear.

Vanadium (V)
it has a great ability to create carbides. An addition of vanadium increases resistance to overheating and makes that steel is fine-grained. In tool steels, it intensely binds with carbon and creates hard carbides thus increasing their wear resistance and

retarding a drop in hardness caused by tempering actions of the temperatures up to 600 °C.

Aluminium (Al)
a great affinity of aluminum to nitrogen and oxygen is used in steels, which gives strong deoxidizing and denitriding effects, and counteracts enlargement of the austenite grains.

Titanium (Ti)
apart from niobium, it is an element with the greatest affinity to carbon, it means it is a strong ferrite forming element. In stainless steels, it stabilizes coal thus limiting intercrystalline corrosion.

Nitrogen (N)
when dissolved in steel it creates nitrides reducing plastic properties. Introduced in the atomic form it easily penetrates liquid steel which is used during the nitriding process. In chromium-nickel steels, it is introduced in order to increase their strength properties.

Hydrogen (H)
it negatively affects the steel mechanical properties, it is easily soluble in steel, creating blisters in the form of so-called snowflakes, being a defect in steel. They are removed by long heating at an approximate temperature of 650 °C – so-called anti-flaking treatment.

Sulphur (S)
sulphur is harmful contamination in steel, it occurs as sulphides; as FeS it makes steel brittle when formed in a hot process. It improves machinability when purposely introduced into free-cutting steels in the presence of manganese.

Phosphorus (P)
the existence of phosphorus decreases the plastic properties of steel making it brittle.