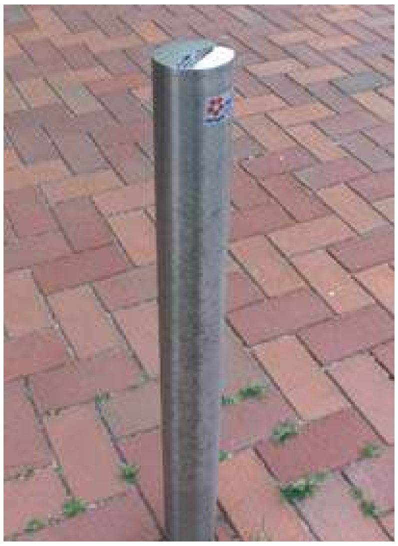
Dry ice blasting of stainless steel

By N.W. Buijs, Van Leeuwen Stainless, The Netherlands

There are many misconceptions surrounding the corrosion performance of stainless steel in seawater, as well as its use in the vicinity of the coast. It is generally claimed that AISI 316 stainless steel is suitable for use in maritime environments, but this is somewhat open to discussion as, more often than not, it leads to problems. At times it appears that AISI 316 stainless steel, which has been immersed in cool, aerated seawater, does perform well, while suffering moderate to severe corrosion when used in coastal areas. The latter is usually caused by so-called "aerosols", which are droplets of seawater transported from the sea by wind. During their journey by air, these droplets evaporate slightly, increasing their concentration of salt, which gives them their destructive quality. Once corrosion has occurred, the flash rust which has developed can be eliminated using an effective technique available nowadays known as dry ice blasting.



Picture 1. A stainless steel AISI 316 post, where all but the polished cap is corroded.

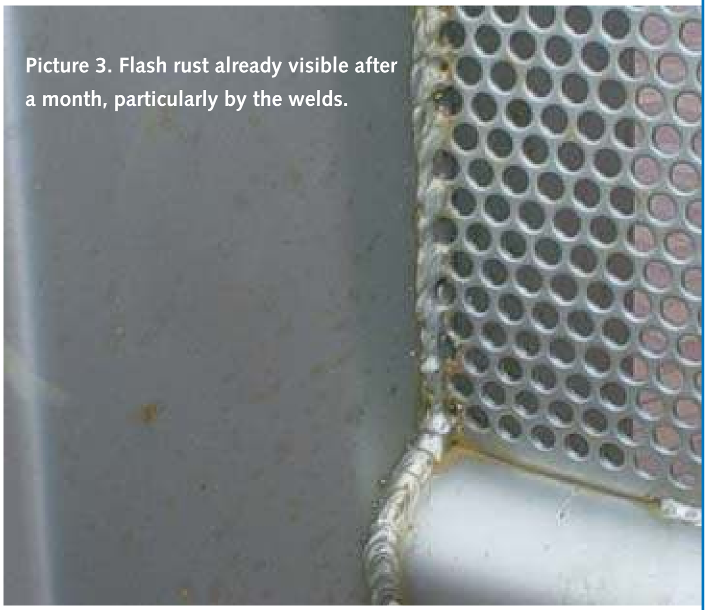
In external environments, stainless steel can sometimes suffer severe corrosion. Nevertheless, as a rule, its performance rates between good and excellent. The latter is especially true when using AISI 316; particularly in inland areas. Problems mainly arise along the coastline, next to railways, and sometimes also close to aggressive gas emissions from factories and vehicles. Another important contributing factor is the condition of the material's surface; the smoother the surface, the greater the material's resistance to corrosion. This is also the reason why ground stainless steel corrodes relatively quickly in maritime environments, while polished surfaces remain in good condition. Picture 1 contains an example of this – the ground tube of the post is somewhat corroded, whereas the polished cap appears to be untarnished. This post is situated on a boulevard along the coast.

The degree to which ground stainless steel is resistant to corrosion partly depends upon the grit size used. The finer the grit, the greater the corrosion-resistance. One disadvantage of grinding compared to pickling, is that grinding can expose small areas which are less resistant to corrosion; these then act as entry points for local attack. If the grit used is too coarse, dirt deposits can collect in the grooves, which can also trigger corrosion; this is especially true in seawater and chloride-containing environments. The reason for this is that small chloride ions can penetrate a lot deeper under dirt deposits than the relatively larger oxygen molecules. This is also known as 'under deposit corrosion'. A clear example of this could be seen on a passenger ship fitted with highly polished AISI 316 railings. After it became apparent that the sun's reflection was causing too much of a nuisance to passengers, it was decided to replace these railings with ground K320 tubes made from AISI 316. After three months, rusty patches started to appear in several places on the tubes, leading the shipping company to believe that AISI 304 had mistakenly been supplied instead of 316. After investigation, this was found not to be the case; instead, it was the surface condition of the tubes which was responsible for this phenomenon. There was no other choice than to use scouring pads to remove the flash rust from the tubes. The annoying part is that this now has to be done on a regularly basis while polished tubes are virtually maintenance-free.

Cleaning methods

For experienced users, surface rust on stainless steel is no surprise; however, removing it remains a labour-intensive and often environmentally-unfriendly process. The latter is certainly the case when special cleaning acids are applied, which, although effective, will attack the surface further if used for a prolonged period of time, causing new flash rust to develop at a faster rate. Thorough rinsing is therefore required, and care must be taken to safeguard the environment, not to mention minimising health risks. A better method would be to use cleaning and scouring products with the necessary caution. There is a real risk of causing permanent scratching to the object, with an adverse affect on its appearance. Another downside is that these

Picture 2. Wind barrier made from stainless steel 316L.



Picture 3. Flash rust already visible after a month, particularly by the welds.

methods are very labour-intensive and need to be repeated on a regular basis. In addition, certain requirements would need to be stipulated regarding the type of scouring product to be used, to avoid the possible problems as described above. It is therefore important to consider innovations in contaminant removal. One such method, which is particularly noteworthy, is the use of dry ice blasting.

Dry ice blasting

Dry ice blasting, also known as cryogenic blasting, is a cleaning process whereby compressed frozen carbon dioxide (CO2), or dry ice, is allowed to sublimate under high pressure on a contaminated or lightly rusted surface. A high-pressure jet is used to blast the ice, at a temperature of -79° C, onto a contaminated stainless steel surface, which is warm by comparison. This then causes a 'thermo shock', which considerably loosens any contamination and flash rust, and the dry ice evaporates instantly. The dry ice rapidly converts into carbon dioxide gas and expands about 700 times in volume. This produces a sort of explosion on the surface, which thoroughly removes all contaminants. As carbon dioxide has no liquid state, there is no moisture to be found, which explains the term 'dry ice'. A significant advantage is that no damp residue is left behind which makes this method very user-friendly. Furthermore, as the carbon dioxide is created during the production of industrial gases, the CO2 is returned to the atmosphere, making dry ice blasting a very environmentally-friendly process. The following lists the main features of this method:

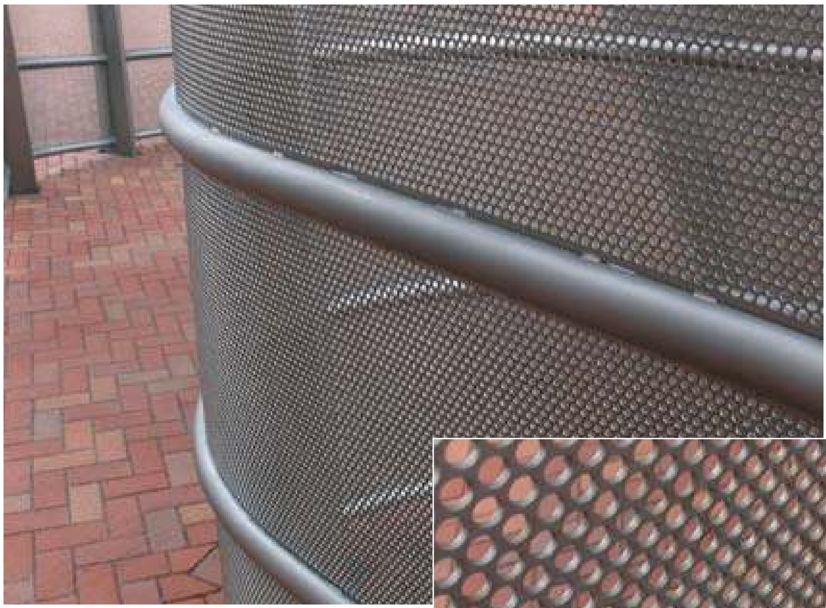
Picture 4. Rust pits showing on the design's posts.

- A quick, dry process;
- No addition of chemicals;
- Non-toxic, therefore kind to users as well as the environment;
- No waste;
- No disassembly of equipment required before cleaning, enabling higher productivity;
- No scouring effect, so no surface damage;
- Cost savings.

The only drawback is that special equipment is required. To avoid additional investment, it would therefore be better to leave this task to specialist companies.

There are three main stages to cleaning with dry ice:

1. Mechanical: the dry ice pellets accelerate in the air stream and hit the contaminants at high velocity, removing the majority of them;
2. Thermal: the low temperature of the dry ice makes the material to be removed more brittle, aiding its further removal (thermo shock);
3. Sublimation: the rapid conversion of the solid dry ice into gas produces an explosion on the surface, eliminating the remaining contaminants and rust. ▶



rust was removed effectively within a relatively short period of time, although it had already been left a little too late. In other words, rust should be treated as soon as it is discovered. Pictures 5 and 6 show the result of dry ice blasting, which can be compared to the contents in pictures 3 and 4. It goes without saying that the difference shown is remarkable, if not unbelievable. Even the toughest rust in the crevices has been eliminated. Dry ice blasting is therefore expected to play a significant part in the future of stainless steel cleaning.

Picture 6. No more rust between the plates and tubes.

Case study

One example that appeals to the imagination is that of a 400 m2 wind barrier made from stainless steel, situated on a boulevard along the coast (Picture 2). A month after being placed, this 316L stainless steel barrier was already exhibiting patches of corrosion (Pictures 3 and 4). The cause of this was indeed found to be the force of the aggressive aerosols. The rate of corrosion was also accelerated by the material's surface condition, as well as the incorrect attachment of the perforated plates to the tubes, which enabled moisture to collect (Picture 3). Although it may seem that the choice of material was incorrect, if the surface had been polished and there had been no crevices, 316L could, in principle, have been used successfully. Another noticeable thing was that welding had been carried out intermittently. Furthermore, the welds were pock-marked and irregular; a result of applying the MIG welding process, which is preferable to TIG welding when joining perforated plates.

It would also have been better to insert slots in those places not requiring welding, to prevent moisture collection, which did occur in this example. Perforations often have rough edges, which are caused when holes are punched out; this is not very conducive to corrosion-resistance. It would have been preferable to have had laser-cut holes. Once more, this demonstrates the importance of clear communication between the metallurgist, the designer and the company commissioned to produce the object. In this case, there was a lack of communication, which meant consequences had to be faced sooner or later. Again, a lot of trouble could have been spared.

Actually, dry ice blasting of stainless steel is still an unexplored area and initial results have therefore proven to be particularly encouraging. The rust must only be superficial, otherwise scars would be left by the corrosion, seeing as the process does not remove any of the underlying material. This method is therefore primarily intended to combat flash rust, which has not been left on the surface long enough to cause further corrosion.
In the case of the wind barrier, the

Post-treatment

Despite thorough cleaning with dry ice blasting, the surface will still contain weak spots, which may corrode quickly again in future. After dry ice blasting, it is a good idea to apply a post-treatment to the surface to prevent the development of any new rust. This is particularly important in maritime environments. For this purpose, good, inherent coatings have been developed, which are also transparent and colourless, ensuring that the "stainless steel look" is maintained. These coatings are predominantly naphtha-based and are extremely difficult to remove, even with hot water and thinner. This enables them to provide lasting protection. A protective coating was applied to the aforementioned wind barrier after it had been cleaned with dry ice blasting, but as you can deduce from pictures 5 and 6, this treatment remains invisible. This coating can easily be applied using a dispenser and its protective qualities emerge once it is 'hardened'. The question remains, however, whether this technical wax offers sufficient protection in the crevices between the perforated plates and the tubes. If in doubt, it would be better to apply a transparent and colourless sealant to these areas.

Conclusion

In principle, dry ice blasting makes it possible to restore contaminated stainless steel to a high standard, as long as the entire surface is then coated with a colourless and transparent adhesive coating, paying particular attention to any weak areas. Another prerequisite is that corrosion has not caused excessive damage to the stainless steel, as this would leave too many scars. Dry ice blasting is relatively cheap compared to chemical treatments, which also carry the risk of acid residues remaining and increasing the likelihood of new patches of corrosion. If you would like to receive more information about this process or a list of companies providing this service, please send an e-mail to: nwbuijs@hetnet.nl. All in all, it can be said that dry ice blasting will play a significant role in the cleaning of stainless steel in future. ■

About the author

Ko Buijs is a recognized metallurgical / corrosion specialist on stainless steels as well as special metals. He works for Van Leeuwen Stainless. In addition, Mr Buijs is a lecturer for various organisations such as steel associations, technical high schools and innovation centres. He has published over 100 papers in a number of technical magazines. In close co-operation with Barsukoff Software Mr Buijs has developed the computer programme Corrosion Wizard 2.0. Info www.corrosionwizard.com