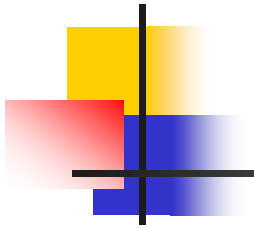


Corrosion Analysis of Stainless steel

Introduction

- **Corrosion** is deterioration of essential properties in a material due to reactions with its surroundings.
- Millions of Naira are lost each year because of corrosion.
- Much of this loss is due to the corrosion of iron and steel, although many other metals may corrode as well.

What is Stainless steel?

- Stainless Steel is a common name for metal alloys that consist of 10.5% or more Chromium (Cr) and more than 50% Iron (Fe).
- 10.5%<Cr<27%= Stainless Steel – used for corrosion resistance

Types of stainless steel

- ***Austenitic Stainless Steel***
- ***Martensitic Stainless Steel***
- ***Ferritic stainless steel***
- ***Duplex stainless steel***
- ***Precipitation hardening stainless steel***

Austenitic Stainless Steel

- Grade type is 304
- 16 – 26% Cr, 6 – 23% Ni
- Have a face-centered-cubic (fcc) structure
- Nonmagnetic, tough, ductile
- Ex. Type 304 most widely used in the world
- Type 304L is always preferred in more corrosive environments

Applications: domestic kitchen sinks,
commerical food processing equipment

Ferritic Stainless Steel

- Grade type is 430
- 12 – 25% Cr
- This is the simplest form of stainless steel
- Easy to machine
- They are moderately corrosion resistant

Application: automotive trim and inside dishwashers and clothes dryers.

Martensitic Stainless Steel

- Grade type is 410
- 6 – 18% Cr, upto 2% Ni
- Strong, hard and magnetic
- Used for mild corrosive enviornments

Application: knives, razor blades and corrosion resistance bearing

Precipitation Hardening S.S

- Type 17-4
- High strength
- Higher corrosion resistance than martensite stainless steel

Application: they are usually used in aerospace and defense industries.

Corrosion

- A process in which metal is destroyed by electrochemical reaction. When the metal is iron, the process is called rusting.

  Example: Rusting of automobiles,buildings and bridges, etc.

Did you know?

- Internationally, 1 tonne of steel turns into rust every 90 seconds.

- The energy required to make 1 tonne of steel is approximately equal to the energy an average family consumes over three months.

Stainless Steel Corrosion

- The name originate from the fact that stainless steel does not stain, corrode or rust as easily as ordinary steel.
- Stainless steel have resistance to oxidation(rust)and corrosion in many natural and man made environments.

UNIVERSALITY OF CORROSION

- Not only metals, but non-metals like plastics, rubber, ceramics are also subject to environmental degradation
- Even living tissues in the human body are prone to environmental damage by free radicals-Oxidative stress- leading to degenerative diseases like cancer, cardio-vascular disease and diabetes.

WHY DO METAL CORRODE?

- Any spontaneous reaction in the universe is associated with a lowering in the free energy of the system. i.e. a negative free energy change
- All metals except the noble metals have free energies greater than their compounds. So they tend to become their compounds through the process of corrosion

FORMS OF CORROSION AFFECTING STAINLESS STEEL

- Corrosion may be classified in different ways
- Wet / Aqueous corrosion & Dry Corrosion
- Room Temperature/ High Temperature Corrosion

WET & DRY CORROSION

- Wet / aqueous corrosion is the major form of corrosion which occurs at or near room temperature and in the presence of water
- Dry / gaseous corrosion is significant mainly at high temperatures

WET /AQUEOUS CORROSION OF S.S

- Based on the appearance of the corroded metal, wet corrosion may be classified as
- Uniform or General Corrosion Of steel
- Pitting Corrosion
- Crevice Corrosion
- Galvanic or Two Metal Corrosion
- Intergranular
- Dealloying

UNIFORM CORROSION OF STAINLESS STEEL

- The reaction starts at surface and proceeds uniformly.
  e.g.. Atmospheric corrosion.
- Maximum metal loss
- Not dangerous, rate can be measured in the laboratory.
- This type of corrosion occurs when there is an overall breakdown of the passive film formed on the stainless steel.

GALVANIC CORROSION OF STAINLESS STEEL

- Galvanic corrosion occur when two dissimilar metals electrically contact with each other and are immersed in electrolyte.
- When a galvanic couple forms, one of the metals in the couple becomes the anode and corrodes faster than it would all by itself, while the other becomes the cathode and corrodes slower than it would alone.

Steel screw in Mg

Requirements For Galvanic Corrosion

- In order for galvanic corrosion to occur, three elements are required

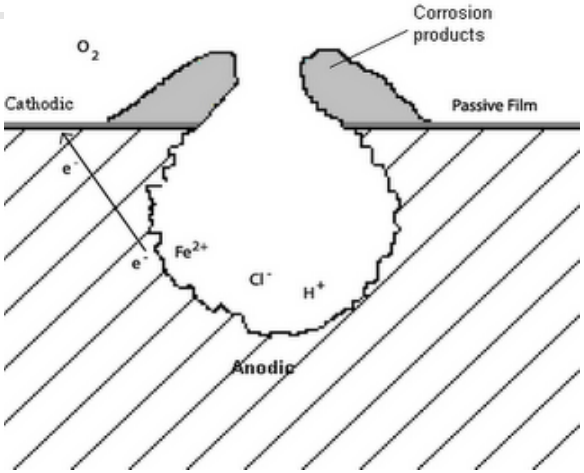
  a) Dissimilar metals

  b) Metal to metal contact

  c) Metals in same conduction solution (usually called electrolyte)

  If any of these elements is missing, galvanic corrosion cannot occur.

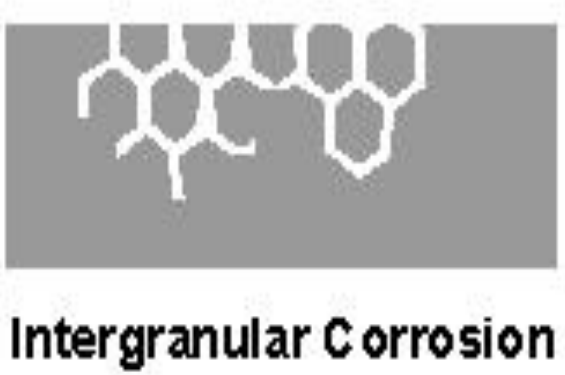
PITTING CORROSION OF STAINLESS STEEL



- Pitting corrosion is a form of extremely localized corrosion that leads to creation of small holes in metal.
- It occurs when the corrosive environment penetrates the passivated film in only a few areas as opposed to the overall surface.
- halogens will penetrate passivated stainless steel.

INTERGRANULAR CORROSION OF STAINLESS STEEL

- Intergranular corrosion is due to the formation of chromium carbides at high temperatures (450°- 859°C).
- Carbides of chromium form in the grain boundary regions thus reducing the chromium content and resulting in a path of lower corrosion resistance around the grains.



ERROSION CORROSION OF STAINLESS STEEL

- Erosion corrosion is the result of a combination of an aggressive chemical environment and high fluid-surface velocities.
- The flow will carry away any protective layer that was intended to protect the material, and even abrade the flow surface.

STRESS CORROSION CRACKING OF STAINLESS STEEL

- Stress Corrosion Cracking (SCC) is the cracking induced from the combined influence of tensile stress and a corrosive environment. The impact of SCC on a material usually falls between dry cracking and the fatigue threshold of that material.

Failure is along grain boundaries in a 316 stainless steel.

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PRINCIPAL ALLOYING ELEMENTS THAT AFFECT CORROSION RESISTANCE OF STAINLESS STEEL

Chromium(Cr):

- Essential element in forming the passive film.The passive film is observed at about 10.5% chromium.
- As chromium content increased , the corrosion protection increase.
- Chromium at 25 to 30%, the passivity of protective film is very high.

Nickel(Ni)

- When nickel is increased to about 8 to 10% resistance to stress corrosion cracking is decreased.
- However, when nickel is increased beyond that level, resistance to stress-corrosion cracking increase with increases in nickel content.

Manganese(Mn)

- Effects of manganese on corrosion are not well documented.
- Manganese combines with sulfur to form sulfides.
- Sulfide composition have substantial effect on the corrosion resistance of stainless steel.

Molybdenum(Mo)

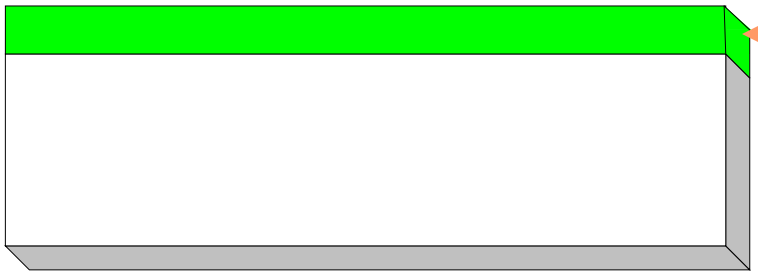
- Addition of molybdenum to the Cr-Fe-Ni matrix adds resistance to localized pitting attack.
- Its better resistance to crevice corrosion.

Corrosion Protection of S.S

- Protection of Anode
- Reduce the activity of cathode and or electrolyte.(Polarization)
- Sacrificial Layer
- Impressed Voltages

Passivation of The Anode

- Passivation, A thin chromium oxide layer forms on the surface and isolates the metal from the environment, called passive film.



Passive Film

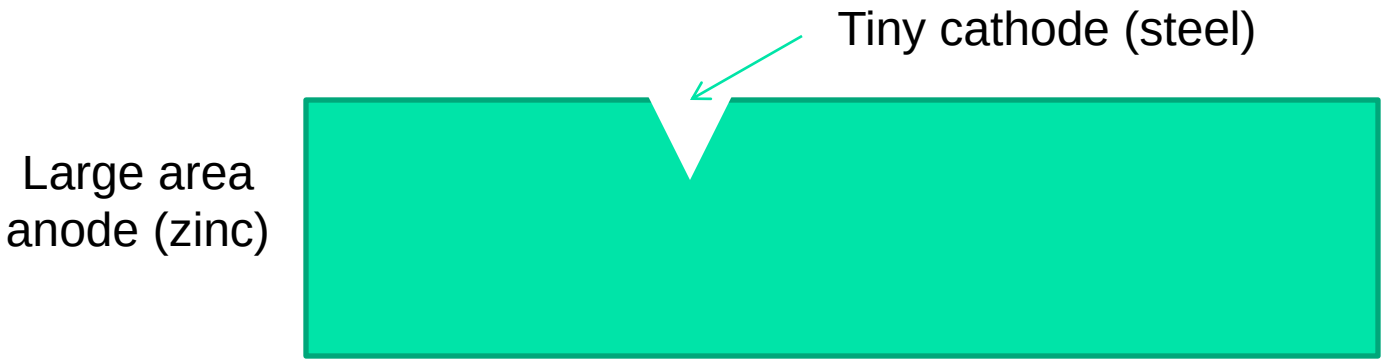
(Only microns thin, invisible and self repairing)

POLARIZATION

- This is the effect which reduces the actual chemical potential driving cell. If the thermodynamic force driving the ion into solution is reduced, this is polarization.
- Easy example: Hydrogen reduction at cathode, if there are not enough hydrogen ions available for reaction at the cathode, the corrosion potential will decrease.

SACRIFICAL LAYER

- Galvanization of Steel
- Dip steel sheet in molten zinc. Get a pretty thin coating.
- Zinc will be anode. Steel exposed by crack is the cathode. Since we have a huge anode having to be served by a small cathode, corrosion rate will be slow.



ANOTHER EXAMPLE

- Zinc is attached to the sheet hull of the vessel.

Attachment points

Stainless Steel For Coastal And Salt Corrosion

- Upgrading the use of stainless steel from 304 to 306 has significant help in reducing the effects of corrosion in several application.
- Molybdenum alloyed grades of type 316 are normally specified for marine atmosphere.

Street Level Application

There is no corrosion on type 316 bench and railing after 5 year of service. A smooth polished finished was used.

These type 304 railing were corroded after one year . They are uphill from a busy highway and salt laden mist is blown on to them. The rough surface finish hold the salt the railing making corrosion worse.

Street Level Application

Type 316 light poles were installed in 1967 with No.4 smooth finish. Although they are in parking area immediately adjoining to beach and exposed to coastal salt, there is no sign of corrosion

Similar light poles of type 304, shown in right bottom was installed in a sheltered location few blocks from a Beach. After one year chloride corrosion is visible.

COST OF CORROSION

- Direct & Indirect losses
- Direct loss: Material cost, maintenance cost, over-design, use of costly material
- Indirect losses: Plant shutdown & loss of production, contamination of products, loss of valuable products due to leakage etc, liability in accidents

CORROSION DAMAGE

- Disfiguration or loss of appearance
- Loss of material
- Maintenance cost
- Extractive metallurgy in reverse- Loss of precious minerals, power, water and man-power
- Loss in reliability & safety
- Plant shutdown, contamination of product etc

Conclusion

- No metal, except for gold and platinum in their natural state, are completely corrosion proof. But stainless steel has proven in thousands of applications, that it is one of the most economical solution's to combat the ever present elements that cause corrosion.
- Yet as its name implies - it is stain-less, not stain-proof