

# Heat treatments

Heat treatment is the thermal change of the metallographic structure of steel by heating and cooling within a certain time to obtain the required properties.

The most common heat treatments in manufacturing fasteners are:

## 1. Annealing

The steel is held at a temperature of just below 721°C for several hours and is then cooled down slowly to make it soft.

The structure changes from hard, lamellar perlite into soft, globular perlite resulting in an optimal condition of the raw material for cold heading.

## 2. Normalizing (Recrystallization)

By heating at 800 – 920°C for not too long time and then cooling slowly, a coarse and thus brittle grain structure due to, for instance, hot rolling or hot forging, especially of thicker pieces, is brought back again in the original fine grain structure. Through this refining, yield point and impact strength are increased without the tensile strength being reduced too much.

## 3. Stress-relieving

By cold deformation internal stresses are induced in the material, increasing the tensile strength but decreasing the elongation.

By heating at between 500 and 600°C for a long time and cooling slowly, most of the cold hardening effect disappears. This heat treatment is applied to cold headed bolts and screws of property classes 4.6 and 5.6.

## 4. Hardening

When steel with minimum C-content of about 0.3% is heated at a temperature above 800°C (depending on the type of steel) and is quenched in water, oil, air or in a salt bath, the very hard but brittle martensite structure is formed.

The achieved hardness depends on the C% (the higher the carbon, the harder the steel) and the percentage of martensite, which, at a certain critical cooling speed, is formed in the core of the material.

So with thinner bolts from unalloyed carbon steel the critical cooling speed will be reached to the core. However with thicker sizes the heat from the core cannot be transmitted to the outside quickly enough and it will be necessary to add alloying elements like boron, manganese, chromium, nickel and molybdenum, which support the through-hardening i.e. decrease the critical cooling speed.

In general, when a type of steel with such a through-hardening is chosen, about 90% martensite is present in the core after quenching. The choice of cooling medium also

influences the cooling speed. Bolts are mainly quenched in oil, because water, which is otherwise more effective, causes too much risk of hardening cracks and warpage.

## 5. Tempering

With increasing hardness, however, the hardening stresses will rise, and therefore the brittleness of the material will also increase. Mostly a second heat treatment, called tempering, must follow as quickly as possible after quenching. For temperatures of up to 200°C only the brittleness will decrease a little; the hardness will barely decrease. Above 200°C the stresses decrease, the hardness diminishes and the toughness is improved.

## 6. Quenching and tempering

This is a combined heat treatment of quenching with high-tempering, at between 340°C and 650°C immediately following. This is the most important and most commonly practised heat treatment for fasteners. An optimal compromise is reached between a rather high tensile strength, particularly a high yield/tensile strength ratio and sufficient toughness, which is necessary for a fastener carrying all kind of external forces to function effectively. The higher property classes 8.8, 10.9 and 12.9 are, therefore, quenched and tempered.

## 7. Decarburizing

By heat treating carbon and alloy steels the danger exists that carbon from the outside of the product is removed by the surrounding atmosphere.

The skin then gets a carbon content that is too low; it is not hardenable and will stay soft.

This means that the screw thread under loading could be slid off. To prevent this, the quenching and tempering of fasteners is always done when the furnace is supplied with a protective gas, which keeps the carbon percentage at the level of the steel type.

## 8. Case carburizing

This heat treatment is the opposite of decarburizing and is carried out in a carbon emitting gas. On the outside of the product a thin layer with an increased carbon content is built up, through which the skin, after hardening, becomes hard and wear resistant, while the core remains tough. This treatment is applied on fasteners such as tapping screws, thread rolling, thread cutting and self drilling screws and chip board screws. Similar heat treatments are carbonitriding, using carbon and nitrogen, and nitriding, only using nitrogen as an emitting gas.

## 9. Induction hardening

For special applications a hard, wear resistant layer is formed without the supply of a gas in a high frequency coil with no contact of the work piece. Mostly only local hardening is executed for the extra protection of weak spots.

Relation between iron-carbon diagram, heat treatment types of steel and mechanical properties

