Introduction

The corrosion according to ISO 9223 – Corrosion of Metals and Alloys is defined as the process of progressive destruction especially of metal materials by the effect of their chemical and/or electrochemical reactions with surrounding gaseous, liquid or solid aggressive environment which causes the loss of the products' functional characteristics. This is cancer which robs the individual countries ca. 4% of gross social product, according to the experts' opinions. Even the well-known expert on tribology, prof. Peter Jost in his colossal work The Jost Report said that corrosion, friction and wear cost the UK huge sums of money every year. From the global aspect, it is about astronomical sums which have significantly progressive tendency caused by the increasing aggressiveness of the environment (Tab. 1).

Rusty Nuts and Bolts - Double Costs

by Jozef Dominik

Table 1
Material loss per a year in μm

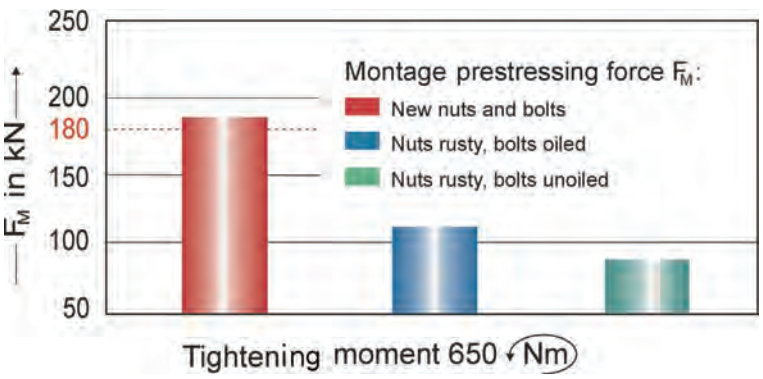
Environment	Material			
	Zn	Brass	Copper	Non-alloy steel
Country air	1 - 3	≤ 4	≤ 2	≤ 80
City air	≤ 6	≤ 4	≤ 2	≤ 270
Industry air	6 - 20	≤ 8	≤ 4	≤ 170
Sea air	2 - 15	≤ 6	≤ 3	≤ 170

(Fig. 1)

The Corrosion of Bolted Joints and Its Consequences

The corrosion cannot be prevented as it is generally known as the nature of the corrosion process. By using the appropriate precautions it is possible to eliminate the losses to the acceptable extent. It is related to the bolted joints in full measure (Fig. 1) because there is a double reason for that. The corrosion does not only cause standard material disruption in this case but it also influences negatively the tightening conditions (Fig. 2). The increased friction coefficient of the corroded screws and nuts is the reason for it. As it is shown in the Sankey's diagram in Figure 3, the whole input tightening moment M_M is effectively used only by a little part M_{ef} for creating necessary pre-stress. The rest is consumed to overcome the friction between the threads and on the contact surfaces under the screw head and the nut and it transforms to the heat.

(Fig. 2)



(Fig. 3)

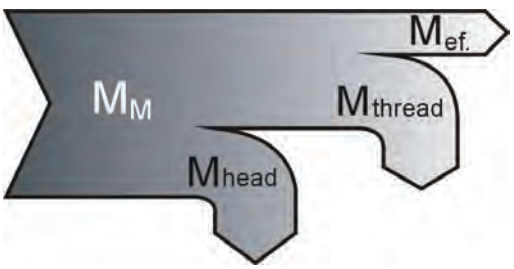
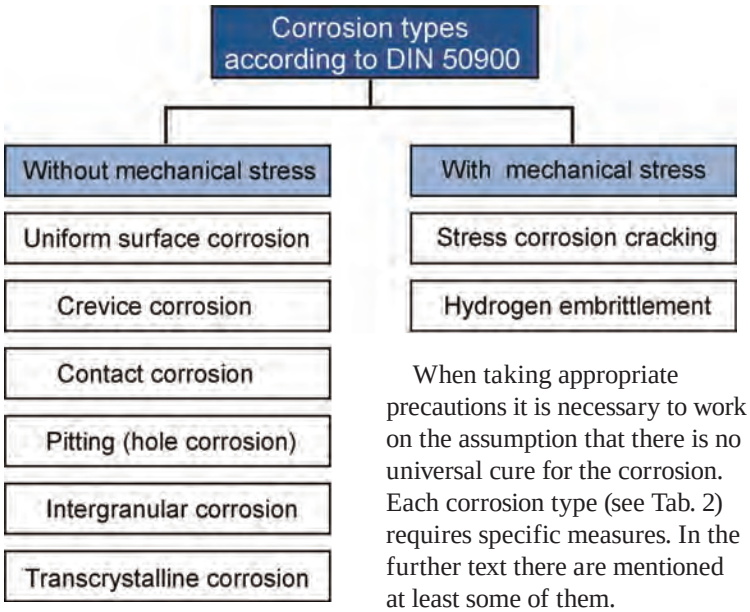


Table 2



When taking appropriate precautions it is necessary to work on the assumption that there is no universal cure for the corrosion. Each corrosion type (see Tab. 2) requires specific measures. In the further text there are mentioned at least some of them.

Uniform Surface Corrosion

Uniform surface corrosion of the bolted joints (Fig. 1) is the least dangerous of corrosion because it invades the parts' surface uniformly and is visible to the naked eye. It results from the effects of atmospheric humidity and aggressive components such as Cl- a SO4--. Paradoxically, sometimes it is even useful because it secures the bolted joints against the spontaneous decay.

Precautions:

- protective coating, such as Zn, Cr, etc.
- stainless steel
- ventilation
- regular visual control, when needing brushing or changing in new

Crevice Corrosion

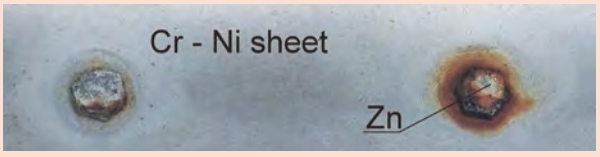
Every slit (boundary of contact sites) absorbs, by the effect of capillary forces, humidity. The result of this process is typical, russet (red-brown) corrosion, localized in surroundings of bolted joint boundary.

Precautions:

- minimization of the number of interfaces with the use of poly-functional joint elements with integrated flange
- smooth contact surfaces
- eliminating the use of washers

Contact Corrosion

Contact (galvanic or bimetallic) corrosion (Fig. 4) occurs when two metals with various potential are in mutual contact in surrounding environment which serves as conductive electrolyte. (Fig. 4)

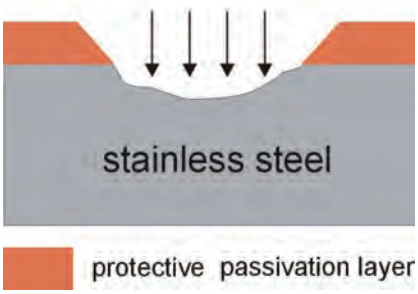


Precautions:

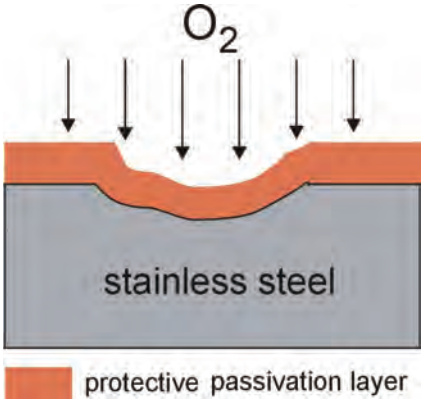
- basic material, resp. protective coating of joint element should be the same or nobler than jointed pieces.
- the surface of less noble structural element should be larger in contrast to the surface of nobler joint element
- Use isolated washers when possible

Pitting (Hole Corrosion)

Pitting corrosion may occur in stainless steels in neutral or acid solutions containing primarily chlorides (Cl-), such as seawater. It is defined by localised attack (microns - millimetres in diameter) in an otherwise passive surface. Pitting can be initiated by a small surface defect (Fig. 5). Apparently unobtrusive corrosion can initiate more serious corrosion such as intergranular or transcrystalline corrosion or stress corrosion cracking.



(Fig. 5)



(Fig. 6)

Precautions:

- provide sufficient supply of the oxygen in order to restore protective passivation layer (Fig. 6)
- control pH, chloride concentration and temperature
- Use materials with the high resistance against the given environment. Elements with the positive influence on a material's resistance to pitting corrosion: Cr, Mo, N
- Use cathodic protection

Hydrogen Embrittlement

Hydrogen embrittlement is defined as metallic materials degradation caused by the presence of hydrogen in structure under load. The diffusion of hydrogen in its atomic form into the crystal lattice of metal is the cause of it. It is one of the most dangerous phenomena of degradation of metallic materials; steels used for the production of the bolted joints are no exception. Critical from this aspect are bolts and nuts with class 10.9 and 12.9, elastic washers and clips for shafts.

Frequently, hydrogen is introduced to the fastener during the electroplating process. In these cases the hydrogen is absorbed into the fastener during the acid cleaning or descaling process.

Precautions:

- critical parts to galvanize by hot dipping, not galvanically
- if galvanic operation is strictly required, then use a clean surface to realize the process in a short time
- annealing to remove hydrogen embrittlement

Conclusion

As it was shown, the corrosion has various forms and each type follows its own mechanism. The cognition of this mechanism is the main assumption for the choice of the appropriate precautions. It is especially important for bolted joints because in this case corrosion is double harmful. On the one hand it destroys material and on the other hand it negatively influences the conditions of the assembly due to the change of the friction coefficient. ■