Characteristics and properties of stainless steel (2)

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On the basis of their properties the different types of stainless steel have a certain corrosion resistance in aggressive environments. This resistance is not the same for each type. The choice of the right type of stainless steel is very important for each application.

Different elements have their influence on the properties of stainless steel (MK1) and offer a certain resistance against corrosion. Each system knows its threats and also stainless steel does. We can divide these threats into two groups, that is to say:

- Threats from the outside
- Threats from the inside.

Threats from the outside

Of course there is much to say about the threats from the outside. Each metal that is subjected to a certain aggressive environment, usually is also affected by its threats. Metals like gold and platinum, and in smaller measure silver and tantalum, in the rule often make an exception, but the majority of the other metals, have their limits especially in chemical environments. It is, therefore, extremely important for the design engineer, the metal expert, and the chemist to look together at the whole situation, in order to make the best material choice.
Unfortunately, there is not often such teamwork, consequently a lot of corrosion has already started, which could have been prevented or slowed down.
Therefore, during the last few years, the interest to join the assessments has become more and more relevant. The main rule is to keep down the maintenance costs, using the best materials possible and in any case to reach the economic lifetime of a system.
There are several corrosion tables, which allow to choose, broadly speaking, the best kind of stainless steel for a certain environment at a certain temperature. It would take too long to pay much attention to this aspect in this article, and this is also the reason for which it will be limited to the enumeration of the facts hereunder.
In principle there are two kinds of chemical load, that is to say: reducing and oxidizing environments. When an environment reacts permanently in a reductive way, than the use of stainless steel is to be advised against, because there is a big chance that the slug layer of chromic oxide will be destroyed.
With certain reductive environments it may happen, that the oxygen of the chrome will be removed, and this will therefore mean, the end of the layer of oxide that was supposed to give the protection.
The material is then going to be dismantled and becomes actually a prey for its environment. Even if the layer of oxide has not been removed, the use of stainless steel is still dubious, because the spots that have been damaged by the lack of oxygen cannot be repaired.
The so-called self healing-effect does not work anymore, as a consequence there can be heavy local corrosions. Therefore, when we have to use the stainless steel in reductive environments, it is important to passivate stainless steel with a kind of regularity in an oxidizing environment (e.g. nitric acid).
Since stainless steel is mainly used in oxidizing conditions, it is in itself already a guarantee, that there are substances that keep the layer of oxide intact, unless the environment is becoming too aggressive. Since the scale of the threats from the outside is almost unlimited, in this article the attention will be focused only on a few practical circumstances that occur quite often, for example, the application in several types of water, air and chemical corrosions.

Corrosion in water

The aggressiveness of water can change considerably according to its chemical composition. The following definition of the composition of different kinds of water and of their effects on stainless steel is related to normal

1. Stainless steel parts for valves

cases, so that there can be also exceptions.
The types of corrosion that generally appear in stainless steel, are pit-, crack- and stress-corrosion. The chloride percentage of water is the most important and the most influential factor. It is especially important to prevent too low stream speeds of water, in order to avoid sediments. The welded joints also ought to be cleaned well.
Distilled and de-ionised water are names for water, containing a very little content of dissolved salts. These kinds of water will not cause, on the whole, corrosion under 100 °C. At higher temperatures, especially when there is a high oxygen content in water, the chance of inter-crystalline stress corrosion will increase in not smouldered AISI 304 stainless steels.
Stainless steel will generally resist to the aggressiveness of potable water, however, limits have to be set to the content of chloride and to other factors. Potable water has for hygienic reasons a chloride content of about 100-200 mg/l.
Water lines for both cold and warm water are generally made of an AISI 304 quality without molybdenum, when the content of chloride is lower than about 200 g/l. When the content of chloride is between 200 and 500 mg/l, the AISI 316 quality needs to be used. When the chloride content and the temperature still rise, than it is necessary to use special types of stainless steel. The choice of materials has than to be made in relation with the content of chloride, but also depending from factors like water stream speed, design details, opportunity to clean the welds, etc.
Sewage has a low temperature, and the content of chloride varies normally between 50 and 300 mg/l. Generally an AISI 304-type (i.e. without molybdenum) pays very well. In some situations you can take an AISI 316 type, because, for example, it is difficult to change a pipe. Fresh and sub soil water can have a very large variety of pollutants. In Sweden, for example, the chloride content of a certain lake is 10 mg/l, however other lakes can reach up to 200 mg/l. Sub soil water being pumped, also has a relatively high content of chloride. Swimming pool water generally has a very high content of chloride and chlorine.
Since the AISI 304 types fade, types containing molybdenum are used. This is valid also for the

2. Filterhouse made of 316L

filtration, chlorinating, and heating apparatus, together with the pipe systems related to it.
Brackish water, a mixture of fresh water and seawater, has a variable content of chloride. There are practical examples where this can oscillate between 2.000 – 10.000 mg/l. Stainless steel without molybdenum should not be used in such an environment. The type AISI 316 is satisfactory, when the temperature remains low.
The presence of certain sulphur compounds, such as hydrogen sulphide, makes water more aggressive for stainless steel. Therefore, higher alloyed sorts of stainless steel should be used with higher temperatures, and with other unfavourable conditions. Each case will need its own specific quality of stainless steel.
Seawater has a very high content of chloride and therefore stainless steel can be applied under certain conditions. Under others the flow rate should be enough; there may not be cracks and the temperature has to remain low. Higher percentages of chromium and molybdenum will make stainless steel more suitable in this environment.

Atmospheric corrosion
Atmospheric corrosion can appear if stainless steel is set up in the open air. The corrosion medium is, in this case, water having a high concentration of oxygen (because of condensation and rainwater), and having a relative low temperature and containing components, originated from the air pollution. This can vary a lot from place to place. Atmospheric corrosion can also be stimulated by the amount of precipitations, sunlight, wind etc. Atmospheric environments can be distinguished in four types namely: industrial, rural, sea and urban environment. Research and practical experience demonstrated stainless steel having a very good resistance to atmospheric corrosion. Studies in Sweden demonstrated, that stainless steel exposed to sea water for a period of ten years, only showed local corrosion on 13 % chrome steel. The depth of this corrosion damage was a mere 0,1 – 0,2 mm. Other qualities, containing at least 17 % of chrome and chrome nickel types, were only faded by a very small corrosion or from dirt.
Concerning the functional aspects of an installation, we can state that atmospheric corrosion does not lead to problems. When aesthetical requirements are made, especially in relation to the prevention of fading, the following guidelines should be followed: a seawater environment requires a quality containing at least 2% molybdenum, for other environments AISI 304 can be sufficient. In a rural environment even chrome steel can be enough. It is also important to make the

3. Heat exchanger made of 304L

surface smooth enough, in order to prevent undesirable corrosion effects. In a seriously polluted atmosphere, the surface will not always remain shiny and therefore the stainless steel should be regularly cleaned.

Warm air and steam

If steel is heated in the air, an oxidized layer will arise on the surface. Chrome alloyed steels have a higher resistance to this oxidation than carbon steel. If the amount of chrome rises from 0% to 27% , the scale forming temperature in dry air will rise from 500 °C to about 1.125 °C. Silicon, aluminium, and in certain cases, also nickel will further improve the oxidation resistance. Quick temperature changes have a negative effect because of the fact that it creates thermal tensions in the oxidized layer. In such situations it is better to use a ferrite quality instead of an austenite one, because the type mentioned before has a lower coefficient of thermal expansion. This negative effect, specific of austenite types, diminuishes again when the amount of nickel increases.
Steel being exposed to water vapour (steam), will also oxidize on the surface. In connection with this it is considered that, an increasing quantity of chrome will increase the oxidizing resistance. Austenite stainless steels are often used because they have a high resistance to oxidation as well as a high mechanical strength at high temperatures. However, together with condensation, the austenite sorts can be affected by stress corrosion.

Flue gases

Gases that are given off by the combustion of oil, coals and coke will always contain a certain amount of sulphur. If the combustion is complete (oxidizing environment), it will lead to sulphur dioxide and if the combustion is not complete (reductive environment), it will lead to the formation of hydrogen sulphide. These sulphur compounds will considerably shorten the lifetime of steel.
Since sulphur dioxide is less corrosive than hydrogen sulphide, the combustion should always take place with an excess of air. Steels alloyed with chromium offer a good resistance against corrosion in an oxidizing, as well as, in a reductive environment.
In general, the ferrite chromium steels can be recommended. But if a high mechanical load will appear, than an austenite quality has to be used. This offers, namely, a better resistance to creeps. In a reductive environment there is a good chance that the alloyed nickel will connect with sulphur, which has a relatively low fusion point.
This nickel sulphide can sit as a melted film around the boundary granules. It is obvious, that this type of corrosion will lead to damages. This form of corrosion can spread very quickly if the temperature of 650 °C is reached (fusion point of nickel sulphide).

Chlorine and hydrochloric acid

The kinds of steel that come into contact with chlorine or hydrochloric acid form metal chlorides, that are volatile, i.e. they have a high vapour pressure. Knowledge of the vapour pressures of metal chlorides can therefore give a rough impression of the corrosion rates to be expected. For pure nickel, for example, the corrosion speed passes off in the same proportion to the vapour pressure of the nickel chloride, in the temperature range from 500 °C till 700 °C. With temperatures under the 350 °C, dry chlorine and hydrochloric acid will not cause corrosion on stainless steel, even if dry gas seems to be extremely aggressive. If the temperature increases the dry gas will also become corrosive, and at the temperature of 350 °C the aggressiveness of dry gas on AISI 304 stainless steel will be the same as of moist gas.
Different types of stainless steel corrode at different rates. Alloys on nickel bases have the highest resistance against such kinds of environments and will therefore be applied in processes where chloride appears at increased temperatures. A good example is the production of vinyl chloride.
Austenite stainless steel is sensitive to stress corrosion in solutions containing chloride at temperatures above 60 °C. Such types can still be used in chloride environments at higher temperatures, if the design is made in such a way that no high tensions originate through external influences.
Internal tensions caused by cold consolidations, welding, etc., can in certain cases be reduced through smouldering with low tension.
Cracking, resulting from stress corrosion, can find its beginning in corrosions which arise from pit- and/of crack corrosion. In other words the prevention of these forms of corrosion also diminuishes the risk of stress corrosion.
Certain elements that are not oxidizing or reductive, can influence the aggressiveness of corrosive solutions. The most important examples of such elements are chlorides and fluorides that strongly increase the aggressiveness of both organic and inorganic acids.
Another threat from the outside is the erosion, in other words, corrosion/erosion. In a flowing medium, this wear and tear can lead to the so called erosion-corrosion. In order to prevent this as much as possible, the designer of the device has to do everything possible in order to prevent turbulence and/or fluid collisions (especially in curves and joints).
Stainless steels have, in comparison with other metals, a good resistance against erosion-corrosion. In certain strong corrosive environments, however, the current velocity has to be as high as possible, in order to prevent corrosion-erosion.

4. Vacuumunit 316L for chemical industry