# Steels Elements

## 5 Main Elements

### Carbon (C)

Carbon is the principal hardening element in all steel. As the carbon content increases, strength, hardness and hardenability increase at the expense of ductility, toughness, and weldability. Carbon is prone to segregation.

The main alloying element of the steel, present in our steels for case-hardening and for quenching and tempering with content, respectively, of up to 0.20% and 0.55%. An increased carbon content in these steels raises the hardenability, the UTS (ultimate tensile strength), the hardness (and brittleness) of the steels, but reduces the plastic characteristics of the material.

The carbon content in austenitic stainless steels, however, is limited in order to avoid the formation of chromium carbides which reduce corrosion resistance.

### Manganese (Mn)

It is “naturally” present in the steels as a result of its use in the de-oxidation phase of processing, with a content of up to 1% (or up to 2% for austenitic stainless steels). It is an element considered necessary since it improves many mechanical characteristics.

For this reason, in certain construction steels it is used as an alloying element, with a content of greater than 1%. In free cutting steels also, Mn is added because it binds easily with sulphur to form manganese sulphides, particularly sought after as they are plastically mouldable at rolling temperatures and ideal for chip fragmentation during machining processes.

### Silicon (Si)

Silicon, too, is an excellent de-oxidant and is always present with a content of up to 0.40% since it is used in manufacturing of the steel. It allows the mechanical characteristics of the material to be improved, but contributes to the formation of “hard” silicate inclusions, damaging to tools used in chip removal processes.

### Sulphur (S)

Always considered an impurity that renders the steel matrix fragile (thus deteriorating the plastic characteristics, in particular toughness), its content is usually limited to 0.030% (in stainless steels), 0.035% (in construction steels) or 0.050% (for structural steels).

With current steel production processes, however, the sulphur content normally reaches no more than a few ppm (parts per million), thus triggering serious difficulties during chip removal processes.

For this reason, car manufacturers insist on a minimum content in all steels (S=0.02-0.04%).

In free cutting steels, sulphur is by definition the fundamental element: it is added so as to obtain up to a 0.40% content and is combines with manganese to form manganese sulphides, which allow breaking down of the chip.

Certain stainless steels exist, also, with added sulphur: in this case the corrosion resistance characteristics prove inferior to sulphur-free steels of the same category.

### Phosphorus (P)

Phosphorus is also considered an impurity, in that it has negative effects on material brittleness. Its presence is therefore limited to 0.035%.

Only for low-carbon free cutting steels, the need to render the matrix fragile imposes a higher phosphorus content (up to 0.11%).

### Lead (Pb)

Given its low melting point, it is added to free cutting and constructions teels, and is destined to chip removal processes, with a content of 0.15-0.35%. It acts as a liquid lubricant between the tool cutting edge and the chip, and in effect has no negative influence on the mechanical properties of the steels.

## Additional Elements

### Aluminium (Al)

Aluminium is a powerful de-oxidant and is added to, or occasionally replaces, manganese and silicon during steel production phases.

In structural steels it has an anti-aging effect and is therefore useful for welded structures and for improving toughness at low temperatures.

In construction steels it is widely used to control austenitic grain size by forming aluminium nitrides in the liquid bath. For this reason, car manufacturers insist upon its presence with a content of 0.02-0.05.

A disadvantage, in a similar way to silicon, it forms very hard inclusions that have a negative effect on the durability of chip removal tools.

### Bismuth (Bi)

With lead, bismuth forms a low-melting point allow which amplifies the lubricating effect already possessed by the lead, to allow melting at even lower temperatures. It is therefore added to certain free cutting steels (around 0.08%) to achieve maximum machinability on particularly difficult chip removal of difficult parts.

### Boron (B)

In construction steels, boron improves hardness potential without altering cold deformability: it is therefore used to replace a part of the carbon content in steels for cold heading of nuts and bolts to be subjected to quenching and tempering.

The addition of boron as an alloying element leads to a certain deterioration in weldability.

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## Calcium (Ca)

Used together with silicon to de-oxidize steel during production.

Calcium oxides, which form during the steel production process, if appropriately treated can modify the nature of hard oxides such as aluminates and silicates, forming complex inclusions (calcium silicoaluminates), less hard than the originals and with a lower melting point. For this reason, calcium-treated stainless steels allow greater durability of machining tools and, if appropriate parameters are chosen during processing, allow clearly superior workability.

## Chromium (Cr)

In construction steels, chromium is a widely used and well-known alloying element. By adding chromium up to a content of 2-3%, improvements are achieved in tensile strength of the materials, toughness and hardenability.

For free cutting steels, chromium is a hard constituent element, and therefore normally to be avoided.

In stainless steels, however, chromium is the main alloying element: this is an element which widens the ferrite field of existence and restricts that of the austenite. A content of at least 11% contributes to the formation of a protective oxide film on the material surface. Increasing chromium content, especially in austenitic stainless steels (up to 25%), allows particular corrosion resistance values to be achieve.

## Copper (Cu)

Copper is considered an impurity in construction steels in that it provokes significant hot shortness. It is always present, however, in more or less tangible quantities (0.1-0.3%), in steels originating from scrap re-melting, whilst it is practically absent from steels originating from iron ore.

It is used as an alloying element (3-4%) in certain kinds of austenitic stainless steels to improve cold formability.

## Molybdenum (Mo)

In construction steels, molybdenum is added to reach a content of 0.2-0.5%, usually together with other alloying elements, especially chromium and nickel. Apart from increasing hardness potential and the resistance and yield point characteristics, it significantly reduces annealing fragility.

In stainless steels it improves heat corrosion resistance (1% in ferritic types) and salt-water resistance (2-3% in austenitic types). From a structural point of view, it behaves similarly to chromium, restricting the austenitic field.

## Nickel (Ni)

Of considerable importance in construction steels since it significantly increases shock resistance (toughness), also at low temperatures, and fatigue resistance. Like chrome, it improves hardness potential and toughness.

In austenitic stainless steels, nickel is a fundamental element: it allows widening of the austenite field of existence up to room temperature, and considerably improves characteristics of the film that protects steels from corrosion in more aggressive environments, for which chromium-only stainless steels are not suitable.

## Nitrogen (N)

Nitrogen generally reduces the toughness of steels since it forms small precipitates that provoke aging and fragility sensitivity.

In austenitic stainless steels, its properties are used to widen the γ field and stabilize the austenitic structure: its minimum content (up to 0.11%) is therefore controlled or is even added (up to 0.20 and more) to increase the UTS and yield point.

## Tellurium (Te)

During hot-rolling, tellurium forms a film around the manganese sulphides, tending to leave their globular form unaltered, which is the most recommended for chip removal processes. Free cutting steels with added tellurium (around 0.03%) therefore have a better machinability than the same types without tellurium.

## Titanium (Ti)

Due to its noted affinity to oxygen and nitrogen it is frequently used as a de-oxidant in the production of steels.

It is used in stainless steels with a content proportionate to that of the carbon present since, alloying with the carbon, it forms titanium carbides, thus avoiding the formation of chromium carbides which would reduce the corrosion resistance qualities of the material.