STANDARD	
ISO : – EN : – DIN : –	

MATERIAL PROPERTIES

of steel bolts, screws and nuts

Heat treatments

OVERVIEW AND DEFINITIONS OF HEAT TREATMENTS FOR FASTENERS

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.

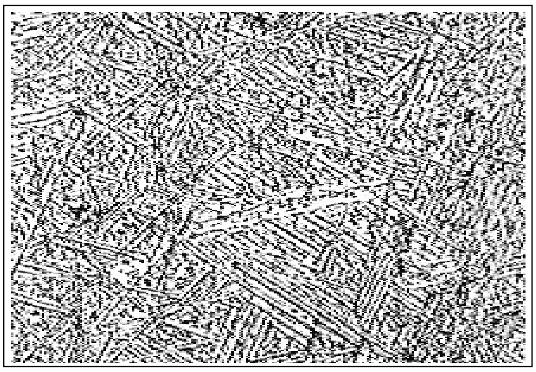
The most common heat treatments in manufacturing fasteners are:

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 a 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 a 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.

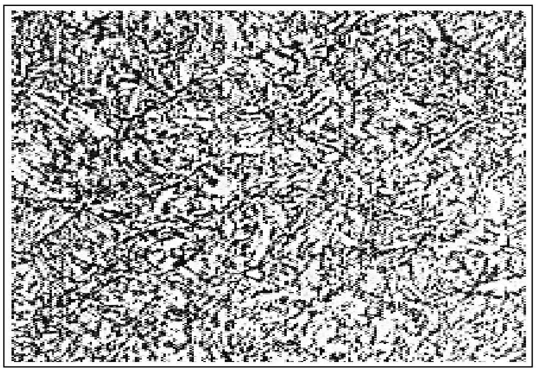


Martensite structure

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° 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.



Structure after quenching and tempering

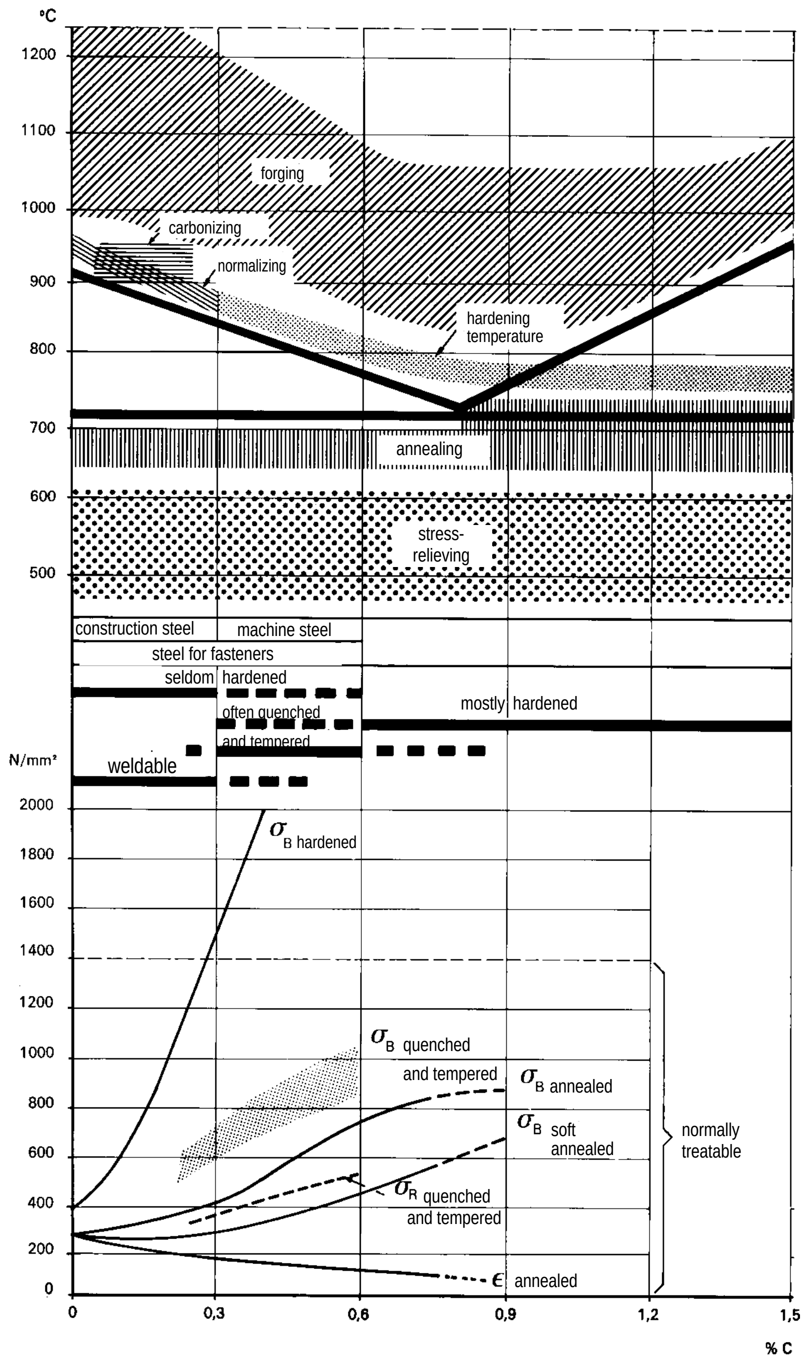
STANDARD	MATERIAL PROPERTIES
ISO : – EN : – DIN : –	**for steel bolts, screws and nuts** Heat treatments

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 workpiece. 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

STANDARD	MATERIAL PROPERTIES
ISO : 898 Part 1 EN : 20898 Part 1 DIN : –	**of steel bolts, screws and studs** Chemical composition

In the table below a specification is given of the steels for the standardized property classes of bolts, screws and studs.
The minimum tempering temperatures are mandatory in all cases.
The chemical composition limits are mandatory only for those fasteners, which are not subject to tensile testing.

Property class	Material and treatment	chemical composition limits (check analysis) % C		P	S	Tempering temperature °C	Examples of commonly used steels for cold forming	
		Min.	max.	max.	max.	min.	Size	Steel designation
3.6 [1])	Carbon steel	–	0,20	0,05	0,06	–	≤ M39	QSt36-2
4.6 [1])		–	0,55	0,05	0,06		≤ M39	QSt36-2, QSt38-2
4.8 [1])							≤ M16	QSt36-2, QSt38-2
5.6		0,15	0,55	0,05	0,06		≤ M39	Cq22
5.8 [1])		–	0,55	0,05	0,06		≤ M39	Cq22, Cq35
6.8 [1])							≤ M39	Cq35, 35B2, Cq45
8.8 [2])	Carbon steel with additives (e.g. Boron or Mn or Cr), quenched and tempered or	0,15 [3])	0,40	0,035	0,035	425	≤ M12 ≤ M22 M24 ≤ M39	22B2, 28B2 35B2, Cq35, Cq45 34Cr4, 37Cr4
	Carbon steel, quenched and tempered	0,25	0,55	0,035	0,035			
9.8	Carbon steel with additives (e.g. Boron or Mn or Cr), quenched and tempered or	0,15 [3])	0,35	0,035	0,035	425	–	–
	Carbon steel, quenched and tempered	0,25	0,55	0,035	0,035			
10.9 [4])	Carbon steel with additives (e.g. Boron or Mn or Cr), quenched and tempered	0,15 [3])	0,35	0,035	0,035	340	≤ M6	35B2, Cq35
10.9 [5])	Carbon steel, quenched and tempered or	0,25	0,55	0,035	0,035	425	M8 ≤ M18 ≤ M39	34Cr4 41Cr4, 34CrMo4, 42CrMo4
	Carbon steel with additives (e.g. Boron or Mn or Cr), quenched and tempered or	0,20 [3])	0,55	0,035	0,035			
	Alloy steel, quenched and tempered [7])	0,20	0,55	0,035	0,035			
12.9 [5]), [6])	Alloy steel, quenched and tempered [7])	0,20	0,50	0,035	0,035	380	≤M18 ≤ M24 ≤ M39	34CrMo4, 37Cr4, 41Cr4 42CrMo4 34CrNiMo6

[1]) Free cutting steel is allowed for these property classes with the following maximum sulphur, phosphorus and lead contents: sulphur: 0,34%; phosphorus 0,11%; lead 0,35%.
[2]) For nominal diameters above 20 mm the steels specified for property class 10.9 may be necessary in order to achieve sufficient hardenability.
[3]) For plain carbon boron alloyed steel with a carbon content below 0,25% (ladle analysis), the minimum maganese content shall be 0,6% for property class 8.8 and 0,7% for property classes 9.8 and 10.9.
[4]) Products shall be further identified by underlining the symbol of the property class.
[5]) For the materials of these property classes, it is intended that there should be a sufficient hardenability to ensure a structure consisting of approximately 90% martensite in the core of the threaded sections for the fasteners in the "as-hardened" condition before tempering.
[6]) A metallographically detectable white phosphorus enriched layer is not permitted for property class 12.9 on any surface subjected to tensile stress.
[7]) Alloy steel shall contain one or more of the alloying elements chromium, nickel, molybdenum or vanadium.

STANDARD	
ISO	: –
EN	: –
DIN	: 267 Part 4 (W)

MATERIAL PROPERTIES

of steel “DIN” nuts

Chemical composition

In the tables below a specification is given of the steels for the standardized property classes of “DIN” nuts e.g. hexagon nuts DIN 555 en DIN 934.

1. NON-CUTTING WORKING

The chemical composition in this table shall also apply to working by chip removal where free-cutting steel is not being used..

Property class	Chemical composition, in % by mass (check analysis) [1]			
	C max.	Mn min.	P max.	S max.
4, 5 and **6**	0,50	–	0,110	0,150
8	0,58	0,30	0,060	0,150
10	0,58	0,30	0,048	0,058
12	0,58	0,45	0,048	0,058

[1]) Chips for the check analysis shall be taken uniformly over the whole cross section.

Thomas steel is not permitted for property classes 8, 10 and 12. "–2" shall be added to the property class code number where Thomas steel shall not be used for manufacturing property classes 5 and 6 nuts.
Nuts assigned to property classes 8 (exceeding size M 16) and 10 shall be hardened and tempered if the proof load values as required on page 15-5-4 cannot be attained in any other way. Hardening and tempering is necessary for all hot forged nuts (exceeding size M 16) with a nominal 0,8D nut height (DIN 934) and for property class 10 nuts for applications at temperatures above + 250°C. The values specified in DIN ISO 898 Part 2 shall apply as the hardness values for hardened and tempered nuts.
Nuts assigned to property class 12 shall be hardened and tempered. If necessary, alloy steels shall be used for manufacturing nuts of property classes 10 and 12.

2. MACHINING FROM FREE-CUTTING STEEL

Property class	Chemical composition, in % (by mass (check analysis) [1])			
	C max.	P max.	Pb max.	S max.
5 AU and **6 AU**	0,50	0,12	0,35	0,34

[1]) Chips for the check analysis shall be taken uniformly over the whole cross section.

Hexagon nuts in accordance with DIN 555, DIN 934 and slotted castle nuts in accordance with DIN 935 assigned to property classes 5 AU and 6 AU shall be specially marked as specified on page 15-5-4, where they are made from free-cutting steel with the chemical composition above.

STANDARD	
ISO	: 898 Part 2
EN	: 20898 Part 2
DIN	: –

MATERIAL PROPERTIES

of steel “ISO” nuts

Chemical composition

In the table below a specification is given of the steels for the standardized property classes of “ISO” nuts, e.g. hexagon nuts ISO 4032 and ISO 4034.

Property class		Chemical composition limits (check analysis), %				Examples of commonly used steels for cold forming	
		C max.	Mn min.	P max.	S max.	Size	steel designation
4 [1]), **5** [1]), **6** [1])	–	0,50	–	0,110	0,150	all	QSt36-2
8, **9**	**04** [1])	0,58	0,25	0,060	0,150	≤M16	QSt36-2 Cq 22
10 [2])	**05** [2])	0,58	0,30	0,048	0,058	>M16	Cq 35
12 [2])	–	0,58	0,45	0,048	0,058	all	Cq 35 Cq 45

[1]) Nuts of these property classes may be manufactured from free-cutting steel unless otherwise agreed between the purchaser and the manufacturer. In such cases the following maximum sulphur, phosphorus and lead contents are permissable:
sulphur 0,34%; phosphorus 0,12%; lead 0,35%.

[2]) Alloying elements may be added if necessary to develop the mechanical properties of nuts.

Nuts of property classes 05, 8 (Style 1 > M16), 10 and 12 shall be hardened and tempered.