Water blasting of stainless steel

Stainless steels are not maintenance-free and must be cleaned regularly to avoid corrosion. This paper describes how polished stainless steel surfaces have an advantage in corrosion resistance to their considerably lower susceptibility to dirt deposition.

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For decades researchers have been searching for optimum techniques to sufficiently recondition the surface of stainless steels after processing. The purpose behind this is to be able to utilize the manufactured machine or system for as long as possible. Examples are processes that are needed as a result of welding, mechanical processes or contamination with carbon steel. This type of reconditioning usually constitutes achieving a sufficient level of corrosion resistance. In particular, annealing colours caused by welding need to be removed as these are microporous and allow for easy penetration of destructive chlorides. The thin oxide film that is only 10–15 nanometres consists of several layers. If these layers swell up due to the combustion process, then internal differences in the coefficient of expansion will lead to the development of additional microporosity with temperature fluctuations. Additionally, more chrome than iron is burned in this zone and this also means less corrosion resistance. In other words, annealing colours caused by welding and/or atmospheric annealing must always be removed if this zone is subsequently exposed to the risk of corrosion.

One of the best known methods is pickling and passivating, which has proved to be a good solution over the years. After all, with pickling and passivating, the damaged, burnt and/or contaminated oxide film is stripped in order to be rebuilt in the end by means of passivation. Although this method is an excellent solution to restore the weakened chrome oxide film to optimum conditions, there are also clear disadvantages. Quite apart from the risks to humans and animals presented by the inorganic acids which need to be used, the goods are often required to be sent to specialist companies, which do little to benefit the internal logistic materials flow. This is why companies have looked for alternatives, which have resulted in the use of processes such as mechanical grinding and glass-bead blasting. In addition, ceramic blasting has also made its appearance and good results have even been achieved with laser ablation. Dry ice blasting with an abrasive additive has also proved to be successful. The aim of all these techniques is to raise the material to an acceptable level of corrosion resistance. More specialist methods are anodic and electrolytic polishing, which result in the development of a high-grade oxide film with a particularly smooth finish. In addition, more iron atoms disappear during these processes than chrome and nickel atoms, which also results in a higher degree of corrosion resistance. Fig. 1 shows the positive potential of type AISI 316 stainless steel as a function of the processes. The basis is taken to be an untreated stainless steel surface that has an approximate positive potential of 260 mV. What is noticeable is that the positive potential or corrosion resistance decreases as soon as the surface is subject to grinding or glass-bead blasting. This is due to its rougher surface and this effect will continue to worsen in the long run through the influence of dirt deposits which then lead to under-deposit attack. This is a form of corrosion that occurs under dirt deposits and is especially the case if chlorides are involved. Chlorides penetrate deeper under dirt deposits than relatively large oxygen molecules, which lead to corrosion of the material. Chlorine is a member of the halogen family which is known for its tendency to form salts. Stainless steel requires oxygen in order to retain its level of passivity, but it will be unable to do this sufficiently under these dirt deposits. This is why stainless steel is not maintenance-free and must be cleaned regularly. It will further be obvious that polished surfaces provide an advantage due to their considerably lower susceptibility to dirt deposition. Fig. 2 portrays these different types of surfaces on a microscopic scale.

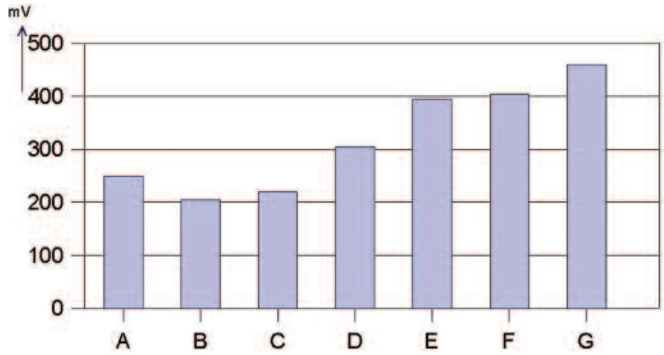

Fig. 1. The corrosion resistance of AISI 316 as a function of the surface treatment (source Packo Belgium).

a = AISI 316L 2B finish unhandled; b = corund-blasted grain 100 µm; c = ground K240; d = pickled and passivated; e = anodally pickled in HF-HNO_3; f = anodally pickled in H_2SO_4; g = electrolytically polished in H_2SO_4/H_3PO_4.

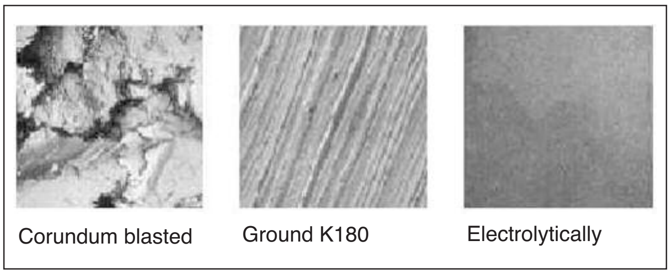

Fig. 2. Microscopic images (V=400x) of various surface treatments pf stainless steel. (Source Packo Belgium). (Left) sand-blasted with korund; (middle) polished K180; (right) electrolytically polished.

It can therefore be said that the corrosion resistance of stainless steel is not only dependent upon the type of alloy used but also upon the condition of its surface. In Fig. 1 it can be seen that pickling and passivating has a good effect on the ultimate level of corrosion resistance, although more can therefore be achieved with electrochemical processes. In terms of possibility and size, pickling is often an ideal compromise. Yet it is advisable to leave pickling to specialist companies as the chemical agents require a considerable number of precautions in connection with the health risks for humans and animals. If the company has its own pickling shop then the stringent rules in this area must always be respected to avoid the risk of physical injury to employees.

Fig. 3. Warning signs on the door of a pickling shop.

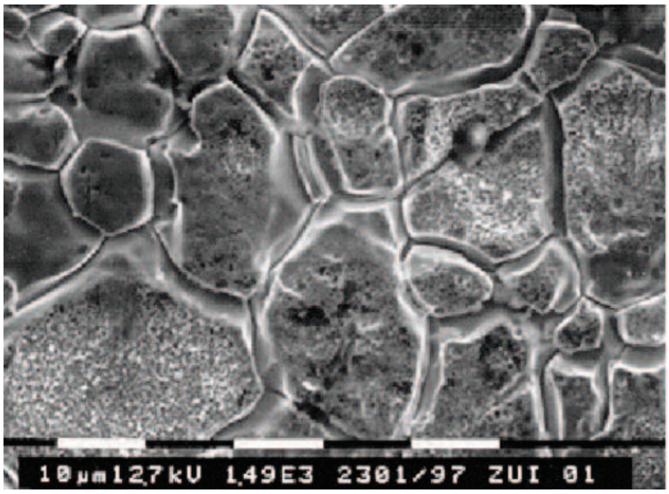

Fig. 4. Pickled stainless steel AISI 316 (V=1500x) in which the grain boundaries have been subject to a preventive attack (photo Dockweiler).

Warning signs must be placed on the door, for example, as shown in Fig. 3.

It will be evident that these types of measures do not make the operational process any easier but 'keeping products in-house' does bring advantages with it such as not disrupting the internal material flows or logistics and saving on transport costs. It is also especially important that the employees responsible for pickling work with the correct parameters and inhibitors in order to prevent overpickling. The grain boundaries in particular, which are often less resistant, can be subject to a quick preventive attack and this leads in turn to a roughening of the surface. Fig. 4 clearly shows a preferential attack on the grain boundaries in austenitic stainless steel. The austenite crystals are also clearly shown and it will be evident that these grain boundaries provide room for all sorts of contaminations and microbial deposition. The latter can, in turn, quickly lead to the dreaded microbial induced corrosion (MIC). The eye is therefore not always an optimum 'instrument' for determining roughness as many rough areas are impossible to observe with the naked eye. It can generally be stated that a ground surface is 2.5 to 4 times as large as a polished surface, as shown in the diagram in Fig. 5.

It is therefore important for a surface to be smooth but, then again, not too smooth as dangerous biofilms can develop with roughness levels under Ra = 0.2 µm as the adhesive forces between the surface and the bacteria then become substantially large. This is shown in the diagram in Fig. 6, in which the degree of cleaning is shown as a function of the roughness. In other words, the rule 'the smoother the surface the easier it is to clean' is not always true in practice. Fig. 7 illustrates what happens in reality.

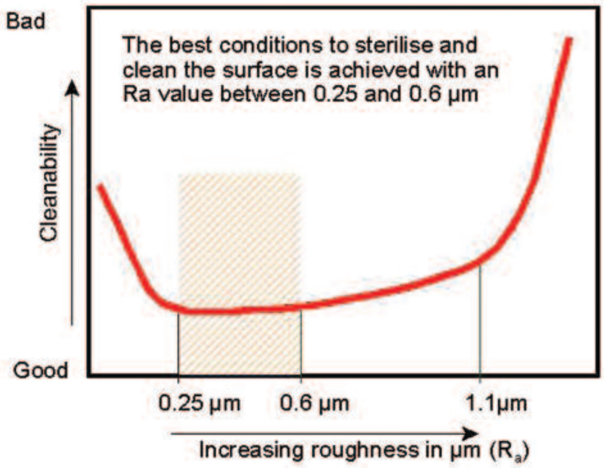

Fig. 6. Stainless steel can best be cleaned if it has a roughness between 0.25 and 0.6 µm (source Leser).

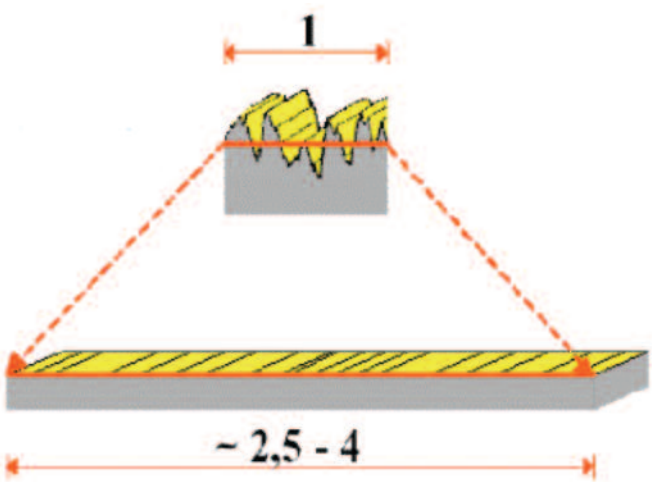

Fig. 5. A ground surface is sometimes 2.5 to 4 times larger than a polished surface.

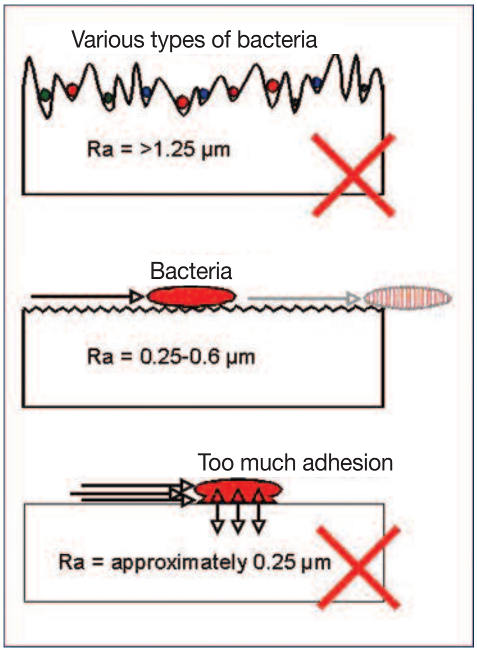

Fig. 7. It is difficult to remove bacteria from a surface that is too smooth (source Leser).

Dry ice blasting with abrasive additive

A less well-known method for the removal of unwanted or burned areas from stainless steel is dry ice combined with an abrasive additive. Frozen carbon crystals with a temperature of –79°C are blasted together with a few percent of 'ground sand' onto a stainless steel surface as a result of which the carbon dioxide transforms from a solid form into a vapour in a very short space of time. This produces sublimation as well as thermo shock on the surface. The special ground sand ensures that, one way or another, the annealing colours totally disappear. This method is efficient in itself but does have the disadvantage of being a rather noisy process. Furthermore, it requires dry ice which is relatively expensive to obtain. The advantage is that no damp residue is left behind but dust. Another disadvantage is that the surface is left a milky white colour which does little to benefit its appearance. An example of this can be seen in Fig. 8.

Fig. 8. The annealing colours on the welded joints have been removed with dry ice which includes an abrasive additive. This results in milky-white patches that are, however, resistant to corrosion.

Water blasting

A brand new development is water jetting or water blasting which is a unique technology developed in the Netherlands in recent years. Developed by the company Vink and marketed as Viwatech, this technology uses special oxygen rich water that has a negligible chloride load. This has a particularly positive effect on the quick formation of the passive chrome oxide film after the old oxide film has been stripped. An abrasive additive is added to the water, which takes over the pickling action in the end. The entire solution is blasted onto the work piece in a specific well-balanced ratio under high pressure, completely removing annealing colours and unwanted contaminations. Moreover, the treated surface is reconditioned in its entirety, which optimises its corrosion performance. This fact is further reinforced through the creation of a relatively low level of roughness, which also has the tendency to reduce dirt deposition. This can therefore help prevent the dreaded 'under deposit attack'. Three-dimensional topographical pictures of the blasted surface have been prepared by TNO so that more can be learnt about its morphology. Fig. 9 shows a breadcrumbs device that has been treated with this technology. You can clearly see that the annealing colours caused by welding have completely disappeared. Fig. 10 shows part of a stainless

Figure 9: A breadcrumbs device treated with water blasting.

Fig. 10. Stainless steel cable channel treated with water blasting.

steel cable channel that has been treated with water blasting as an experiment instead of pickling. The company concerned has been very pleased with the results achieved up until now. In addition, this technology has produced an exceptionally smooth surface, which considerably reduces the chance of corrosion through aerosols.

Aerosols are droplets of sea or brackish water, which, due to an unfavourable surface/volume ratio, evaporate relatively quickly when airborne, which increases their concentration of salt and chlorides. In other words, they have a very aggressive impact on stainless steel and even AIS 316 has great difficulty in resisting this corrosive load. These aerosols also pose a significant threat in particular for outside furniture made from stainless steel. Ground surfaces are especially susceptible to this. Fig. 11 shows a turnstile in a coastal area that has been attacked by these aerosols.

Fig. 11. Turnstile manufactured from stainless steel 316 that has been attacked by aerosols.

The surface:

A topographical study conducted by TNO found that ceramic and glass beads produce a relatively rough surface. Fig. 12 illustrates a surface that has been glass bead blasted and the average roughness here is Ra = 1.257 µm. Ceramic bead blasting also produced a result that was very similar to that of glass bead blasting, with an average roughness of Ra=1.490 µm. This is represented two-dimensionally in Fig. 14.

Fig. 15 shows a topographical representation of a water jet blasted surface and Fig. 16 shows a two-dimensional image. What is striking is that the roughness produced is a mere 0.26 µm, which is exceptionally smooth.

This type of surface is therefore fairly immune to dirt deposits,

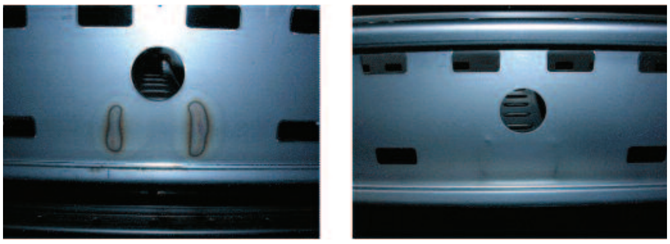

Fig. 12. Detailed shot of annealing colours that have been removed by water blasting.

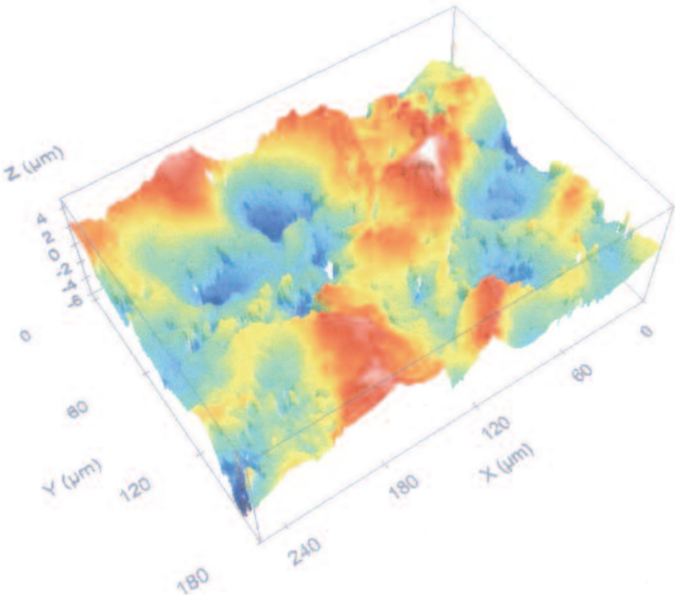

Fig. 13. Topographical 3D picture of a ceramic bead blasted surface.

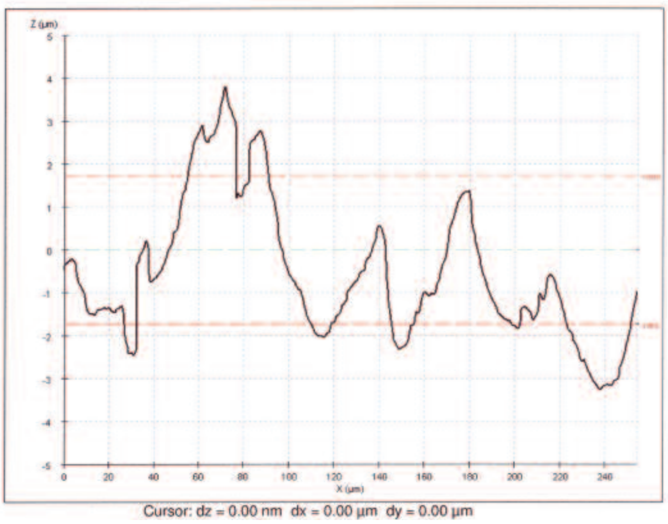

Fig. 14. Two-dimensional graphic representation of the roughness produced by ceramic bead blasting.

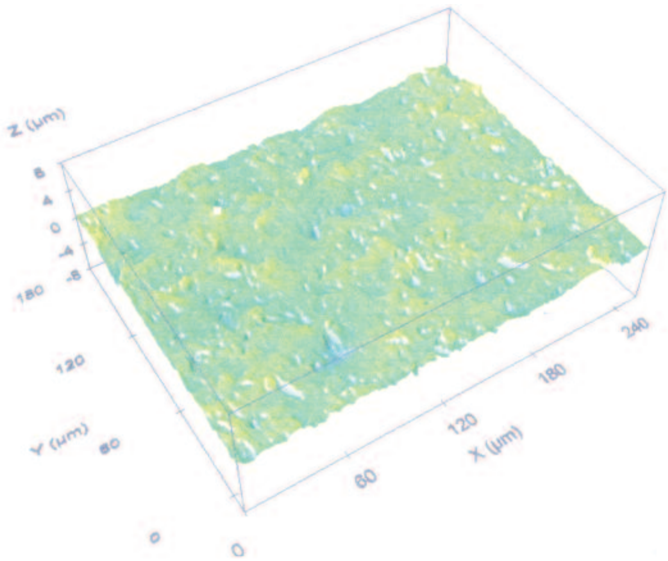

Fig. 15. Topographical 3D picture (TNO) of a water jet blasted surface with a roughness of 0.26 µm.

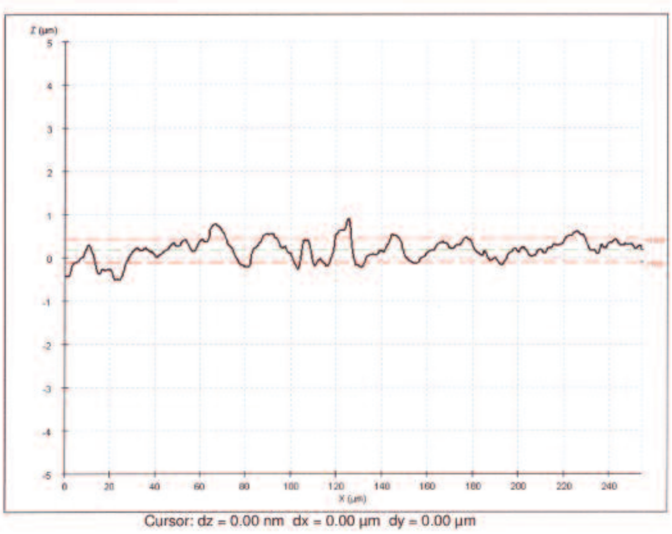

Fig. 16. Two-dimensional representation of a water jet blasted surface.

which significantly reduces the risk of under deposit corrosion. This is also why aerosols will have less of a harmful effect on such surfaces. In addition to these benefits, there is the significant advantage of practically no impact on the environment as with pickling. Pickling agents often contain hydrofluoric acid and nitric acid and the impact of these inorganic acids on the environment and the risks for humans and animals need no further explanation. This is why water blasting provides an attractive alternative to these established processes. This method will still undergo further optimisation, however, and mobile installations are also currently under development.

More information can be obtained from info@innomet.nl