Adhesives are best handled as a pre-applied material. While they may be applied "on-line", the process is messy to operators and surrounding surfaces. The compounds today can be doctored to meet the application's conditions of breakaway, holding, cure time, and so forth. Many compounds cure in minutes and some are not hardened for as much as 24 hours (a condition that makes them unusable on fast assembly lines). They have low torques but exhibit very high breakaway torques after fully cured. However, once broken free they have little prevailing torque. A major plant problem is the fact that adhesives cannot be quality control checked for proper torque as they harden slowly and checking later breaks the adhesive bond of the joint. Summation of the good and bad about these locking elements is tabled below:

	Plastic Patch	Adhesive Patch
Installation Torque	No	Low
Breakloose Torque	Low	High
Resist Vibration	Good	Poor
Reuseable	Yes	No
Inspectionable	Yes	No
Heat Area Usable (250F+)	No	Yes (some)
Time to Partial Cure	N/A	1-4 minutes
Time to Full Cure		24-72 hours

Why use a locknut? The answer seems to be that the extra measure of security is worth the extra cost. The forces that a product sees in service are unknown and unexpected despite the best guess and testing of engineering. The costs of repair, replacement and legal complications outweigh any immediate monetary advantages. Th overall impact of adding a locking feature can be lessened with the selection of the right type to fit the application.

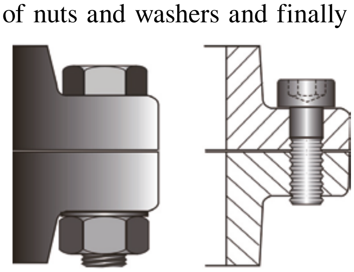
The Steels for Screws and Nuts Production and Their Heat Treatment

by Jozef Dominik

Introduction

Steels and their heat treatment determine decisively the final mechanical, physical and chemical characteristics of bolted joints such as their hardness, strength, tenacity, weldability and resistance to corrosion, etc. In the past, the strength of constructions was realised by their increased dimension. Thanks to the development of new alloy structures, the strengths from 800 to 1200 MPa are nowadays commonly reached by heat treatment. The advantages of the application of the screws at higher strength follow from Fig. 1. From this figure, it is clear that the replacement of the unhardened hexagonal screw DIN 931 at the strength 5.6 for the screw of DIN 912 in strength class 10.9 enables to reduce its size from M18 to M10. Logically, the size of the flange is smaller, with the saving of nuts and washers and finally the simplification of the assembly and logistics.

Fig. 1



M18 cl. 5.6 M10 cl. 10.9

1. Heat Treatment Procedure

There are various kinds of heat treatment. The most important operation is hardening, i.e. quenching and tempering to a certain temperature (Fig. 2).

The principle lies in the heating of steel parts at hardening temperature ca 870°C (1600°F) in continuous furnaces with the protective atmosphere with sequential immediate cooling down in oil bath and tempering at ca 370°C (700°F) for two hours. During this process the phase shift $\gamma \rightarrow \alpha$ occurs

Fig. 2

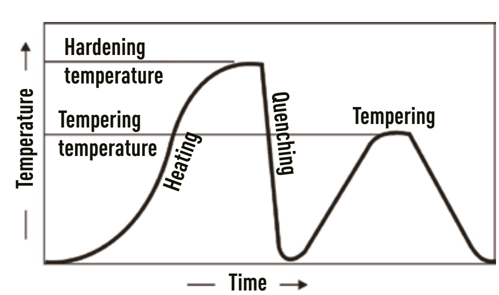


Table 1 The Mechanical Properties of Steel Bolts (ISO 898-1)

Property			Strength class											
			3.6	4.6	4.8	5.6	5.8	6.8	8.8		9.8	10.9	12.9
									d≤16mm	d≥16mm			
R_m [Mpa]	Nominal value		300	400		500		600	800	800	900	1000	1200
	min.		330	400	420	500	520	600	800	830	900	1040	1220
Vickers [HV]	min.		95	120	130	155	160	190	250	255	290	320	385
	max.		250						320	335	360	380	435
Brinell [HB]	min.		90	114	124	147	152	181	238	242	276	304	366
	max.		238						304	318	342	361	414
Rockwell [HR]	min.	HRB	52	67	71	79	82	89	-				
		HRC	-						22	23	28	32	39
	max.	HRB	99.5						-				
		HRC	-						32	34	37	39	44
R_{el} [Mpa]	Nominal value		180	240	320	300	400	480	-				
	min.		190	240	340	300	420	480	-				
$R_{p\,0,2}$ [Mpa]	Nominal value		-						640	640	720	900	1080
	min.		-						640	660	720	940	1100
A [%]	min.		-	22	-	20	-	-	12	12	10	9	8
Impact strength [J]	min.		-			25	-		30	30	25	20	15

resulting in martensitic microstructure. This procedure is responsible for reaching the strength from 8.8 (6.8) to 12.9 (Tab.1) depending on the steel type.

Besides the hardening temperature, the speed of quenching (cooling down) is also important. As shown in the transformational diagram in Fig. 3, when the speed of cooling down (red curve) is slow, the mixture of austenite + bainite + martensite arises in the final microstructure. The cause can also be too long initial phase of cooling down when the so called "steam cushion" created on the parts' surface prevents the heat transfer. Therefore, it is important to ensure that the quenching medium will be circulating in the vessel.

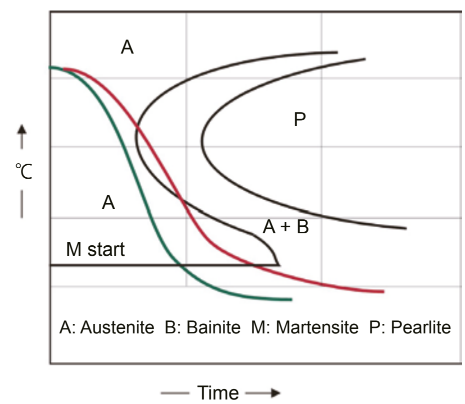


Fig. 3

To prevent surface oxidation or decarburization when heating to the hardening temperature, it is necessary to use protective atmosphere with the appropriate carbon potential, relevant to the content of the carbon in the steel. The protective atmospheres are produced in special generators which are the part of the hardening line, consisting of continuous hardening furnace, quenching tank, washing machine, continuous tempering furnace and the already mentioned generator of the protective atmosphere. There are several types of protective atmospheres, and they are exothermic, endothermic or inert which is essentially pure N2.

The common hardening and tempering is not the only way of increasing the screws strength. Self-cutting and self-drilling screws are surface-hardened either by carburization, i.e. case hardening or inductively (Fig. 4).

Both cases serve to strengthen only surface layers of the parts while the core remains in original unhardened state. The ways of surface heat treatment have such an advantage that their products are positive pressure stresses on the surface of the processed parts.

The most modern methods of surface strengthening use laser or electron beam. Their advantage is the absence of the hardening medium because the speed of cooldown is realised by conducting the heat into the cold core of the part. Besides this, the speed of parts heating is so fast that their surface does not oxides and therefore no protective atmosphere is necessary. However, these methods are hardly ever used in production of fasteners.

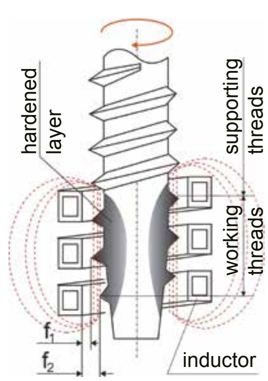


Fig. 4

2. Corrosion-resistant Stainless Steels for Production of Screws and Nuts

Stainless steel plays the significant role in the theory and practice of mechanical joining from the aspect of corrosion-proof protection. Their share within the production of fasteners is not negligible and the consumption has an increasing tendency. They are divided into austenitic, martensitic and ferritic according to the predominant component in the microstructure (Fig. 5).

The most used group of stainless steels is austenitic. The basic system of alloying is created by the combination of Cr – Ni or Mo. Nickel is able to postpone the beginning of the phase shift $\gamma \rightarrow \alpha$ (Ms - martensitic start) towards the temperatures below the freezing point. Therefore, these steels are in austenitic state in normal temperatures and it is not possible to harden them by common methods of the heat treatment. The increased strength is possible to achieve only by the mechanical cold hardening of the surface (Fig. 6) up to the values 800N/mm^2 while the commercial values are around 500N/mm^2 - the natural state an 700N/mm^2 – mildly mechanically hardened.

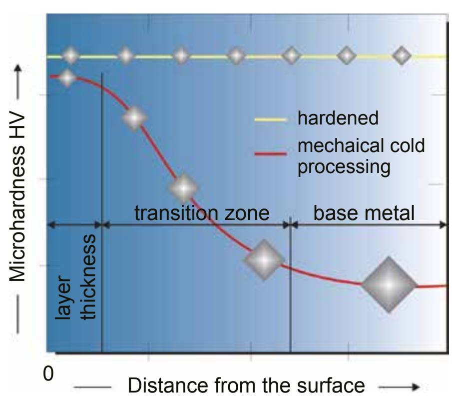
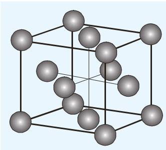
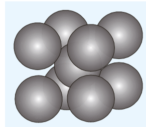
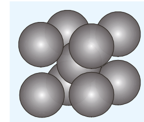
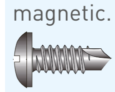
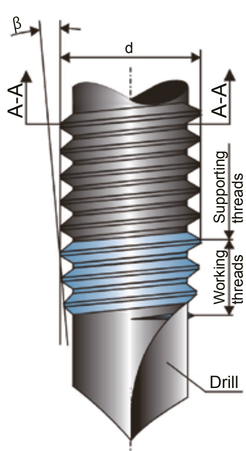
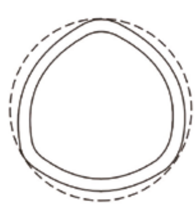


Fig. 5

Fig. 6 Stanless Steels for Production of Screws and Nuts

Austenitic A1 - A2 - A3 - A4 - A5 (γ – Fe)	Martensitic C1 - C3 - C4 (α – Fe)	Ferritic F1 (α – Fe)
 Solid solution of C in FCC Fe	 Solid solution of C in BCC Fe	
Content: ca. 18% Cr and 8% Ni. For better corrosion resistance, Mo is added (group A4). Non-hardening, non-magnetic. Higher strength is achieved by mechanical cold processing.	Stanley steels of martensitic type are hardening. They are magnetic. Typical example: 	Content: ca. 17% Cr, 0,02% C. Little tough, Rarely used.





Section A-A

Fig. 7

The stainless steels of the martensitic type are the only ones of this category which can be classically hardened and tempered. It is necessary to exclude higher fragility.

The combination of stainless and structural steel is worth mentioning. This so-called bi-metallic version is used especially with self-drilling screws where the body of the screw is made of austenitic stainless steel on which a hardened drill bit is soldered. However, the economic advantages of such a combination are partially suppressed by the increased susceptibility to the corrosion located on the boundary of two various steel types.

There is an interesting variant in the state of the development. It is characterized by the thread forming screw with triangular diameter of the thread part, commercially known as Taptite to which a drill bit is soldered (Fig.7), similarly as in the case of bi-metallic screws.

Advantages:

- elimination of a separate drilling operation and associated costs,
- a proper hole size is always drilled,
- no problem with positioning during automatic assembly,
- exclusion of collision at the entering of the screw into the assembly hole,
- bigger length can be an advantage in the case of short screws ($l \leq d$) which could get stuck in the feeder canal during their automatic transporting from vibrational container towards the assembly place.

3. Conclusion

As shown, the bolted joint steels and their heat treatment are responsible for the final screws and nuts characteristics. The ISO standard 898-1 (Tab. 1) does not prescribe a specific steel type but only the product characteristics. The current offer of the suitable steels and their heat treatment is sufficient and therefore the constructor can choose the optimal alternative. He is responsible for whether he chooses volume or face hardening or whether he decides to use construction or stainless steels. It is important to know the conditions in which the bolted joints will work in operation.