Is stainless steel really maintenance-free?

Fig. 1. A revolving door made from stainless steel that appears free from rust at first sight.

It may well be a remarkable or even a somewhat strange question to ask whether stainless steel is a maintenance-free material. Many uninitiated, however, are convinced it is and are in no doubt about it. You often hear people say "use stainless steel to make it, then you won't ever have to worry about maintaining it ever again". When people are told that even stainless steel can get rusty at times, they reply that this just isn't possible as stainless steel is completely rustproof. This article therefore sets out to explain why this is not always necessarily the case.

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Stainlesssteel is a ferro-alloy that contains chromium, nickel and often also molybdenum, which offers a certain amount of resistance to corrosion as long as series requirements are met. This is why these types of alloys should not be called rust proof, which is a term reserved, in principle, for noble metals such as gold, silver and platinum. On closer analysis, the truth is that stainless steel is not a noble metal as the German term Edelstahl would suggest. In actual fact, the base material is virtually just as active or 'base' as ordinary carbon steel. The noble nature of the material is due to an ultra-thin passive chromium oxide layer that acts incredibly noble in moist environments. In the absence of this layer, however, the material is subjected to devastating corrosion mechanisms. Good care should therefore be taken of this oxide layer and the stainless steel will then be able to last a lifetime without any problems. In other words, stainless steel is not at all maintenance-free. It can, however, be said to be low maintenance.

A component made from stainless steel can be somewhat compared to a healthy apple that keeps for a long time thanks to its peel, which is less than a tenth of a millimetre thick. Despite the thinness of the peel, no substances are able to escape and no substances are allowed to enter. Even though it is extremely thin, the peel provides complete enclosure until a worm eats its way through it, triggering the rotting process. The flesh of the apple will also oxidize quickly when the apple is cut in half. In other words, the apple stays

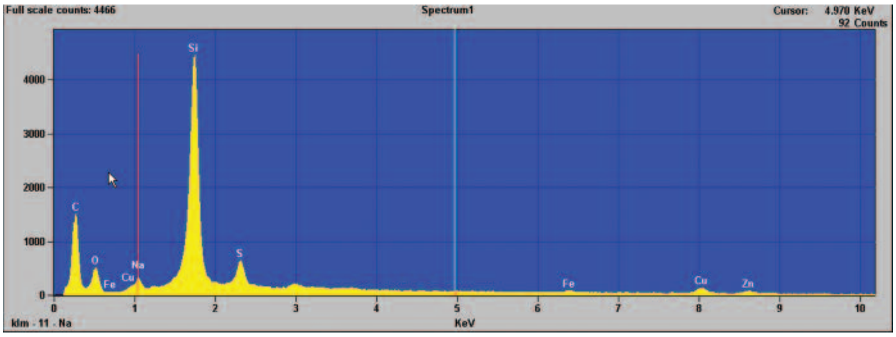


Fig. 2. EDX analysis of dirt in pores of stainless steel.

in perfect condition thanks to its thin peel. Stainless steel also has a skin, though it is more than a hundred thousand times thinner than an apple peel. Its thickness is estimated to be around 10 to 15 nanometres (1 nanometre is 10^{-9} metres). And yet it also provides complete enclosure, which is why, normally speaking, no metal ions can escape and no foreign substances can enter. If this skin is exposed to an excessive chemical load, it will break down, leading to corrosion. The skin is 'eaten away' as it were and the chemical substances activate the metal, causing it to corrode. The biggest difference with the apple, however, is the ability of stainless steel to repair its oxide layer by itself. This is particularly applicable when the layer is damaged mechanically and the chromium oxide layer disappears in local areas. Thanks to the oxygen in the air, passivation of the material will occur in those areas through the formation of a new layer of chromium oxide. This is known as the 'self healing effect'. This mechanism can be badly disrupted, however, due to the presence of too many chlorides. If this is the case, the chlorides, which are members of the halogen family, will form metal salts, which are also corrosion products. This is why, for example, demineralised water must always be used after spray pickling, as tap water contains too many chlorides to achieve proper passivation. If this is not done, the new oxide layer will be blotchy and have an uneven thickness. Naturally, an oxide layer like this will not be able to function at its best.

Dirt deposits.

The subversive effect of dirt deposits on stainless steel surfaces is not very well known at all. Stainless steel must be able to 'breathe' as it exists thanks to oxygen. Although oxygen serves to maintain the thickness of the oxide layer, this relatively large molecule must, however, be able to reach it. This is obviously not a problem when the surface is clean. But the question arises of how clean is clean and this is where people often make a huge mistake. Even when the laser film is removed from stainless steel sheets and this 'clean' surface is cleaned with a detergent containing tensides, a white cloth will soon become dirty. This is even the case with a stainless steel pan that comes clean out of the dishwasher. It, too, has plenty of dirt in its pores. Examination of this dirt by means of an Energy Dispersive X-ray analysis (EDX) shows that it mainly consists of sulphur compounds, which indicate miniscule food particles deposited in the pores. This analysis also finds silicon compounds, which is most probably caused by the sodium silicate added to the dishwasher powder as an inhibitor (see Fig. 2). The carbon and oxygen peaks are caused by the tissues needed to remove the remaining dirt after using a special detergent.

All in all, we can say that stainless steel is far dirtier, as a rule, than first thought and those places not exposed to rain are particularly susceptible to under deposit corrosion. Figs. 1 and 3 show a revolving door that was brought into operation four years ago. It incorporates a reasonably large amount of stainless steel and is located in the vicinity of sea water. At first sight, there is nothing wrong with it until you take a closer look at the arch above the door (Fig. 4). You then see all kinds of rusty spots also known as tea stains. As this revolving door is located near sea water, we can be certain that this destruction is the work of aerosols, together with dirt deposits. Aerosols are small droplets of sea water which evaporate when airborne, increasing their concentrations of salts and chlorides.

Fig. 3. Close up of Fig. 2 which shows corrosion due to aerosols.

Fig. 4. Stainless steel cladding that could not be cleaned by frequent rain showers.

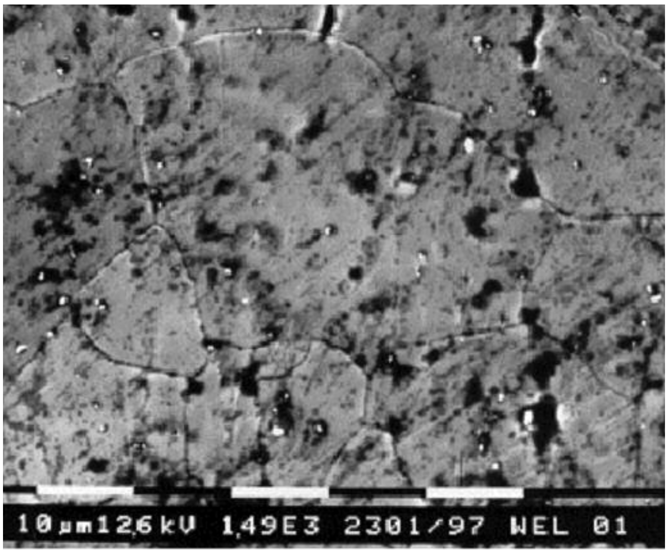


Fig. 5. Dirt pockets are clearly visible on the stainless steel surface (V =1500x). Photo by Dockweiler Nederland b.v.

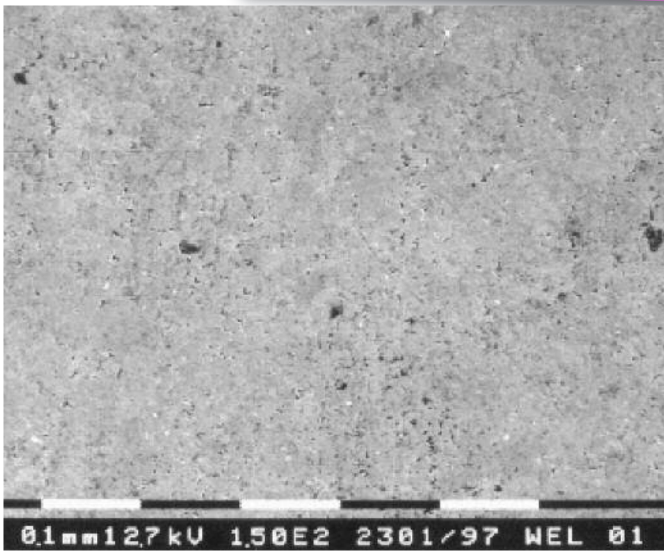


Fig. 6. The same surface as in Fig. 5 after electrolytic polishing (V = 1500x). Photo by Dockweiler Nederland b.v.

These settle on the stainless steel surface and the chlorides push their way under the dirt deposits in the pores, where they attack the material. If nothing is done, this corrosion will slowly spread further. In Fig. 3 you can also see that the stainless steel under the porch has suffered far greater corrosion than the section exposed to rain. The reason for this is that rain water washes away most of these salt residues, which means that the material experiences less corrosion. If the stainless steel arch had been cleaned regularly, these 'tea stains' would not have developed. The cause is therefore the dirt deposits in the pores.

Another example can be seen in Fig. 4, in which a stainless steel cladding unit has started to rust as no rain water could reach it to clean it regularly.

As stated earlier, the surface of stainless steel contains a considerable amount of dirt, which can easily be seen using a microscopic image. In Fig. 5, a magnification of 1500x shows a significant amount of dirt in the pores on the surface and this, in itself, should not be considered an exception. In fact, this is more the rule than an exception.

Electrolytic polishing of this type of surface not only smoothens it but also removes these dirt deposits as can be seen in Fig. 6.

Various cleaning techniques have been developed to clean stainless steel surfaces and a couple of well-known examples are chemical cleaning with organic and inorganic agents. Anodic and ultrasonic cleaning methods also exist but this article restricts itself to the method based on organic agents; in particular, with a view to reducing the impact on the environment.

Fig. 7 shows a diagrammatic representation of a stainless steel surface that has greatly been magnified. The pores are filled with all kinds of dirt deposits, under which chlorides will find it easy to move. This will be much easier for small chlorine ions than for relatively large oxygen molecules and that is precisely the problem. Chlorine, just like fluorine, iodine and bromine, is a member of the halogen family, which are known as salt formers. Chlorine ions will therefore be inclined to combine with metals to form metal chlorides and this is certainly the case when (a sufficient amount of) oxygen is prevented from reaching the oxide layer to keep it in good condition. This layer will then break down, inevitably resulting in under deposit corrosion. Once this surface is cleaned right down to the pores, oxygen will be able to do its job to sufficiently guarantee passivity. This will eliminate the risk of the aforementioned form of corrosion. Picture 8 illustrates this form of corrosion. It shows a switchboard cabinet made from AISI316 that is situated in the open air near to the coast. It is thought that a seawater resistant stainless steel should be chosen in this case, but this turns out to be rather relative. It is mainly aerosols that attack this surface under the dirt deposits. If this surface had been cleaned regularly, then this form of corrosion would not have occurred. As the entrance gate in question is covered, it is very difficult for rain water to reach the object to clean it extra thoroughly. Once again, a mistake was made here in thinking that stainless steel was maintenance-free. The

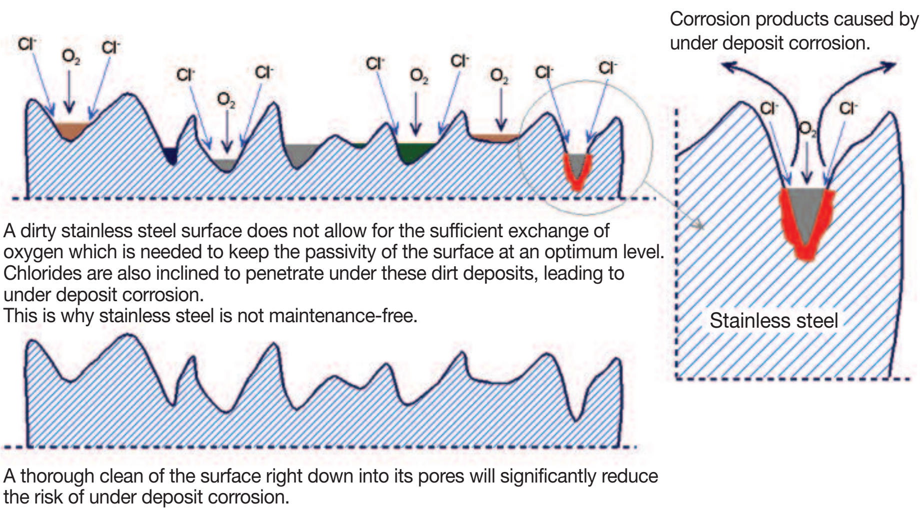


Fig. 7. Diagrammatic representation of dirt in pores and its consequences for a stainless steel surface.

Fig. 8. Flash rust on switchboard cabinet made from 316 steel caused by aerosols from the sea.

corrosion shown in Fig. 8 is no reason to replace this part as the corrosion can still be removed. It will be necessary, however, to apply extra protection after cleaning as minute blemishes have developed that could quickly lead to new corrosion.

Surface tension.

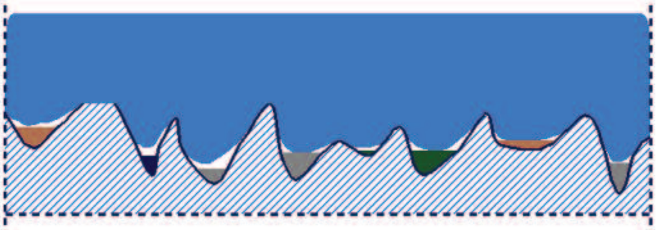
Every liquid has a specific surface tension. This can clearly be seen with drops of mercury that form globules on a sheet of glass. Water forms droplets that look more like toadstools. Mercury will not moisten the glass sheet like water does. The reason for this is that liquid mercury has a very high surface tension or contraction and water a relatively low one. Adding soap to the water will reduce this contraction even more. Substances that lower or break the surface tension are also called tensides. These can be either ionic or anionic. The lower the contraction, the deeper the agent will penetrate into the pores. A diagrammatic representation of this can be seen in Fig. 9. The top picture illustrates a cleaning agent with a relatively high surface tension and the bottom picture illustrates an optimum one.

In this way, the detergent or cleaning agent present can do its work dissolving the dirt. In other words, the pores are stripped of dirt deposits as optimally as possible, enabling the effective control of under deposit corrosion. This can mainly be attributed to the fact that oxygen can freely access the complete surface of the stainless steel. This method also results in almost no differences in aeration, which is often the cause of pitting corrosion. To sum up, this demonstrates how important it is to keep the surface clean.

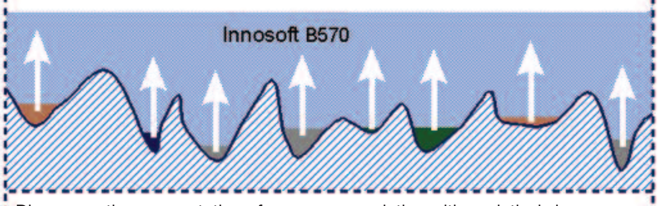
The new product Innosoft B570 that has already become quite well-known for its effective removal of (flash) rust and contaminations also contains special tensides, which enable the agent to penetrate deep into the pores. Moreover, this agent contains a powerful detergent that dissolves dirt thoroughly. In this way, the risk of under deposit corrosion can be eliminated as much as possible. In other words, although Innosoft B570 is an excellent product for the removal of rusty corrosion products, it would be far better to use it as a preventative measure to prevent flash rust as much as possible. If the distribution cabinet in Fig. 8 had been treated with Innosoft B570 beforehand, then corrosion would probably have stayed away completely. The chance of this would have been increased further if the liquid Innoprotect B580 had been applied after using Innosoft B570. This liquid also provides extra protection on a nanoscale. This can best be imagined as an atomic bonded layer that allows for the necessary exchange with oxygen as well as increased resistance to possible corrosion. A stainless steel bridge railing, which continued to rust along the longitudinal joint due to insufficient chromium, was treated with these two liquids. Prior to this treatment, the brown rust lines had to be removed every week, but after treatment with these liquids there is still no sign of rust returning even after a year. Other practical examples have also demonstrated this since.

The expression ‘prevention is better than medicine’ certainly also applies to stainless steel because the removal of rust spots means that a certain point has been passed which should not really have happened. Although it can be applauded that the rust can be removed again in an environmentally-friendly manner and that the surface can be given extra protection, it should never really have been allowed to come this far. It is therefore far better to use the products mentioned beforehand in order to create a good basis for keeping the material as resistant as possible.

For more information please visit www.inno-soft.nl or send an email to nwbuijs@hetnet.nl



Diagrammatic representation of an aqueous solution with a relatively high surface tension. As the pores are not moistened, the dirt is not dissolved by the detergent present.



Diagrammatic representation of an aqueous solution with a relatively low surface tension. The pores are moistened and the dirt is dissolved thanks to the detergent present.

Fig. 9. Diagrammatic representation of effect achieved through a low surface tension