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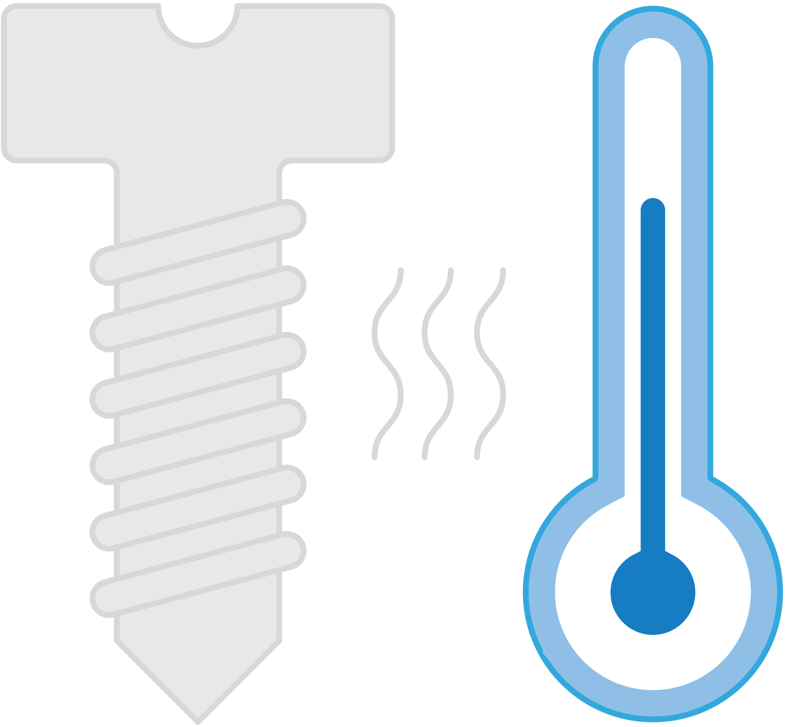

Heat treatment of fasteners

White Paper

Heat treatment of fasteners

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The recommendations and advices mentioned must be adequately checked by the reader in practical use and be approved as suitable for its application. Changes reserved.

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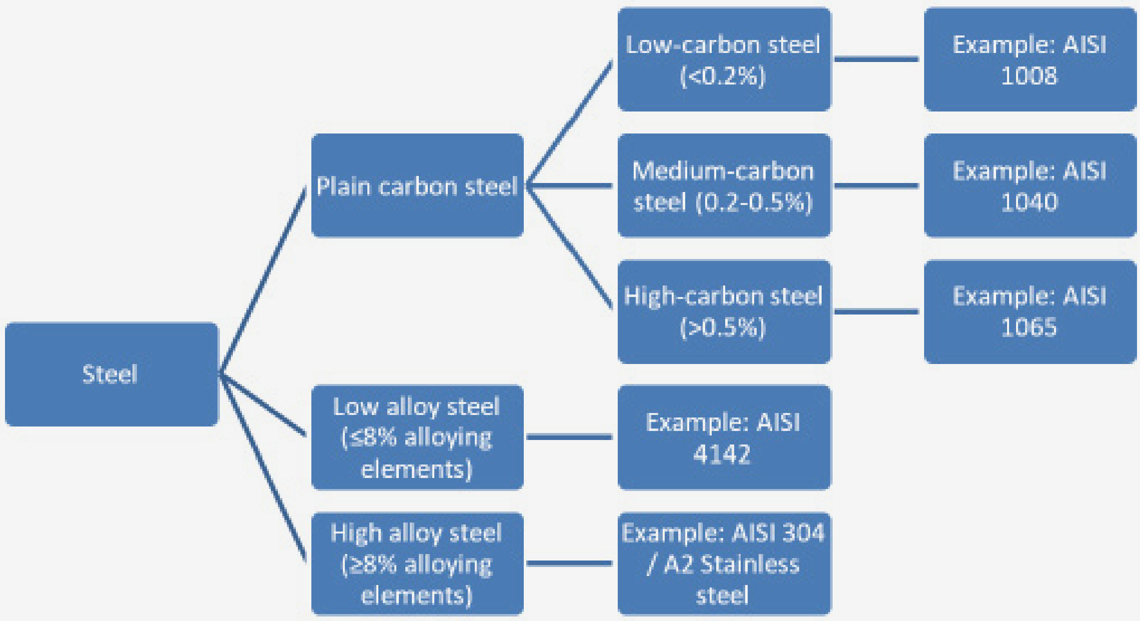
HEAT TREATMENT OF FASTENERS

Introduction

Fasteners come in a variety of materials. The choice of materials will be decided by the application and environment. Steels and stainless steels are the most popular material options however aluminum and other non-ferrous alloys are also available. Depending on the material selected, different processes are required to obtain the proper mechanical properties. Heat treatment is a process used to increase mechanical strength, ductility, toughness and, for some alloys, its resistance to corrosion. The following sections will go thru a few examples of materials needing a heat treatment before being put in service.

Steels

The most used material group in the fabrication of fasteners is carbon and alloy steels. Steels are classified as:

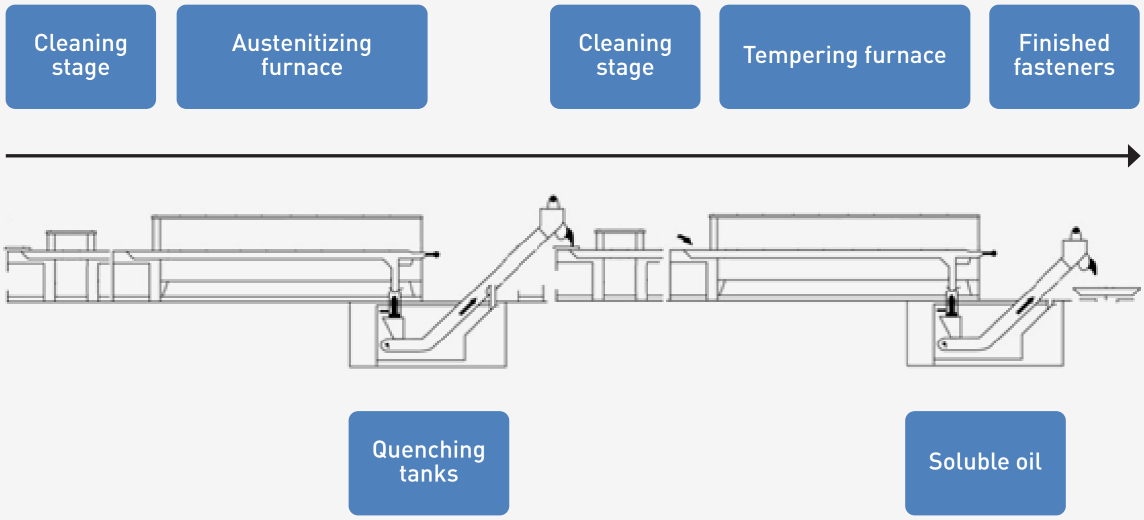


Classes of steel

Before the fastener fabrication step, a subsequent heat treatment is performed on the steel wire to facilitate cold heading. This heat treatment is called spheroidizing. It softens the steel, allows improved cold forming and reduces tooling cost. Once the fastener is formed, the steel used has slightly increased in strength because of the mechanical deformation however is not capable of meeting the property classes and grade as prescribed in specifications for high strength (grade 8 / class 10.9 / class 12.9).

The newly formed fasteners will go thru a 2-step heat treatment process:

Austenitizing and tempering

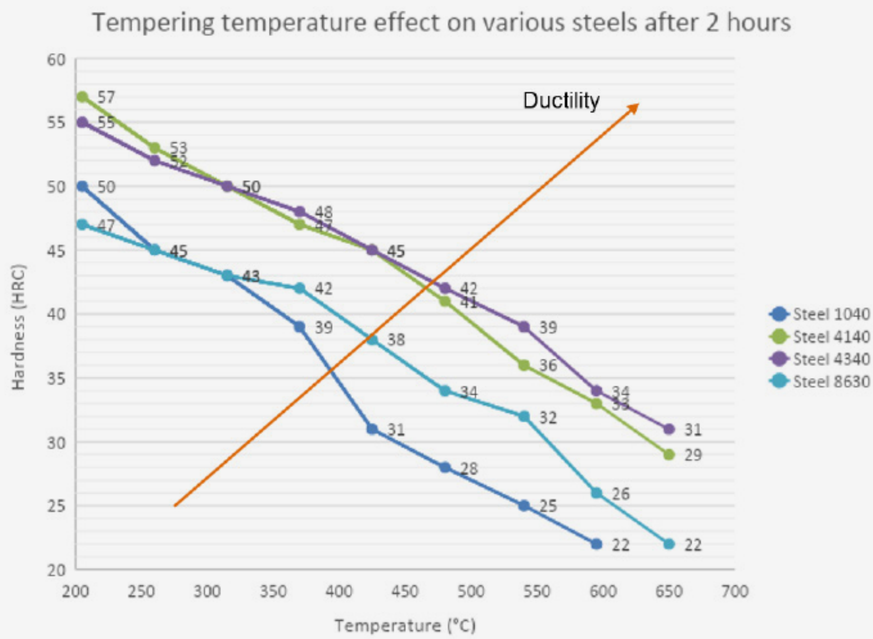


Austenitizing and tempering process

This is the most common heat treatment process used in industry. The austenitizing process involves heating up the fasteners typically between 815-870°C, holding a determined duration and then quenching to produce a harder/stronger micro-structure called martensite. The most common quenchant medium are either oil or water. The formation of martensitic microstructure leads to:

- higher strength
- residual stresses
- less ductility
- lower toughness

A subsequent tempering heat treatment is then performed. Tempering will slightly decrease the fastener hardness, help increase ductility, improve toughness and dimensional stability. By adjusting tempering temperatures and duration, the desired hardness can be obtained. Figure 1 shows a few examples of tempering temperatures affecting the final hardness of 4 different steels. The required final hardness can be controlled by tempering temperatures and duration.



Tempering temperature effect (Source: ASM Handbook: Volume 4 – Heat treating)

Stainless steels

Stainless steels are classified as iron-based alloys having at least 10.5% chrome. They can be grouped under the following 5 types (according to ISO 3605-1):

Types	Base chemistry	General properties
Austenitic	Minimum 16% chromium and 6% nickel	Moderate temperature and corrosion resistance
Ferritic	15 to 18% chromium / small amounts of carbon	Moderate corrosion resistance
Martensitic	10.5 to 18% chromium / up to 2.5% nickel / high levels of carbon	High strength and moderate corrosion resistance
Duplex	19 to 26% chromium / 1 to 8% nickel / up to 4.5% molybdenum	Higher strength and corrosion resistance than austenitic grades
Precipitation-hardening	11.75 to 17% chromium / important levels of nickel and / or aluminum	High strength and good corrosion resistance

Austenitic grades

Austenitic grades like 304 (18-8, A2) and 316 (A4) cannot be hardened by a heat treatment. This type of stainless steel will hardened only during fabrication processes like cold forming and thread rolling. This hardening process is called cold working. However, in some cases, a heat treatment is done to help regain corrosion properties and remove residual stresses from other manufacturing processes like welding. Cold working also increases magnetic permeability - a heat treatment can be performed to remove cold working effects of items requiring low magnetic permeability.

Ferritic grades

Ferritic grades like 430 can only be slightly hardened by cold working. Heat treatments will not increase the strength of this type stainless steel. However, the cold working process during fabrication will reduce ductility and therefore trigger the need to a full anneal heat treatment to regain it.

Martensitic grades

Martensitic grades like 410, 431, 440A/B/C/F are heat treated in the same way as carbon and alloy steels. These grades are quenched in either oil or air.

Duplex grades

Duplex grades like SAF 2205® (UNS S31803) are used when high strength (twice the yield strength then typical austenitic stainless steels) and higher corrosion resistance to chloride stress corrosion cracking is required. This grade consists of a mixture of two microstructures: ferrite and austenite. The heat treatment is an anneal.

Precipitation-
-hardening grades

Precipitation-hardening grades consist of 3 types: low carbon martensitic, semi-austenitic and austenitic. Each type has its unique heat treatment recipe to achieve the desired mechanical and corrosion properties. Precipitation-hardening is a heat-treatment step that increases the materials strength. This type of heat-treatment can also be performed on other alloys like aluminum, titanium, etc.

Aluminium

Aluminum alloys can be classified as non-heat-treatable and heat-treatable. The non-heat-treatable aluminum corresponds to the 1XXX, 3XXX, 4XXX, 5XXX series. Most of these will rely on the work hardening effect of cold forging and thread forming to gain strength. As the strain rate increases, strength is increased.

The heat-treatable aluminum series 2XXX, 6XXX and 7XXX would require a solution treatment and quench followed by a precipitation heat treatment (aging) to obtain the desired mechanical properties. A solid solution treatment causes alloying atoms to place themselves between the aluminum atoms without forming compounds. The following are the most common types of alloys and heat treatments:

Alloy and temper	Heat treatment [1]	Resulting hardness (HRB) [2]	Tensile (MPa) / Yield (MPa) / Elongation (%) minimum - machined specimen [2]
2024-T4	Solution treatment at 495°C and naturally aged (room temperature)	70-85	427 / 275 / 10
6061-T6	Solution treatment at 530°C and artificially aged at 160°C	40-50	290 / 241 / 10
7075-T73	Solution heat treated at 490°C then specially artificially aged (2-stage: 107°C + 177°C)	80-90	469 / 386 / 10

Titanium

Titanium alloys are used when corrosion protection, strength and weight saving is important. Weight savings is 40% of steel with equal strength depending on the titanium grade. These properties make the use of this alloy an easy choice for the aerospace and automotive racing industry for example. Grade 5 is one of the most popular titanium grades used in the fabrication of fasteners. The following table details the heat treatment and mechanical properties of grade 5 titanium:

Alloy and temper	Heat treatment [1]	Resulting hardness [2]	Tensile (MPa) / Yield (MPa) / Elongation (%) minimum - machined specimen[2]
Grade 5 (Ti-6AL-4V)	Solution treat between 955-970°C for 1 hr., water quench and age for either 4-8 hr. between 480-595°C or 2-4 hr. between 705-760°C	30-39 HRC	896 / 827 / 10

[1] ASM Handbook – Volume 4
[2] ASTM F468

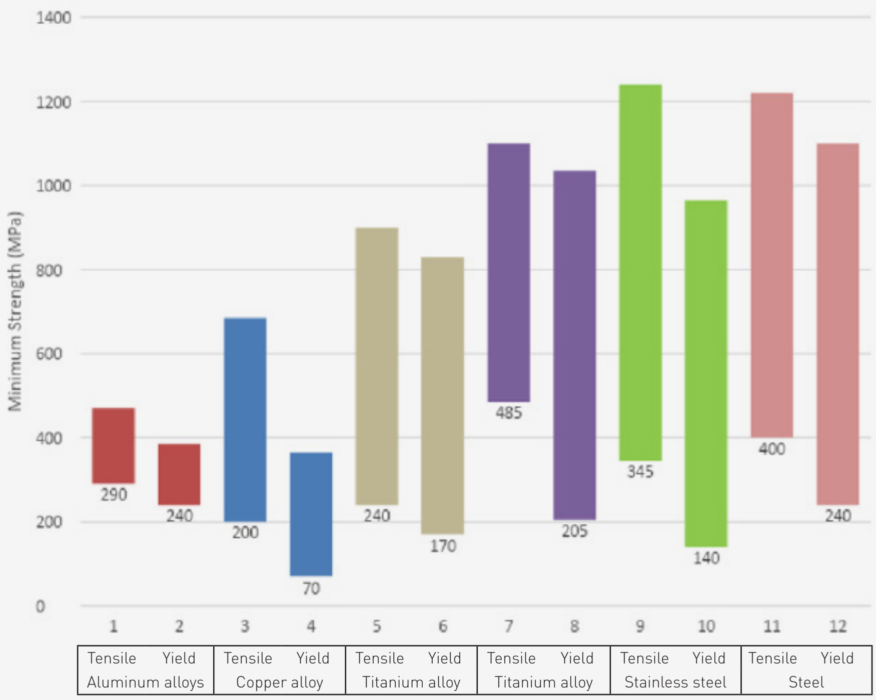
Nickel alloys

Nickel based alloys are employed where high corrosion and heat resistance is required. Examples of applications are aircraft and land-based gas turbine engines, and cryogenic tankage[5]. The following Inconel® 718 is an example of an alloy used in the fabrication of fasteners. This material can be used in applications from -250 to 700°C.

Alloy and temper	Heat treatment [1]	Hardness minimum [2]	Tensile (MPa) / Yield (MPa) / Elongation (%) minimum - machined specimen[2]
Inconel® 718 (AMS 5662)	Solution treat at 980°C for 1 hr., air cool and age to 720°C, hold 8 hr.; furnace cool to 620°C, hold until furnace time for entire age-hardening cycle equals 18 h; air cool.	331 HBW	1275 / 1034 / 12

[3] ASM Handbook – Volume 4
[4] ASTM F468
[5] http://www.specialmetals.com/documents/Inconel%20alloy%20718.pdf

The following graph shows minimum strength ranges by alloy:



Minimum strength ranges by alloy

Different alloys require different heat treatments to obtain desired properties. Some alloys used in the fabrication of fasteners can be used as is. However, when high strength properties are required for an application, a proper heat treatment needs to be properly performed. For more information regarding fastener heat treatments, please don't hesitate to contact Bossard.

References:

1. ASM Handbook – Volume 4
2. ASTM F468
3. ASTM F593
4. ISO 898-1
5. www.specialmetals.com

If you need further assistance or have special finish requirements, please check out our contact page at **www.bossard.com** and talk to your nearest Bossard customer service representative.