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A service provided by the
British Stainless Steel Association

Introduction to the Corrosion Resistance of Stainless Steels

The inherent corrosion resistance of stainless steels is derived from alloying the base iron with chromium.
BSEN 10088:1 defines that a stainless steel must have a minimum of 10.5% (by weight) chromium & a maximum of 1.2% carbon to be classified as "stainless".
Other alloying elements including nickel, molybdenum, nitrogen, titanium (or niobium) are added to form the various grades.
These additions are made to enhance the "basic" corrosion resistance of the steel but can also usefully modify other properties, such as formability, strength and cryogenic toughness.

The corrosion resistance of stainless steel arises from a "passive", chromium-rich, oxide film that forms naturally on the surface of the steel. Although extremely thin at 1-5 nanometres (i.e. 1-5 x 10^{-9} metres) thick, this protective film is strongly adherent, and chemically stable (i.e. passive) under conditions which provide sufficient oxygen to the surface.

The key to the durability of the corrosion resistance of stainless steels is that if the film is damaged it will normally self repair (provided there is sufficient oxygen available). The passive state can be broken down however under certain conditions and corrosion attack result.

In contrast to other steels "general" corrosion, where large areas of the surface are affected, stainless steels in the passive state, are normally protected against this form of attack.
However, localised forms of attack can occur and result in corrosion problems.
The assessment of corrosion resistance in any particular environment, therefore usually involves a consideration of specific corrosion mechanisms.
These mechanisms are principally :-

- Crevice corrosion
- Pitting corrosion
- Intercystalline (or intergranular) corrosion (ICC)
- Stress corrosion cracking (SCC)
- Galvanic (bi-metallic) corrosion

Other related mechanism can also occur, which include:-

- Erosion – corrosion
- Corrosion fatigue

Localised corrosion is often associated with chloride ions in aqueous environments.
Acidic conditions (low pH) and increases in temperature all contribute to localised mechanism of crevice and pitting corrosion.
The addition of tensile stresses, whether applied by loading or from residual stresses, provides the conditions for stress corrosion cracking (SCC).
These mechanisms are all associated with a localised breakdown of the passive layer.

A good supply of oxygen to all surfaces of the steel is essential to maintaining the passive layer but higher levels of chromium, nickel, molybdenum & nitrogen all help in their individual ways to prevent these forms of attack.

As a general rule increased corrosion resistance can be expected by moving through the grades:-

1.4512 - 1.4016	409 - 430	increasing chromium from 11 to 17%
1.4301	304	adding nickel which aids to reformation of the passive layer if it is disturbed
1.4401	316	adding molybdenum reduces the effectiveness of chloride ions in locally breaking down the passive layer
1.4539 & 1.4547	904L & 254SMO	further increases in chromium, nickel and molybdenum result in overall improved localised corrosion resistance

Duplex grades such as (1.4462 / S31803 / 2205) are specifically designed to combat SCC by "balancing" the structure to increase its strength, but additionally molybdenum & nitrogen enhance the pitting resistance, which in turn has the additional benefit in improving their SCC resistance.

With appropriate grade selection, stainless steels, will give good corrosion resistance, but the choice an inappropriate grade can result in failure by perforation or catastrophic cracking failure in shorter times than failure by uniform corrosion in "lower resistant" alloys such as ordinary, plain carbon steels.
Selection of the appropriate grade of stainless steel is of course a balance between attaining the appropriate degree of corrosion resistance, with the need to minimise cost, but an appreciation of the possible failure mechanisms does help avoid unnecessary & possibly costly failures.

To help in the selection of the correct grade corrosion tables are listed in references such as the Avesta Sheffield Corrosion Handbook.
Here a wide range of chemical environments (concentration of chemical species and temperature) are listed.
These indicate corrosion rates by weight loss and also as the risk to localized corrosion such as pitting or stress corrosion cracking.

Other programs have also been designed to predict the likelihood of crevice corrosion failure in chloride waters (NiDI Corrosion Engineering Guide disc).

References

Avesta Sheffield Corrosion Handbook for Stainless Steels
Avesta Sheffield AB,SE-774 80 Avesta, Sweden
ISBN 91-630-8118-0

Crevice Corrosion Engineering Guide
Nickel Development Institute, Alvechurch, B48 7QB
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