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Corrosion: Its Impact and Prevention

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ABSTRACT

Determination of functional and mechanical properties of metal owning to corrosion caused by moisture, chemicals, temperature and several environmental factors propels the demand for corrosion prevention and acid proof lining in numerous end –use industries. Corrosion preventive coatings are devised to protect structures from degradation caused due to exposure in extreme corrosive environment. By acting as a barrier between the materials and the corrosive environment, corrosion prevention coating or linings function as agents that enhance the life of structures by preventing their wear and tear.

Keywords: *Corrosion, environmental factors, prevention*

Introduction

Corrosion is the gradual destruction of material, usually metals, by chemical reaction with its environment. It is a constant, indiscriminate and costly enemy of metal corrosion means the breaking down of essential properties in a material due to chemical reaction with its surroundings. In the most common use of the word, this means a loss of electrons in the metals reacting with water and oxygen. Weakening of iron due to oxidation of the iron atoms is a well known example of electrochemical corrosion. This is commonly known as rust.

Step 1 iron + oxygen --> iron oxide

Step 2 iron oxide + water --> hydrated iron oxide (rust)

In the most common use of the word, this means electrochemical oxidation of metals in reaction with an oxidant such as oxygen rusting, the formation of iron oxides is a well-known example of electrochemical corrosion. This type of damage typically produces oxide (s) or salt(s) of the original metal. Corrosion can also occur in materials other than metals, such as ceramics or polymers although in this context, the term degradation is more common. Corrosion degrades the useful properties of materials and structures including strength, appearance and permeability to liquids and gases. Many structural alloys corrode merely from exposure to moisture in air, but the process can be strongly affected by exposure to certain substances. Corrosion can be concentrated locally to form a pit or crack, or it can extend across a wide area more or less uniformly corroding the surface. Because corrosion is a diffusion-controlled process, it occurs on exposed surfaces. As a result, methods to reduce the activity of the exposed surface, such as passivation and chromate conversion, can increase a material's corrosion resistance. However, some corrosion mechanisms are less visible and less predictable. Knowing about corrosion and the methods to control it is not enough; we have to incorporate those measures in order to insure complete corrosion prevention.

Factors affecting the corrosion reaction

The process of corrosion depends on various factors as under:

Factors Associated Mainly with the Metal

- Effective electrode potential of a metal in a solution
- Overvoltage of hydrogen on the metal
- Chemical and physical homogeneity of the metal surface
- Inherent ability to form an insoluble protective film

Factors which vary with the environment

- Hydrogen-ion concentration (pH) in the solution
- Influence of oxygen in solution adjacent to the metal
- Specific nature and concentration of other ions in solution
- Rate of flow of the solution in contact with the metal
- Ability of environment to form a protective deposit on the metal
- Temperature
- Cyclic stress (corrosion fatigue)
- Contact between dissimilar metals or other materials as affecting localized corrosion.

Types of corrosion: Some common types of corrosion are as follows:

- General Attack Corrosion
- Localized Corrosion
- Galvanic Corrosion
- Environmental Cracking
- Flow-Assisted Corrosion (FAC)
- Intergranular corrosion
- De-Alloying
- Fretting corrosion

Recognizing the symptoms and mechanism of a corrosion problem is an important preliminary step on the road to finding a convenient solution. There are following methods of corrosion control:

- Change to a more suitable material
- Modifications to the environment with the use of inhibitors
- Use of protective metallic or organic coatings
- Design modifications to the system or component

Corrosion prevention

There are several common corrosion prevention methods

1. Coatings

Forming a barrier on the metal surface against corrosive elements, to enhance the protection effect, most paints and coatings that form that barrier contain inhibitors and/or anticorrosive pigments. If environment is controlled (especially in recirculating systems), corrosion inhibitors can often be added to it. These form an electrically insulating or chemically impermeable coating on exposed metal surfaces, to suppress electrochemical reactions. Such methods obviously make the system less sensitive to scratches or defects in the coating, since extra inhibitors can be made available wherever metal becomes exposed. Chemicals that inhibit corrosion include some of the salts in hard water, chromates, phosphates, polyaniline, other conducting polymers and a wide range of specially-designed chemicals that resemble surfactants (i.e. long-chain organic molecules with ionic end groups).Corrosion resistant resins are used in end use industries such as automotive and transportation, oil and gas , heavy industries and others. Thus, rising demand for corrosion resistant resins from varied industries is also influencing the market of corrosion resistant resin market. The growing prominence of corrosion resistant resin market can also be attributed to increasing losses due to corrosion in structures, equipment, and machineries especially from chemical industry plants, especially parts such as boilers, heaters, pumps and chimneys.

2. Corrosion inhibition

The inhibition acts either by forming barrier layer on the metal surface or by providing buffering action. The effectiveness of a corrosion inhibitor depends on fluid composition, quantity of water, and flow regime. A common mechanism for inhibiting corrosion involves formation of a coating, often a passivation layer, which prevents access of the corrosive substance to the metal.

3. Cathodic Prevention

It provides corrosion control by bringing the potential of the metal to be protected to the immunity region. Cathodic protection (CP) is a technique to control the corrosion of a metal surface by making that surface the cathode of an electrochemical cell. Cathodic protection systems are most commonly used to protect steel, water, and fuel pipelines and tanks; steel pier piles, ships, and offshore oil platforms.

➢ ***Sacrificial anode prevention***

For effective CP, the potential of the steel surface is polarized (pushed) more negative until the metal surface has a uniform potential. With a uniform potential, the driving force for the corrosion reaction is halted. For galvanic CP systems, the anode material corrodes under the influence of the steel, and eventually it must be replaced. The polarization is caused by the current flow from the anode to the cathode, driven by the difference in electrochemical potential between the anode and the cathode.

Fig1: Sacrificial anode in the hull of a ship

➢ **Impressed current cathodic prevention**

For larger structures, galvanic anodes cannot economically deliver enough current to provide complete protection. Impressed current cathodic protection (ICCP) systems use anodes connected to a DC power source (such as cathodic protection rectifier). Anodes for ICCP systems are tubular and solid rod shapes of various specialized materials. These include high silicon cast iron, graphite, mixed metal oxide or platinum coated titanium or niobium coated rod and wires.

4. Anodic Prevention

It transforms the protected metal to the anode of the corrosion cell and bringing it into the passive area of the metal. Anodic protection impresses anodic current on the structure to be protected (opposite to the cathodic protection). It is appropriate for metals that exhibit passivity (e.g., stainless steel) and suitably small passive current over a wide range of potentials. It is used in aggressive environments, e.g., solutions of sulfuric acid.

5. Anodization

Aluminium alloys often undergo a surface treatment. Electrochemical conditions in the bath are carefully adjusted so that uniform pores several nanometers wide appear in the metal's oxide film. These pores allow the oxide to grow much thicker than passivating conditions would allow. At the end of the treatment, the pores are allowed to seal, forming a harder-than-usual surface layer. If this coating is scratched, normal passivation processes take over to protect the damaged area.

Fig 2: Anodized climbing descender with a yellow finish.

Anodizing is very resilient to weathering and corrosion, so it is commonly used for building facades and other areas that the surface will come into regular contact with the elements. Whilst being resilient, it must be cleaned frequently. If left without cleaning, panel edge staining will naturally occur.

6. Galvanization

Plating, painting and the application of enamel are the most common anti-corrosion treatments. They work by providing a barrier of corrosion-resistant material between the damaging environment and the structural material. Aside from cosmetic and manufacturing issues, there are tradeoffs in mechanical flexibility versus resistance to abrasion and high temperature. Platings usually fail only in small sections, and if the plating is more noble than the substrate (for example, chromium on steel), a galvanic couple will cause any exposed area to corrode much more rapidly than an unplated surface would. For this reason, it is often wise to plate with active metal such as zinc or cadmium. Painting either by roller or brush is more desirable for tight spaces; spray would be better for larger coating areas such as steel decks and waterfront applications. Flexible polyurethane coatings can provide an anti-corrosive seal with a highly durable slip resistant membrane. Painted coatings are relatively easy to apply and have fast drying times although temperature and humidity may cause dry times to vary.

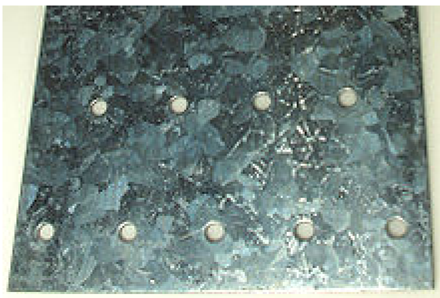

Fig 3: Galvanized surface

7. Biofilm coatings

A new form of protection has been developed by applying certain species of bacterial films to the surface of metals in highly corrosive environments. This process increases the corrosion resistance substantially. Alternatively, antimicrobial-producing biofilms can be used to inhibit mild steel corrosion from sulfate-reducing bacteria.

8. Controlled permeability formwork

Controlled permeability formwork (CPF) is a method of preventing the corrosion of reinforcement by naturally enhancing the durability of the cover during concrete placement. CPF has been used in environments to combat the effects of carbonation, chlorides, frost and abrasion.

Socio-Economic Impact

Because of corrosion only, 2003-2006 Mitsubishi Lancer and 2003-2013 Mitsiubishi Outlander recalled in Canada. In 2002, the US Federal Highway Administration released a study titled *Corrosion Costs and Preventive Strategies in the United States* on the direct costs associated with metallic corrosion in the U.S. industry. Rust is one of the most common causes of bridge accidents. As rust has a much higher volume than the originating mass of iron, its build-up can also cause failure by forcing apart adjacent parts. It was the cause of the collapse of the Mianus river bridge in 1983, when the bearings rusted internally and pushed one corner of the road slab off its support. Three drivers on the roadway at the time died as the slab fell into the river below. The following NTSB investigation showed that a drain in the road had been blocked for road re-surfacing, and had not been unblocked; as a result, runoff water penetrated the support hangers. Rust was also an important factor in the Silver Bridge disaster of 1967 in West Virginia, when a steel suspension bridge collapsed within a minute, killing 46 drivers and passengers on the bridge at the time.

Similarly, corrosion of concrete-covered steel and iron can cause the concrete to spall, creating severe structural problems. It is one of the most common failure modes of reinforced concrete bridges. Measuring instruments based on the half-cell potential can detect the potential corrosion spots before total failure of the concrete structure is reached.

Until 20–30 years ago; galvanized steel pipe was used extensively in the potable water systems for single and multi-family residents as well as commercial and public construction. Today, these systems have long consumed the protective zinc and are corroding internally resulting in poor water quality and pipe failures. The economic impact on homeowners, condo dwellers, and the public infrastructure is estimated at 22 billion dollars as insurance industry braces for a wave of claims due to pipe failures. The global market size of anticorrosion coating is projected to reach USD 30, 04 Billion by 2021.

CONCLUSION

As discussed above, the process of corrosion and the factors affecting the corrosion and impact of corrosion on the surroundings ie environment the prevention of corrosion needs far more greater attention than the step taken so for by our nation and abroad. For corrosion prevention one of the above methods discussed can be employed. Corrosion prevention is of greatest concern where substrates exist in the harsh environments. Leading end use applications include general industrial, marine, automotive and refinish, coil and direct to metal coatings for the household consumer (architectural or decorative). Each industry segment has its own performance standards. Above prevention methods can be used for the protection of surface from atmospheric corrosion and thus prevent losses due to corrosion. Hence it could prove to be an efficient method in industrial and consumer sectors.

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