

Important Facts on Stainless Steel

The term "Stainless Steel" is a collective term for over 120 different types of Stainless Steel alloys. Over a period of decades, a large number of various alloys has been developed that offer the best particular properties for a wide range of applications. These alloys all have one thing in common: They require no additional surface protection, thanks to the chrome contained in the alloy. This Chromium component forms a colourless, transparent oxide coating on the surface which, following damage, independently seals with the help of the oxygen in the air or water.

Stainless steels are summarised in DIN 17440 and DIN EN ISO 3506.

Basically, Stainless Steel alloys are divided up into 4 main groups depending on their crystalline structure:

1. Martensitic Stainless Steels

Based on the structure, materials with a 10.5 - 13.0% Chromium component and a carbon content of 0.2 - 1.0% are assigned to this group. Other elements can be added as an alloy component. The Carbon ratio must permit heat treatment, referred to as tempering. This allows improvements in strength.

2. Ferritic Stainless Steels (referred to as Chrome Steels)

These materials have Chrome components of 12 - 18% and a very low carbon content of less than 0.2%. They cannot be hardened.

3. Austenitic Stainless Steel

(referred to as Chrome-Nickel / Chrome-Nickel - Molybdenum Steels) The austenitic Chrome-Nickel Steels offer a particularly favourable combination of working properties, mechanical properties and corrosion resistance. They are therefore recommended for many possible applications and are the most important group of stainless steels. The most important property of this group of steels is the high corrosion resistance, which is increased along with the alloy content, particularly of Chromium and Molybdenum. As with the ferritic steels, a fine-grain structure is also necessary with Austenitic steels in order to obtain favourable technological properties. Solution annealing at temperatures of between 1000° C and 1150° C followed by cooling in water or air is carried out as the final heat treatment in order to prevent the formation of deposits. Unlike Martensitic Steels, Austenitic Steels cannot be hardened. The high stretching capacity of Austenitic Steels guarantees good cold forming properties. The Austenitic structure has a 15 to 26% Chromium component and a 5 - 25 % Nickel component. Resistance to rust and acids is increased by the addition to the alloy of 2 - 6% molybdenum.

This also includes so-called stabilised Stainless Steels alloyed with Titanium or Niobium. These elements prevent the formation of Chrome carbides during welding.

4. Austenitic - Ferritic Stainless Steels (referred to as DUPLEX steels)

Duplex Stainless Steels, named after their two structure components, contain 18 - 25 % Chrome, 4 - 7 % Nickel and up to 4 % Molybdenum in an Austenitic - Ferritic structure.

The term "V2A" originated in the year 1912 and refers to a product from "Test Series 2 Austenite". This was later followed by "V3A", "V4A" etc. and although these terms are today generally referred to for short as "A2", "A3", "A4" etc., these designations are not unambiguous. Today there is a material numbering system that applies throughout Europe.

It must be noted here that there is no 1:1 correspondence between the AISI and UNS designations and the material numbers as defined by EN 10088.

For example, the material AISI 304L is equated to the material number 1.4306, even though it displays similar properties to 1.4301 and 1.4541.

Compatibility with other materials

In practical use, there is often a need to combine Stainless Steels with various metallic materials in one component. When there is an electrically conductive connection between these materials, corrosion reactions occur in the presence of a conductive medium, which can cause damage through contact corrosion. According to DIN 50 900 Part 1, the contact corrosion is an "accelerated corrosion of a metallic area that is attributable to a corrosion element, consisting of a metal/metal pairing or a metal/electron-conducting solid body with different free corrosion potentials. Here, the metallic area that corrodes faster is the anode of the corrosion element". The corrosion manifestation that occurs with contact corrosion is frequently even or uneven surface abrasion.

The surface abrasion or material consumption of the "base" partner in the combination depends on the strength of the flowing element current ("potential differential current") and the level of intrinsic corrosion in the mixing potential of the metal combination. The element current is a complex variable that depends on the geometric arrangement, the size of the electrode surfaces in contact with the medium, the resting potentials and the polarisation resistances of the partners, as well as on the electrolyte resistance of the medium.

The characteristic of the partial flow density potential curves of both materials in the attacking medium is responsible for assessing the corrosion risk of the more base partner in a material combination, and not the level of the potential difference (voltage difference) between the materials connected to each other. The corrosion flow density (element current) and therefore the contact corrosion attack can change by several orders of magnitude with the same potential difference, depending on the characteristic of the anodic and cathodic partial flow density potential curves.

What is crucial is whether the anodic or the cathodic part reactions can occur unhindered or hindered, e.g. by the outer layers that form. If unfavourable surface conditions (large cathode / small anode) exist alongside good conductivity of the corrosive medium, the contact corrosion can result in corrosion damage.

If that is the case, then using the theoretical electrochemical series and also the practical electrochemical series as the basis to estimate the risk to the materials in the event of conductive contact with each other is unsuitable in practice. Corrosion tests as defined in DIN 50 919 are necessary in order to precisely assess the risk associated with a material combination.

Physical properties

The physical properties of a few selected steel types are shown in the table below for comparison purposes. Pay attention to the higher thermal expansion and the lower thermal conductivity of Austenitic Steels. Their electrical resistance is higher than with unalloyed steels because of the alloy contents.

One important distinguishing characteristic between the ferritic / martensitic Chrome Steels and the Chrome-Nickel Steels is magnetisability. In contrast to magnetisable Chrome Steels, Austenitic Steels display largely unmagnetisable behaviour in the solution-annealed state.

With the Austenitic Steels, cold forming can cause a structure change, with the result that limited magnetisability then exists. However, the Nickel content significantly influences the magnetisability of the austenitic Stainless Steels, with the result that when the Nickel content is higher, the tendency towards magnetisability can be largely prevented even in the cold-formed state.

Physical properties

Type		Modulus of Elasticity at 20° C Nm/mm ²	magnetizable	magnetic
W. Nr.	Type VD			
1.4016	X 6 Cr 17	200	no	yes
1.4122	X 35 CrMo 17	200	yes	yes
1.4301	X 5 CrNi 18 10	200	no	no
1.4305	X 10 CrNiS 18 9	220	no	no
1.4404	X 2 CrNiMo 17 13 2	200	no	no
1.4510	X 6 CrTi 17	200	no	yes

Corrosion of Stainless Steels

Corrosion Resistance

A basic prerequisite for achieving optimum corrosion resistance is a surface that is absolutely clean metallically. Stainless Steels display particular resistance to chemically aggressive, aqueous media. They generally have a mass component of the element Chromium (Cr) of at least 12% and a mass component of the element Carbon (C) of maximum 1.2% (1.4016).

The high corrosion resistance of Stainless Steels is attributable to their capability of forming what is referred to as a passive coating on the surface. This is a Chrome-rich Metal Oxide or Metal Oxide Hydrate coating just a few Angstrom thick that separates the metal from the attacking medium.

The passive coating of a Stainless Steel is not something unchangeable. Rather, over time it strikes an equilibrium with the surrounding medium in terms of its composition and its structure. After the metal surface suffers mechanical damage, a new passive coating forms generally on its own.

If a medium cannot form a sufficient passive coating or if the existing passive coating is chemically interrupted or destroyed completely, corrosion damage can occur. Chromium is the decisive alloy element for the capability to form a passive coating.

Increasing the Chromium component and adding Molybdenum (Mo) to the alloy along with other alloy elements enables the steel's resistance to much more aggressive conditions of use to be increased.

Only the amount of alloy elements dissolved in the metal is effective for passivation. The respective highest corrosion resistance therefore displays a separation-free matrix, which is not reduced by deposits or the formation of intermetallic phases such as chrome and molybdenum.

Stainless Steels can suffer abrasive surface corrosion and various forms of local corrosion. Abrasive surface corrosion can mainly be expected upon contact with acids and alkalis. In most cases however, the various forms of local corrosion are more important in practice.

Intercrystalline Corrosion

Intercrystalline corrosion is an attack along the so-called grain boundaries, while the grains themselves are not or are hardly ever abraded. The attack along the grain boundaries can go so far that individual grains are released from the grain structure, causing the structure to lose its cohesion.

The cause of intercrystalline corrosion in Stainless Steels are deposits of Chrome-rich carbides at the grain boundaries, which result in Chromium depletion in the areas near to the boundaries.

The zones of low Chromium content thus formed are not sufficiently corrosion-resistant against most attacking media and can therefore dissolve quickly.

The Chrome carbide deposits require a certain Carbon content and occur in the temperature range of between approximately 500° C and 800° C, for example in heat treatment or welding.

To prevent a Chrome carbide deposit, it is possible to reduce the Carbon content in Stainless Steels to below 0.03% or to bind the existing carbon by using so-called stabilisation elements such as Titanium (Ti) or Niobium (Nb), which have a greater Carbon affinity than Chromium.

If Chromium carbide deposits have occurred, these can be dissolved again at solution annealing temperatures of over 1050° C. In the case of unstabilised ferritic steels, a susceptibility to intercrystalline corrosion can be remedied by annealing at 800° C - 885° C. This remedies the Chromium depletions in the zones near to the grain boundaries by post-diffusing Chromium out of the interior of the grains.

Crevice and Pitting Corrosion

In most cases, crevice corrosion is caused mostly by Chloride ions. The more rare Halogenides Bromide and Iodide can also cause this. Pitting corrosion is caused by an interaction between the halogenide ions and the passive coating, whereby the passive coating is penetrated locally. Pinprick-type impressions form and, as a result of their expansion, pits that can have a different character. The risk of pitting increases along with the concentration of Halogenide ions, the temperature and the steel's electrochemical potential.

Crevice corrosion occurs in gaps in which the exchange of liquid with the environment is restricted. Such gaps are related to construction or operation and occur for example on flanges, pipes, under seals, screw heads or encrustations. The corrosion mechanism is basically the same as that for pitting. The gap geometry and the type of gap-forming materials are additional influencing factors. Since crevice corrosion occurs when there is much less corrosion stress than pitting corrosion, the occurrence of crevices should be avoided via constructive measures as much as possible in media containing chlorine.

When there is a homogeneous alloy element distribution, the relative crevice and pitting corrosion resistance of a Stainless Steel can be approximately estimated via the variable "W".

$$W = \%Cr + 3.3x\%Mo + 30x\%Ni \quad \text{or} \quad W = \%Cr + 3.3x\%Mo.$$

However, the influence of the alloy element Nitrogen is more complex than expressed in this equation. The high effectiveness expressed by the factor 30 should only fully apply in the case of high-alloy steels with greater Molybdenum contents. Non-metallic impurities, particularly Sulphide deposits, promote crevice and pitting corrosion if they reach the surface. As smooth a surface as possible can be advantageous, making it more difficult for deposits to stick that can cause crevice corrosion.

High resistance to crevice and pitting corrosion is achieved only with perfect surface properties, i.e. a metallogically bright surface.

Tarnishes and scale residues after welding, extraneous metal abrasion particles, extraneous rust, grinding agent residues etc. must therefore be completely removed.

Extraneous Rust

Extraneous rust is deposits of rust particles that did not arise at the place in question but came from elsewhere. Extraneous rust mostly occurs when "black" and "white" steels are not stored and worked separately.

However, tool abrasion can also cause extraneous rust. Deposits of extraneous rust allows the conditions for gap corrosion to be fulfilled.

Stress Crack Corrosion

Media that have specifically-acting components - particularly Chloride ions - can cause a corrosion attack with crack formation in Stainless Steels if tensile stresses are acting at the same time, even if the steel is sufficiently resistant to the medium when there is no mechanical stress. This manifestation, called stress crack corrosion, can be caused not just by work-related tensile stresses applied from the outside. Rather, the cause is more often internal stresses applied during working, for example during welding, grinding or cold forming.

As with crevice and pitting corrosion, the risk of Chloride-induced stress crack corrosion increases along with the temperature and chloride concentration. Other influencing variables act on the material side. For example, Austenitic Steels of the type 18/10 - CrNi and 18/10/2 - CrNiMo are at particular risk of chloride-induced stress crack corrosion at temperatures above approximately 50° C. However, resistance can be greatly increased by increasing the Molybdenum content and particularly the Nickel content. Ferritic and Ferritic-Austenitic Stainless Steels are also comparatively less sensitive.

Vibration Corrosion

The vibration strength of all Stainless Steels is reduced to a greater or lesser degree by additional chemical attack. The decrease in vibration strength depends on the attacking medium and the multi-axial nature of the alternating stresses occurring.

Contact Corrosion

The possibility of contact corrosion exists when two metals with different free corrosion potentials are conductively connected to each other in a corrosion medium. The metal with the lower free corrosion potential can at least be polarised to higher potentials and can be attacked more as a result.

However, contact corrosion does not necessarily occur even when there are great differences between the free corrosion potentials of the metals involved. This depends on the electrochemical behaviour of the two metals.

The conductivity of the medium and the surface behaviour of the metals involved is also important. If the "more base" metal has a much larger surface than the "more noble" metal and the corrosion medium displays high conductivity, the risk of corrosion damage is lower. However, a connection between a "base" metal with a small surface and a "noble" metal with a large surface must be avoided.

Generally, Stainless Steels assume high free corrosion potentials and are therefore hardly subject to the risk of being heavily attacked by contact corrosion. Much more frequent is the case in which contact corrosion occurs in other metals with a low free corrosion potential as a result of a connection with a Stainless Steel.

Selection of Material

Requirements regarding the practical value properties of stainless steel such as strength, surface design, processing, processibility, resistance to environmental influences and other media as well as quality and price allow an optimal selection of material meeting the demands on products to be manufactured.

Our customers have the option to choose between different materials, we offer, however, the most favourable material or the most favourable combination of materials as a standard.

As a general rule, in the solar field rustproof stainless steels such as chromium steel with a chromium content of approx. 17% and a carbon content of < 0,2% (X 6 Cr 17 1.4016) are produced on their own, in conjunction with a duplex stainless steel e.g. X 5 CrNi 18 10 (1.4301) or completely of duplex stainless steel. The latter case makes the production easier for the manufacturer, but it cannot be produced at such a reasonable price.

Furthermore, X 5 CrNiMo 17 12 2 (1.4401) is used for stainless steel applications at the seaside, in outdoor and indoor swimming pools, as chloride ions lead to pitting corrosion and crevice corrosion. The addition of Mo as an alloying element results in an essentially improved resistance to pitting corrosion and crevice corrosion.

In the field of processing stainless steel every weld seam is, as a basic principle, a weak spot regarding corrosion. Hence the passivating by stainless steel shot peening introduced by the company ALTEC SOLARTECHNIK has meanwhile become a commonly employed procedure.

So welding torsions are reduced and the hazard of corrosion is reduced to a large extent by compacting the surface.

Quality Assurance

The company ALTEC SOLARTECHNIK is a certified welding company with all the licences necessary for high-quality manufacturing e.g. for manual welding and automatic welding for steel and stainless steel, TÜV [Technical Inspection Agency] certified welding of roof hooks made of the materials 1.4016, 1.4301 as well as welding of joints of 1.4016 and 1.4301.

Roof hooks and mounting brackets are tested on their strength on a static test bench; on a dynamic test bench these hooks take a long term test in order to discover potential symptoms of fatigue of the material which could lead to breakage in 40 or 50 years. All stainless steel components are tested on potential corrosion in long term tests. The close cooperation with the TÜV [Technical Inspection Agency], the SLV [German Welding Institute for training and testing] as well as academies, universities and other institutes and institutions allow a continuous improvement and further development of our products on a high level of quality.

The company operates according to the seal of approval and is presently certified according to DIN EN ISO 9001:2000.