by Jozef Dominik www.ferodom.com

Latent Corrosion of Screw Connections

Corrosion is the big enemy of most civil engineering structures including a screws and other not only steel construction elements. According to the Corrosion Technology Laboratory at the NASA Kennedy Space Center the cost of corrosion to the U.S.A. is $276 billion/ year. This huge cost includes direct and indirect expenses associated with corrosion. The prevailing opinion is that costs on corrosion are roughly 4-5% of the country brutto social product yearly. It can be assumed that they will grow. This pessimistic view is based on statistics on the state of the Earth's environment. 250,000 tons of sulfuric acid fall each day as acid rain in the Northern Hemisphere. We add 12,000 tons of carbon dioxide each minute to the atmosphere and 1000 million tonnes of CO2 per year produces international shipping. It is estimated that every second corrosion "eats" worldwide about 5 t steel. This all is the sufficient reason why to speak about them.

Some examples from practice

There are several types of corrosion, which is standardised (Table Nr. 1) and often published.

The most dangerous, no matter what it is, is the corrosion that is not visible to the naked eye. And that's right will be specifically the speech in this post.

When taking appropriate precautions it is necessary to work on the assumption that there is no universal cure for the corrosion. Each corrosion type requires specific measure. Fig. 1 shows an example of corrosion of a stainless A2 (Cr-Ni) steel bolt. In a swimming pool the ceiling was suspended through the stainless steel A2-70 bolts. The designer had correctly calculated it (strength class, dimension, number of screws), and it seemed that nothing could happen. Mistake! The heavy ceiling has collapsed over time. Why? The answer is given in Fig. 1.

Corrosion types according to DIN 50900	
Without mechanical stress	With mechanical stress
Uniform surface corrosion	Stress corrosion cracking
Crevice corrosion	Hydrogen embrittlement
Contact corrosion	
Pitting (hole corrosion)	
Intergranular corrosion	
Transcrystalline corrosion	

Table Nr. 1

The cause is vapors from the water with chlorine lime and the inability of Cr-Ni stainless steel to resist them. These vapors come into the space between the roof and the ceiling and wash the surface of the screw. Negative charged ions of chlorine Cl- increasing acidity of the electrolyte according to the reaction:

$$FeCl^2 + 2H_2O = Fe(OH)^2 + 2HCl$$

Remarkable on the Fig. 1 is the difference between the space above the ceiling and under the ceiling. The space under the ceiling is well ventilated with sufficient fresh air. Therefore, the screw head is in good condition and makes the mistaken impression that everything is OK. But let's do what's going on over the ceiling. At first glance, another world. There is a body of bolts exposed to the aggressive effect of a mixture of water vapor and chlorine Cl^- that it is unable to withstand. Combined effect of aggressive environment and tensile load

F=W/Number of screws

caused reducing the cross-section of the screw and at the end collapse of the whole ceiling. Unhappiness could not be avoided because space above the ceiling was not visually accessible. Unfortunately, it is not possible to publish the photo documentation, but the consequences were tragic.

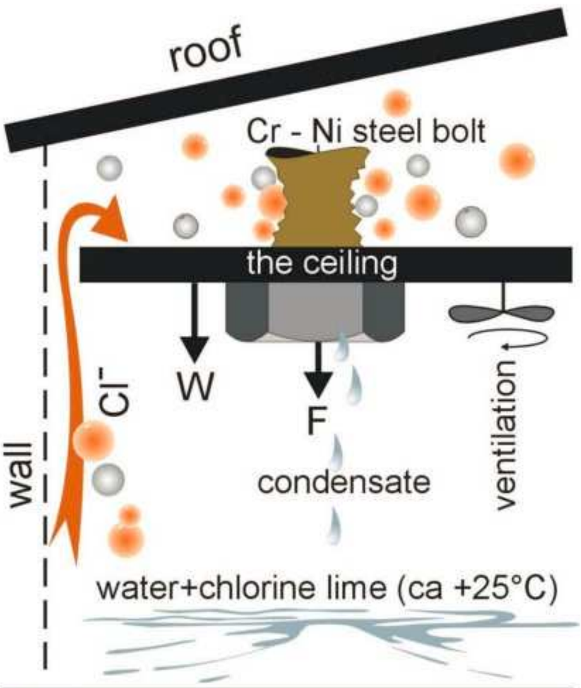

Fig. 1

This example shows that even stainless steel does not prevent corrosion due to improper application. Other important lessons: Screw connections, especially those supporting, **should be visually accessible** in order to take the appropriate action in a timely manner as the environmental modification due to ventilation or replacement of rusty screws for the news.

Another example of latent corrosion is hydrogen brittleness (Fig. 2 and 3). This is a very dangerous type, because unlike the first case, the steel stripping takes place inside the crystal lattice. In acid or galvanic treatment hydrogen diffuses into the steel structure in atomic form and weakens the cohesion of the metal lattice. The diffusion of hydrogen occur during the operation too as shown the case of the pump on Fig. 2.

Experience shows that steel with a strength of 1000 N/mm² is susceptible to hydrogen brittleness. In terms of hydrogen brittleness, the screws are of

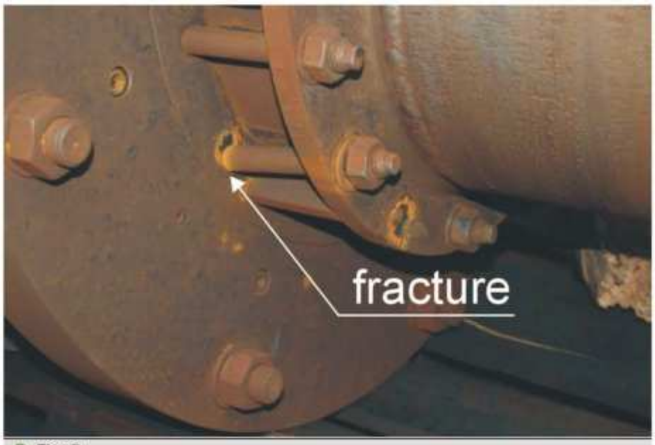

Fig. 2

critical strength 10.9 and 12.9, the elastic washers (DIN 127) and the safety rings on the shafts and the holes or threaded bolts.

Hydrogen brittleness is a very dangerous kind of corrosion because it comes suddenly, without the advice. The only rational option to prevent it is to eliminate the contact of the connecting elements with the hydrogen source. Good prevention is a coating of zinc flakes according to ISO 10683:2014 "Fasteners – Non-electrolytically applied zinc flake coatings".

There are other manifestations of visually inaccessible corrosion. One of them is stress corrosion cracking (SCC). SCC is the cracking induced from the combined influence of tensile stress and a corrosive environment. Generally, it occurs if the bearing surface is not perpendicular to the axis of the bolt (Fig. 4). The resulting crack can then be propagated trans-crystalline or inter-crystalline.

Measures is very easy - to compensate for the fitting surface. In order to check the perpendicularity of the fitting surfaces, there are special foils which react at uneven pressure due to change of intensity of the colouration. It is a simple, inexpensive and reliable method of checking the perpendicularity of the bearing surfaces.

Another example of latent corrosion of screws is worth mentioning. As C. O. Bauer writes in his book "Handbuch der Verbindungstechnik" (Hanser Verlag München, 1991) particularly dangerous can be "protective caps" (Fig. 5).

These caps are often used in truck traffic in a misconception that they protect the wheel nuts against corrosion. The truth is, however, that these caps will never completely leak and due to the effect of capillary forces is absorbed the humidity and creates inside the caps an aggressive microclimate. Moreover, the plastic caps aging and cracking over time, so the situation gets worse. Unshielded wheel nuts without caps are less prone to corrosion and especially the complete screw connection is visible to the naked eye. The case is analogous to Fig. 1.

CONCLUSION

Against any enemy you can only fight effectively if you know about it. As shown by this post, it is also the case of latent corrosion of screw connections. With a little exaggeration it can be said that corrosion is like cancer. It can be cured if it is revealed in time. When is neglected, it's too late to „cry over the spilled milk."

Several practical examples of latent corrosion have been shown, which, if seen, could take the necessary measures in time. Current science provides enough good insight into the nature of corrosion and the possibilities of its elimination, but no one has ever invented a reliable method of timely identifying it until it is invisible to the naked eye. That is why the greater responsibility lies on the designer, who must have the ability to predict it. A small aid is also provided by this article. ■

Fig. 3

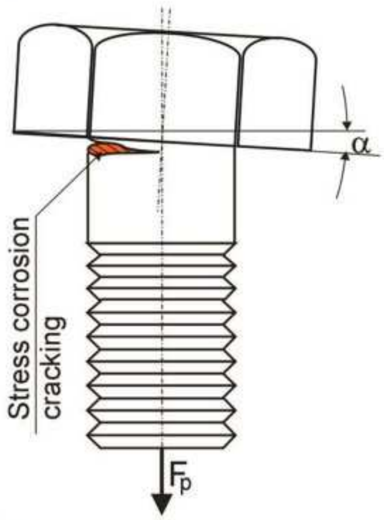

Fig. 4

Fig. 5