Increasing the corrosion resistance of stainless steels, Part 2

In Part 1 of this article, we looked at how the surface condition of stainless steels can affect its corrosion resistance. New technologies have been developed that substantially increase the resistance of the oxide layer, significantly increasing corrosion resistance. In this second half of the article we will look at applications where AISI304 type stainless steel excels.

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AISI304 type stainless steel is typically never used near seawater, but as soon as the ratio between chromium and iron content in the oxide layer becomes favourable, good potential applications appear. That is shown in image 5, where the pitting potential of this type of stainless steel in seawater is shown, depending on surface treatment. Here, it is assumed that the seawater is at ambient temperature. Therefore, the pitting potential indicates the electrical potential at which pitting corrosion begins.
There are various assumed conditions for these measurements, specifically 2b and 3d finishing, a surface sanded with 240 grain. A shot-peened and pickled surface and an electrolytically polished surface are assumed as well. The red bars indicate the pitting potential of the common condition that is typically encountered in practice. It is worth noting that the pitting potential substantially declines as soon as the material is sanded with 240 grain or shot peened. That is entirely in line with the previous statement in this article that a rougher surface offers less corrosion resistance than a smooth surface.
The green bars represent the pitting potential of AISI304 that has been submerged for a number of hours in specially designed organic acids known as Polinox Protect. The blue bars indicate this potential after the additional thermochemical treatment (TC) has occurred. Organic acids are natural acids that can simply be disposed of into the regular sewage system. No further explanation is required for how much the corrosion resistance increases with these newly developed techniques.
The minimum corrosion potentials of stainless steel that are necessary to prevent corrosion in various environments are:

- Rural environment: 150 – 200 mV
- City environment: 350 – 450 mV
- Coastal region: > 650 mV

The last value explains why stainless steel corrodes so quickly in coastal environments. For this reason, the removal of iron bonds is so important, because these new techniques can significantly increase the potentials.
Below are recommendations for the use of AISI304 stainless steel in exterior applications, depending on the various surface treatments.

- Electrolytically polished: this makes AISI304 resistant in rural and urban areas;
- Pickling: this makes AISI304 resistant in rural environments, but not resistant enough for urban areas and coastal regions—this is why at least AISI316 is recommended in these cases;
- Polinox Protect treatment: it makes AISI304 sufficiently resistant for rural and urban environments; this goes for coastal regions as well, but in that case, it is preferable to use AISI316 instead;
- Polinox Protect + TC: makes AISI304 resistant in all environments, including coastal regions and maritime environments.

Car manufacturer Rolls Royce has developed car types with AISI304 motor caps that have been treated with Polinox Protect. After four years of testing in corrosive environments, from tropical maritime environments to

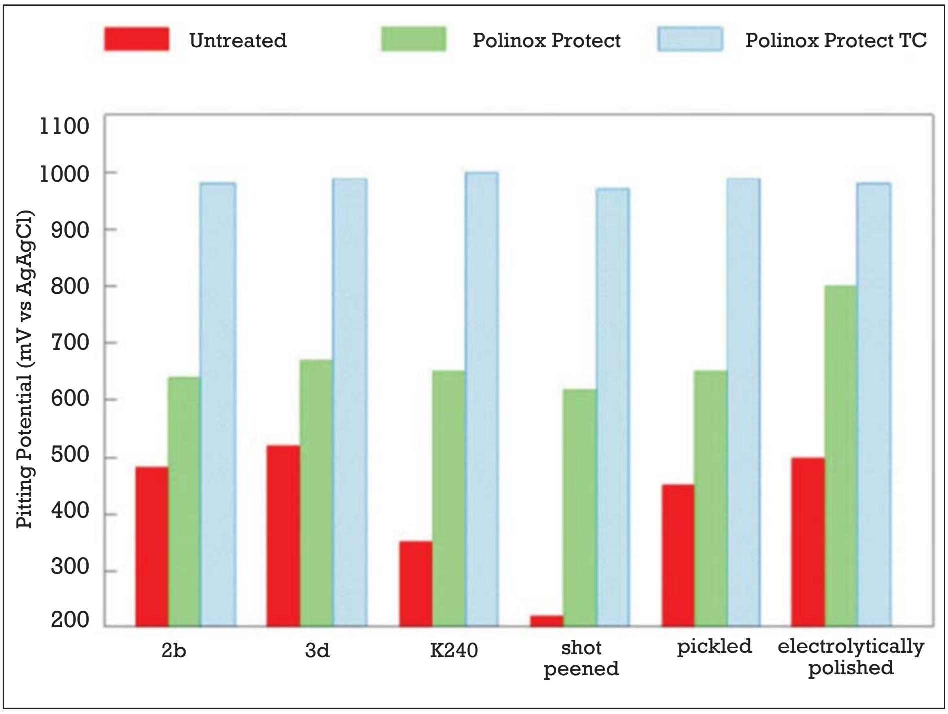

Image 5. Pitting potential of AISI304 stainless steel in seawater (source: Poligrat Gmbh).

winter conditions with heavy road salt, it turned out that this stainless-steel type does well both externally and internally (image 6).
Intensive testing has also been performed in an environment containing chlorides with 240-grain sanded, stainless steel of the chromium steel qualities EN 1.4016 (AISI 430), EN 1.4301 (AISI 304), and EN 1.4571 (AISI 316Ti). The samples were exposed in the untreated and passivated condition, as well as with a Polinox Protect treatment, and furthermore, with an additional thermochemical treatment (image 7). One sees that the simple chromium steel acquires a potential after the Polinox Protect treatment that is somewhat higher than that of the AISI316Ti in the untreated condition. The pitting potential of AISI304 (1.4306) is even 60 mV higher than that of the 316Ti (1.4571) in the untreated state. The thermochemical treatment sets the bar higher again—significantly so—before pitting corrosion will occur. The rest are further explained in this graphic.
Image 8 shows the pitting potential of various stainless-steel types, specifically AISI 430 (1.4016), 304 (1.4301) and 316Ti (1.4571). The red bars represent the potentials of 240-grain sanded surfaces. The green bars represent the potentials of a Polinox Protect treatment and the blue ones represent an additional TC treatment. Here, it is also evident how much stainless steel can be improved for optimal resistance to corrosion. Even the resistance to stress corrosion is enormously increased by this.
During the welding of stainless steel, temper colours often appear and one of their causes is the presence of iron in the oxide layer. For this reason, testing is done on a comparable sample. The right half of this has been immersed in a bath of organic acids (50°C) and the results can be seen in image 9. The whole creates the impression that this half has been pickled, but that is not the case.

Image 6. AISI304 motor cap treated with Polinox Protect after four years of use.

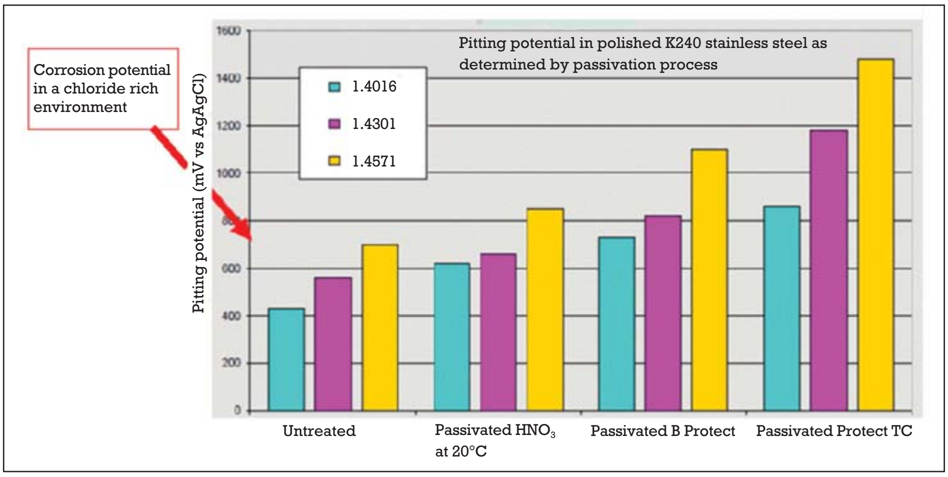

Image 7. Pitting potentials of various stainless-steel types, depending on the passivation (source Poligrat Gmbh).

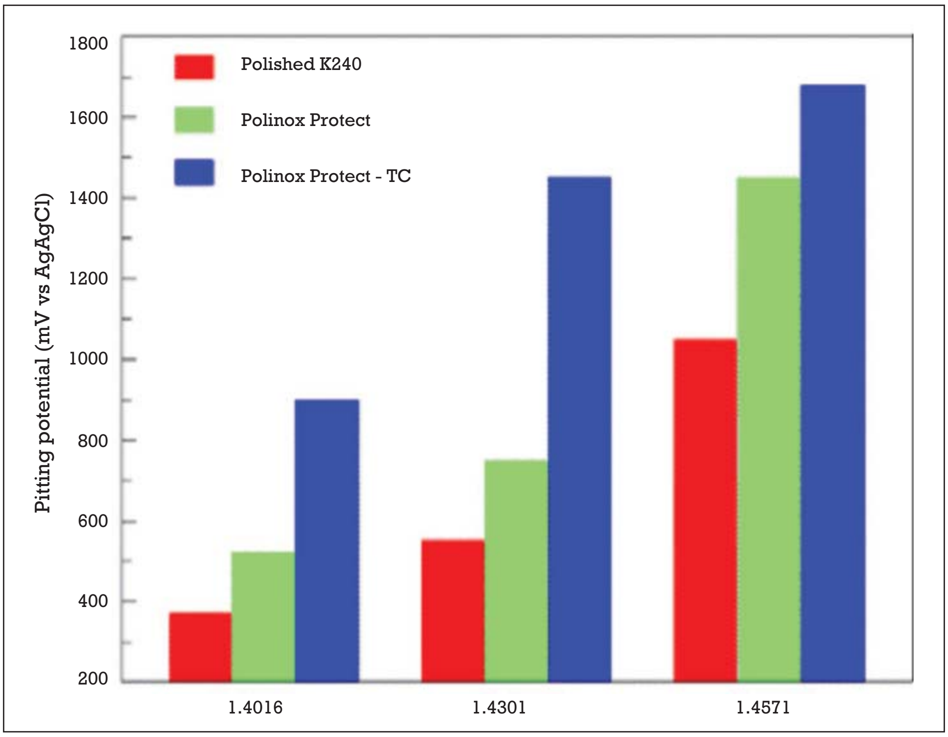

Image 8. Pitting potential of chromium steel, stainless steel, and a nickel layer in seawater with 20,000 ppm chlorides (source: Poligrat Gmbh).

If, during the production of stainless steel, some free iron accidentally reaches the surface, this will not be removed through wet blasting, but it will after the Polinox Protect treatment. It is important to remember that prevention is better than having to fix it.
Fish hooks are typically made of ferritic chromium steel, because this material possesses better mechanical properties. Surgical tools are mostly made from martensitic stainless steel, because it is more wear resistant and therefore, remains sharper. Both alloys have a highly limited corrosion resistance, but with the removal of the iron bonds from the surface, there is much better corrosion resistance.
Fish hooks made of 430 ferritic chromium steel rust fairly quickly in seawater, but with a treatment in a Polinox Protect bath of 60°C, followed by a TC treatment at 140°C, these products can last for 500 hours without issue (image 10). This applies for martensitic components as well.
In short, it can be proposed that removing iron as much as possible from the oxide later will lead to the following results:

- Substantially increases the resistance to pitting corrosion;
- It lasts nearly twice as long before stress corrosion occurs;
- More resistance to the occurrence of temper colours during welding;

Image 9. The right half is nearly free of iron bonds which makes it look as if it has been pickled (photo: Poligrat).

Image 10. Untreated AISI430 fish hooks, treated fish hooks on the right (source: Poligrat)

- Removes rust, free iron, contaminants, and corrosion products;
- Restores the corrosion resistance of welding seams and heat-influenced areas;
- Keeps the surface in optimum condition;
- Mechanically damaged areas are restored to good surface quality;
- Combats rouging.

A thermochemical treatment (TC) is performed at high temperatures, which thermally enhances the oxide layer, resulting in a further increase of the potential of the already "purified" oxide layer. TC involves a short treatment of 5 to 10 minutes at 140°C – 200°C, depending on the alloy and the structure. A thin layer of haematite that is extremely corrosion resistant will appear on the surface. This will further increase the electrical potential and, in turn, the corrosion resistance as well.

The combination of PureFinish and the above treatment will lead to an extraordinary resistance to corrosion. Not to mention, these processes can also be used individually. If this unique combination is used, the condition applies that the PureFinish treatment must be performed first. The complete improvement of corrosion resistance can be explained by the fact that the surface offers little room for dirt and debris to settle or for damaging deposits and furthermore, a higher potential is achieved on the surface as well. For this reason, it is expected that this unique combination will lead to a greater range of applications for the well-known AISI304 and 316 qualities. However, the ferritic and martensitic qualities will also perform much better thanks to these techniques and that will appeal primarily to medical professionals, who have to work with such materials the most. The company that has exclusive access to this combination of techniques in the Netherlands is the Metalfinish Group in Joure.