Manufacturing of Stainless Steel

How the different Processes affect the Corrosion Resistance

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No matter how the stainless steel is used, a certain degree of manufacturing is required. This may include cutting, bending, welding or grinding; however, no matter what we do, the corrosion resistance of the steel is affected.

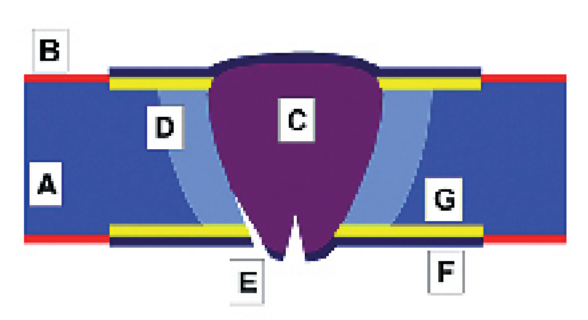
When the stainless steel leaves the factory, it is “perfect”. From this moment, its corrosion resistance is at its best, and the vast majority of manufacturing processes affect the resistance in a negative way. Most processes will tend to weaken the corrosion resistance, and, consequently, all manufacturing should be performed in such a way that the negative effect is as small as possible. If this is not possible, the manufacturing should be followed by a chemical surface treatment.

Welding

One of the most severe processes is welding. Apart from introducing a second phase (the filler metal), the steel is subject to a very powerful heat treatment, which may affect the corrosion resistance in a number of different ways. All negative, of course.

The risk of corrosion connected to the weld itself is often reduced by choosing a filler metal with a higher content of Cr and Mo than the base metal. Still, any crevice caused by inadequate binding, pores or so, and suddenly, one has to cope with the risk of crevice corrosion.

A rule of the thumb states that CC occurs at a temperature 20-25 °C below the critical pitting temperature (CPT). To cope with this, crevices should be completely avoided below the water line (= intensified control), or a better steel with a higher PREN should be chosen. Thereby, a larger safety margin is induced allowing a few more “defects”.



Schematic drawing showing the various effects on a weld:
A: Base metal
B: Weld / filler metal
C: Natural, protective oxide film
D: Heat tinting
E: Chrome poor layer (underneath the heat tinting)
F: Heat Affected Zone (HAZ)
G: Pores and other crevices

Heating the steel to a temperature in between 500 and 850 ºC, an inevitable phenomenon close to the welding zone, implies a risk of formation of harmful chromium carbides. This does not happen in the weld itself, but rather in the Heat Affected Zone (HAZ), close by. Normally, this problem is greatest when welding thick steel plates, and in practice, one can cope with it by choosing lowcarbon steel (4306, 4307 or 4404), or titanium stabilized steel (4541 or 4571).

A related phenomenon is the formation of harmful intermetallic phases such as the “sigma” (Cr-Fe) or the “ksi” phase (Cr-Mo). This problem is particularly big when welding high-alloyed “super duplex” steels (i.e. 4410, duplex 2507) and the high-end ferritic steel types (i.e. 4509, 4526 and 4521).

At least just as harmful is the bluish or yellowish heat tinting, which is formed on the steel surface during welding. These discolorations are caused by a warm oxidation of the steel surface and consist of thick oxides of mainly chromium and iron. If left untreated, these layers imply a significant loss of corrosion resistance, and to cope with the problem, either their formation should be entirely prevented (by using extreme amounts of purge gas) or they should be removed afterwards. In most cases, the latter is the more economical, and in practice it is feasible to accept a certain level of bluish discoloring and later remove the layer by pickling or a combination in between grinding and a subsequent pickling or passivation.

Removing the heat tinting by a glass blasting is less desirable as the heat tinting and the dechromed layers will be mashed into the surface rather then being removed. Prior to the glass blasting, a pickling will do the job.

Finally, any welding process implies the formation of tensile stress, which will increase the risk of stress corrosion cracking. As removal of the stress is not feasible, this problem should be taken care of in the design phase by choosing a steel type possessing a sufficient resistance towards SCC. Fighting SCC by hoping to reduce the level of tensile stress is not recommended.

Cutting, sawing and others

Due to the risk of heat tinting, the most dangerous methods are the hot ones. A “hot classic” is the angular cutter, which, apart from producing a rough and uneven surface, gives rise to a spray of hot particles. These have a nasty tendency to stick to stainless steel surfaces, and the result is heat tinted crevices, a very sad combination implying a severe loss of corrosion resistance. The easy way to cope with the problem is to remove the spray particles carefully with i.e. a screw driver and perform a subsequent pickling.

Even the cold cutting processes may affect the corrosion resistance in a negative way. The center of the steel normally contains a larger concentration of harmful inclusions and segregations than the surface, and thus the center of even thin sheets is less corrosion resistant than the surface. This inevitable effect originates from the making of the steel at the steel works. When the steel solidifies, it takes place from the outside and inwards pushing the insoluble impurities towards the center of the slab. Hot and cold rolling the slab from a thickness of 200 mms to, say, less than 1 still maintains the impurities in the center, and cutting the steel exposes these impurities and creates a less corrosion resistant surface. A subsequent chemical treatment (such as a pickling) will minimize the problem.

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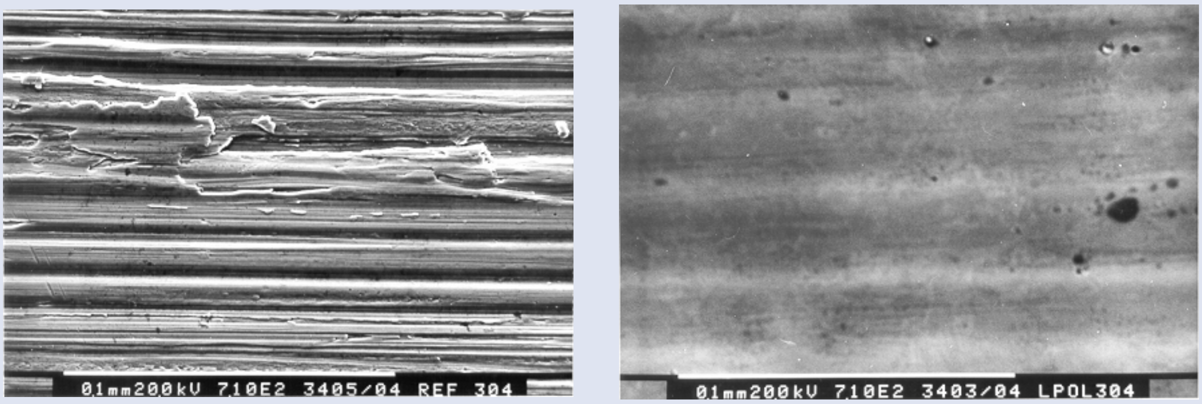
Brushing, Blasting, Grinding etc.

Any mechanical treatment of stainless steel affects the surface roughness and thereby the corrosion resistance of the steel. As a general rule, the corrosion resistance decreases with increasing surface roughness, and a very rough surface (say, sandblasted) performs markedly worse in a corrosion testing than the normal, smooth 2b.

The reason for this is double: At first, a rough surface is much better than a smooth one at "collecting" dirt and corrosive salts, thus forming "local elements". Secondly, a rough grinding will tend to expose a larger concentration of impurities from the steel itself. Such impurities, in particular sulfides, may act as points of attack for pitting corrosion, and thereby lower the corrosion resistance.

In addition, a rough grinding will tend to increase the level of tensile stress in the surface of the steel, increasing the risk of stress corrosion cracking. In contrast, a fine blasting (shot peening or glass blasting – not sand blasting) may increase the level of compressive stress and thus increase the resistance against SCC.



Two stainless steel plates, both EN 1.4301 (AISI 304). The left one has been grinded, while the right one has been electro polished (Chapter 8). It is not hard to imagine which surface is most effective collecting salts and moisture. The white line in the bottom of each photo is 100 µm. Both photos courtesy of Technical University of Denmark (DTU).

From a corrosion point of view, it is normally an advantage not to perform any kind of mechanical sur-face treatment at all! The smooth and pickled 2b surface of the cold-rolled sheets possesses its maximum corrosion resistance and no matter how much we grind, it just gets worse. As above, a proper chemical surface treatment (Chapter 8) will reduce the damage of the steel.

Handling and Transport

A particular risk when dealing with stainless steel is iron contamination originating from using the same tools and equipment for handling mild steel along with stainless steel. Using the same trucks, the same fork lifts or the same machinery may transfer minor amounts of mild steel or rust onto the stainless steel. Apart from looking ugly, the contaminations may cause corrosion of the stainless steel itself.

A nasty example of carbon steel particle, having been mashed into the stainless steel surface during cold forming. The iron particle must have been very hard, as it has been pressed into the stainless steel, and even though a pickling will remove the iron contamination, the holes remain.

Iron contaminations may be removed chemically; however, preventing the whole thing from happen-ing is at least as effective. In particular, all tools, trucks and lifts used for stainless steel should only be used for stainless steel – not mild steel.

Even if the tools are separated, another risk is the transfer of metal dust from the grinding of mild steel onto the stainless steel further down the alley. This can only be prevented by keeping the production of mild steel and stainless steel separated completely, preferably in two separate buildings. If this can not be arranged, a chemical post-treatment is mandatory.