Stainless Steel
St St Corrosion Resistance

Corrosion

Corrosion can be defined as the attack of a metallic material by its environment. Stainless steels all possess a high resistance to corrosion. This resistance is conferred by the naturally occurring chromium - rich oxide film which is always present on the surface of stainless steel. Although less than 130 Angstrom thick (1 Angstrom unit = 10-8 cm) this invisible film is extremely protective as it is inert and adheres tightly to the metal. The oxide film has the unique property of self-repair which is unattainable in applied films. This means that if the film is removed or damaged or a new metal surface is created by cutting then in the atmosphere or other source of oxygen the protection will be instantaneously re-established. The more highly alloyed grades of stainless steel possess the best corrosion resistance and are able to withstand more aggressive environments.
Selection of the correct grade of stainless steel is the key to avoidance of corrosion problems.

Corrosion Resistance

Corrosion takes many different forms. Its initiation and subsequent rate of progress is affected in varying degrees by numerous material and environmental factors. A comprehensive assessment of the exact 'corrosion resistance' of a material is therefore difficult. However, corrosion tables covering a vast range of stainless steels and environments are available.

OXIDATION

Oxidation is the combination of a metal with oxygen to form the metal oxide which occurs in dry conditions. When this process is ongoing the whole of the metal may be converted. Stainless steels are oxidation resistant, even at elevated temperatures. Special heat resisting grades, such as type 310, are operated at temperatures of up to 1100°C.

PICKLING AND PASSIVATION

To achieve optimum corrosion performance stainless steel must go into service fully passivated. Its protective surface oxide layer must be intact and uncontaminated. In particular weld tint and any fabrication debris must be removed. It is particularly important to remove any Carbon or mild steel contamination. This is done using proprietary solutions, chemical and pastes based on Nitric Acid or a mixture of Nitric and Hydrofluoric Acids.

DESIGN CRITERIA

To achieve optimum corrosion performance care must betaken at the design stage. In particular design should employ smooth contours and radiused corners whilst avoiding sharp edges and crevices. Design should also promote material flow and mixing to avoid localised concentrations and/or stagnant conditions. Other considerations are ease of cleaning and maintenance as well as avoidance of dissimilar metal contact.

FORMS OF CORROSION

Forms of Corrosion

There are many different forms of corrosion.

General Corrosion is the uniform overall attack of a component across its whole surface. It is avoided by correct grade selection.

Other types of corrosion are explained on page 2.

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REVISION HISTORY

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Pitting Corrosion is the highly localised attack seen as small spots across a surface occurring mainly at sites of metallurgical heterogeneity. Particularly prevalent in chloride environments, especially if Oxyqen is in plentiful supply, it can lead to perforation. Higher Chromium, Nickel and Molybdenum contents improve pitting resistance, thus type 316 is extensively used in such situations. Laboratory tests can be carried out to confirm pitting resistance such as ASTM G48-03. The Pitting Resistance Equivalent (PRE) number can be calculated and gives a good indication of the resistance to pitting:

Austenitic Stainless Steel
PRE = (%Cr) + (3.3 x %Mo) + (16 x %Ni)

Duplex Stainless Steel
PRE = (%Cr) + (3.3 x %Mo) + (30 x %Ni)

Atmospheric Corrosion occurs due to the attack from oxygen, water and the pollutants therein such as chlorides, sulphur compounds and solids. The problem is particularly prevalent in coastal, industrial and highly polluted areas where necessitates the use of type 316 is recommended for outdoor applications in such environments.

Acid Corrosion occurs due to aggressive attack by acids which may be accelerated by the presence of other chemicals. A large number of acid environments are resisted by stainless steels - resistance to oxidising solutions is very good provided the correct grade is used.

Galvanic Corrosion covers situations where attack is caused by a potential difference. This potential difference can be set up in a number of ways including contact between dissimilar metals in an aqueous or conducting solution, differential aeration (variation in oxygen concentration) and local variations in concentration of the solution. Correct material selection and good design can eliminate this.

Waterline Corrosion is a form of galvanic corrosion taking place at the surface of a liquid in which the stainless steel is partially immersed.

Crevice Corrosion occurs in crevices such as joints, cavities, holes, corners, grooves, slots, gaskets and gaps between components. It is caused by the breakdown on the protective oxide layer, normally in reducing environments and can be seen as another types of galvanic corrosion. Good design should be used to eliminate such crevices and thus avoid this phenomenon.

Stress Corrosion Cracking (SCC) can occur in austenitic stainless steels when they are operated under tensional stress in chloride environments at temperatures in excess of about 60°C. The stress could arise through in-service loading, pressurisation of pipework and vessels or as residual stress from cold working. Nickel content assists resistance to SCC and thus grade 316 is more resistant to this form of attack than 304, whilst the duplex grades such as 2205 perform very well. Ferritic stainless steels are immune to this form of attack.

Sulphide Stress Corrosion (SSC) is another form of Stress Corrosion Cracking that can occur in environments containing both chlorides and Hydrogen Sulphide (H_2S). It is of particular concern in the off-shore oil and gas industry.

Bacterial Corrosion occurs due to the presence and activity of certain types of bacteria and tends to be localised, for example in crevices. It is overcome by good design, continuous flow and regular cleaning.

Inter-Granular Corrosion in austenitic stainless steels is a rapid and localized phenomenon. Called sensitization, it is caused by Chromium Carbide precipitation at grain boundaries which depletes the surrounding area of chromium thus reducing its corrosion resistance. This may be caused by incorrect heat treatment, heat input during welding, service in the temperature range 450 to 850°C or service at a higher temperature and slow cooling through this range. Modern steelmaking, correct grade selection and post weld heat treatment prevents this occurring. Various types of stainless steel can be considered to avoid the problem including extra low carbon grades and titanium (321 & 316Ti) or niobium (347) bearing grades.

Weld Decay is a form of intergranular corrosion occurring in the heat-affected zone of the parent metal parallel to the weld. Susceptibility to this attack is assessed using one of these standard tests:

- Test as given in BS1449/BS1501 using boiling copper sulphate/sulphuric acid,
- Test as given in ASTM A262 Practice C using boiling nitric acid. Low carbon grades perform better in the more severe (latter) test.

Fretting Corrosion which can also be called corrosion-abrasion is caused by continuous removal of corrosion product due to surfaces rubbing together, which leads to progressive wasting of material. Stainless steels do not suffer from this form of attack.

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