When Stainless Steel Fasteners?

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Introduction

Stainless steels play a significant role in the theory and practice of mechanical fastening. Their involvement is not negligible within the fasteners production and their usage is increasing.

Stainless steels are used to produce fasteners, designated for working in difficult climate conditions with the increased risk of corrosion. From the strength point of view they do not reach the quality of hardened steels **(Fig. 1)**, despite there is the number of practical applications, where they are irreplaceable.

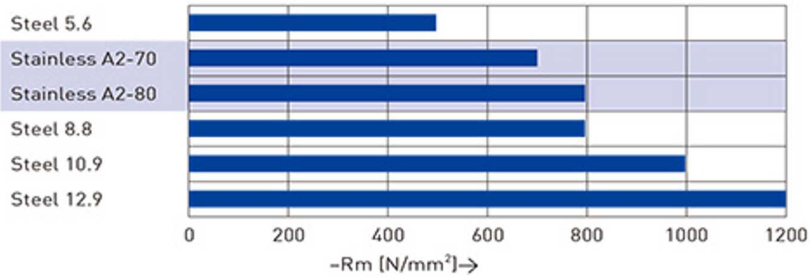
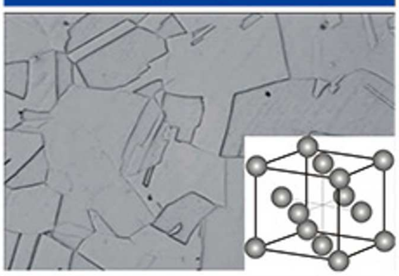
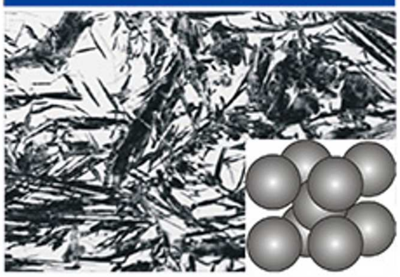


Fig. 1. Strength (Rm) of various steels.

According to dominant ingredient in microstructure, they are divided into: austenitic, martensitic and ferritic, as it is shown in **Table 1**.

Table 1. Stainless Steels for the Production of Bolts and Nuts

Austenitic **A1 - A2 - A3 - A4 - A5**	Martensitic **C1 - C3 - C4**
	
It contains about 18% Cr and 8% Ni. For higher corrosion resistance there is added Mo (group A4). These steels cannot be hardened. Higher strength is reached by mechanical hardening only. They are paramagnetic.	Martensitic stainless steels are the only type of stainless steels that can be hardened. They are ferromagnetic. They contain about 12% Cr, 0.12% C and the rest is Fe. Typical examples are self-tapping screws Marutex®
Ferritic stainless steels contain about 17% of Cr, and 0.02 % of C. Low toughness, they cannot be hardened. In practice, they are rarely used.	

A. Austenitic Steels

They represent the most widely used group of stainless steels. The basic alloying system is comprised of Cr, Ni or Mo. Nickel is able to move the inception of phase transformation $\gamma \rightarrow \alpha$ to the temperatures below freezing point and therefore these steels are in austenitic state under normal temperatures and they cannot be hardened by common procedures of heat treatment. The increased strength is possible to provide with mechanical cold-strengthening to the values 800 N/mm2 while commercial values are 500 N/mm^2 – natural state and 700 N/mm^2 – slightly mechanically strengthened. The austenite, with its cubical, square centered elementary grid, is paramagnetic under normal conditions. After cold-forming, it can reach specific magnetism, expressed by magnetic permeability μ_r **(Table 2)**.

Table 2.
Magnetic Permeability of Austenitic Stainless Steels

Type of steel	A2	A4	F1
Permeability μ_r	~1,8	~1,05	~3,5

Note: Steel at zero magnetism is μ_r = 1.

Austenitic stainless steels are divided into the following subgroups A1 – A5:

A1	Corrosion-proof steel with S ingredient for improvement of workability.
A2	Cr-Ni steel with excellent resistance to corrosion. It is also suitable for the production of food-processing machines. It is low temperatures resistant.

A4	Cr-Ni-Mo steel resistant to corrosion and acids. It is often used for the production of components exposed to the influence of marine water and its vapors. Equally, it is suitable for food-processing purposes and for low temperatures.
A3, A5	Austenitic stainless steels which are hardened by titan, niobium or tantalum to suppress the occurrence of inter-crystalline corrosion.
With the exception of A1 group, other austenitic stainless steels are quite easy/well to weld.	

B. Martensitic Stainless Steels

They represent the only type of the stainless steels that are able to be hardened, i.e. quenched and tempered after preceding austenitic process. The final microstructural component is a martensite, i.e. α – a phase with cubical, spatially centered elementary grid. They are ferromagnetic; the well-known stainless self-tapping screws Marutex® are made of it **(Fig. 2)**.

Fig. 2. Self-tapping screws made of martensitic stainless steel.

C. Ferritic Stainless Steels

The final microstructure is a ferrite, i.e. – a phase with cubical, spatially centered elementary grid. It has a low content of C; therefore these steel cannot be hardened. The mechanical strengthening can provide the increased strength. They are ferromagnetic. In practice, they have not a significant function and they are rarely used.

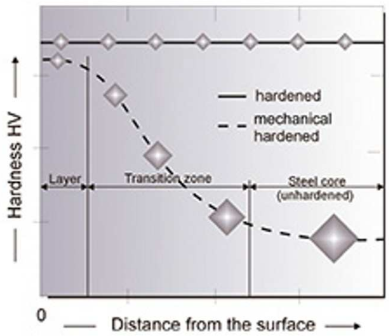


Fig. 3. Micro-hardness progress

The general strength at all types of stainless steels is the strength at their natural state (from 500 to 600 N/mm^2). The increased strength (from 700 to 800 N/mm^2) at martensitic steels can be reached by their hardening and mechanical cold-strengthening at austenitic and ferritic steels. While in the case of hardening, there originates homogenous microstructure within the whole content without the hardness gradient, after mechanical strengthening there is increased hardness located only into the area of surface layers and a so-called core remains in its original, natural state **(Fig. 3)**. The advantage of this method is the existence of convenient pressure stressed on the thread surface.

The Use and the Risks

The stainless steels for fasteners are regulated by the ISO norm 3506. The general alloying element is Cr, which is characterized by high affinity to oxygen; therefore it creates very quickly a thin, transparent oxidized layer on the surface of steel when in contact with air. This layer fulfils the function of passivation coating and prevents corrosion. In other words, without the oxygen the stainless steels are not resistant to corrosion. The increased resistance to corrosion can be reached by adding Ni and Mo. The formation of this passivation coating can be artificially induced by immersion into HNO_3 at 20 to 40°C within 10 to 20 minutes.

In most of the cases, the above mentioned passivation coating provides sufficient resistance to corrosion of steel parts, despite that neither stainless steels nor any other steels represent panacea for corrosion. Under specific conditions, the corrosion can cause catastrophic consequences.

As it is illustrated in **Table 3**, stainless Cr-Ni steels are almost defenceless against the effect of Cl-. The indoor swimming pools are the typical example of it; they are saturated with aggressive vapours of Cl- from chlorinated lime, which is added there due to disinfection of water. These vapours wash the surface of steel components and block the protective passivation coating formation there.

In the case of the air sufficiency, stainless steels, at local mechanical surface damage **(Fig 4)**, can regenerate damaged area very quickly and can still fulfil the function of corrosion-proof protection.

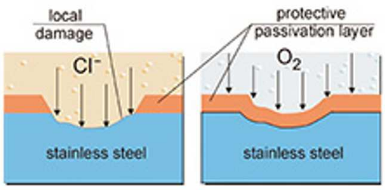


Fig. 4. Auto-regeneration of stainless steel surface

Table 3. Resistance of material

Environment \ Material	Zn	Ms 63	Cu	Alloyed steels	Stainless Cr-Ni 18/9
	Reduction of material [µm/year]				
Indoor	1 ÷ 3	4	2	60	< 2
Outdoor	6	4	2	70	< 2
Industrial atmosphere	6 ÷ 19	8	4	170	< 2
Seaside air	2 ÷ 15	6	3	170	< 2
Sea water	90	15 ÷ 100	15 ÷ 30	170	< 2
HCl	nonresistant	nonresistant	30	nonresistant	**2100**
H_2SO_4	nonresistant	15 ÷ 150	8	nonresistant	< 2
NaOH	nonresistant	75	8	relatively resistant	~ 5

Another example of the stainless steel corrosion is inter-crystalline one, as illustrated in **(Fig. 5)**. It occurs when Cr diminution of steel solid solution (matrix) predominantly in the area of grains limits under the critical value as a consequence of Cr-carbides excretion while a slow cooling from forging or welding temperature or by the result of high content of C within steel **(Fig. 6)**. The higher content of C, the more susceptible to inter-crystalline corrosion steel is.

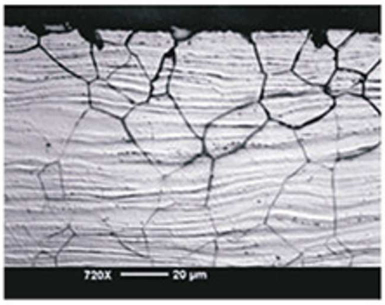


Fig. 5. Inter-crystalline corrosion of stainless steel (Wikipedia)

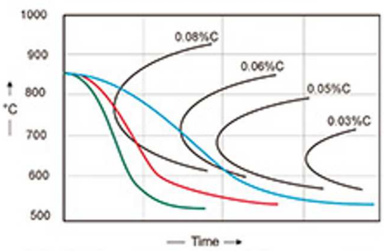


Fig. 6. Transformational diagram of stainless steel

Security measures:

1. To increase the rate of cooling from forging or welding temperature by the immersion into liquid. The rate of cooling cannot be too fast, in order to prevent causing cracks.
2. The stabilization of steels by Ta, Nb or Ti alloying (steels A3, A5)
3. The content of C should not exceed the value 0.05% at the hot-forging steels.

Of course, the corrosion occurring at simultaneous tensile loading cannot be neglected. This situation can occur, e.g. when the seating surface is not perpendicular to the screw axis **(Fig. 7)**. The caused crack under the head is easily available to aggressive components of surrounding environment. It is a very dangerous case because the crack is not visible to the naked eye and usually ends with tearing off the head of a screw.

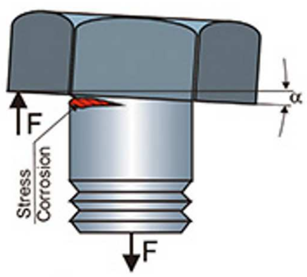


Fig. 7. The crack under the head of a screw

When contributing about the risks of stainless steels use, so we cannot omit their unpleasant tendency to "cold-welds" within the incorrect material combination of the screw and the nut **(Fig. 8)**. The disassembly of such a joint is practically impossible with the use of the common tools. The effective precaution lies in application of special pastes on the thread before assembly.

Fig. 8. Cold-weld on the nut A2

Conclusion

Stainless steels have their indisputable practical role and in many cases, they are irreplaceable within the technology of mechanical joining. The evidence of it is visible on the increasing proportion of such fasteners production. In no way, they cannot be considered as a universal panacea against corrosion. As it was shown, they have their specific characteristics, which is necessary to respect; only then, they can fulfill their basic function due to which they were developed. ■