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Electrochemical reaction of corrosion and its negative economic impact

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Electrochemical reaction of corrosion and its negative economic impact

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Abstract
Persistent corrosion problems through hazardous chemicals and hydrocarbon are potentially harmful resulting into failure and breakdown of infrastructure in marine, oil and gas vessels, petroleum distillation plant, and chemical processing industries. Despite this unstoppable catastrophe, reduction in the amount of cost incurred by corrosion has been an effort by researcher in the field of material science to tackle. This paper addresses the major challenge of materials failure in services resulting to high cost, and the potential remedy form from several applications.

Keywords: Material failure, electrochemical reaction, infrastructure, protection

1. Introduction

Material selection is a very important part of the manufacturing process as it determines the performance of the operation and the cost. Meeting product performance as well as cost minimization is the main targets of material selection. So obtaining the knowledge of service conditions as well as looking at the types of materials that can be selected are of paramount importance [1]

Iron is the fourth most abundant element on earth and is the most abundant by mass. This makes Iron of relatively good cost compared to other materials. Iron is a metal that has a wide range of applications and is very versatile coupled together with its low cost of processing makes it a desirable material in material selection [2] Iron coupled together with Carbon and other elements such as: Manganese, Silicon, Phosphorous and Sulphur make Mild steel [3]

Mild steel is a material that is of high importance to industry due to its low cost and its very wide areas of application. Mild steel is useful in applications that range from engineering, services domestic, marine, industrial applications etc. [4-6]. Its excellent mechanical properties allow for mild steel to participate effectively in manufacturing and construction of large structures such as bridges buildings etc. Mild steel is used in applications of room temperature and in applications of high temperatures involving boilers, pipelines and is involved in the chemical industry for handling salts, alkalis and acids [7].

Mild steel is used in most of the steel applications on the planet; however it is very susceptible to acidic environments, especially environments that contain chloride ions. Mild steel is a metal of choice because of its ease of fabrication, low cost and wide applicability but when it comes to acidic environments mild steel has a very low resistance to corrosion in these conditions. The environments help lead to the dissolution of the metal which eventually leads to failure of the metal in service shortening its service life, and it leads to more costs and lower profits [8].

Corrosion may be defined as the chemical deterioration of any material and its properties due to the electrochemical reaction between that material and the environment [9-11]. The Corrosion of a material cannot happen without any electrochemical reaction taking place; likewise corrosion cannot take place without the appropriate environment [12-15]. The electrochemical reactions that take place within metals consist of oxidation and reduction reactions and these reactions occur simultaneously [16-18]. Oxidation reaction cannot take place without reduction reactions and vice versa. In other words, Corrosion involves transfer of electrons between a material and its environment [19]. The figure below shows the anodic and cathodic reactions of corrosion.

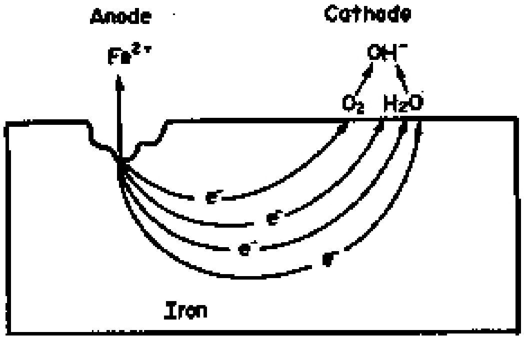

Figure 1. Electrochemical reactions in Corrosion [19]

As shown in the above figure Corrosion takes place at the anodic side of the reaction. In other words, dissolution of the metal into its ionic form takes place at the anode while the cathode is where electrons from the solution enter into the metal. A representation of the typical reactions that happen at the anode and cathode of the corrosion of Iron is shown below through equations 1 and 2

Anodic Reaction

$$Fe \longrightarrow Fe^{2+} + 2e^- \quad (1)$$

Cathodic Reactions

$$O_2 + H_2O + 4e^- = 4OH^- \quad (2)$$
$$O_2 + 4H^+ + 4e^- = 2H_2O \quad (3)$$
$$2H^+ + 2e^- = H_2 \quad (4)$$
$$Fe^{3+} + e^- = Fe^{2+} \quad (5)$$

Equation 1 represents the anodic reaction of Iron as electrons leave it and enter the solution to form Iron ions. The Cathodic reactions are represented by equations 2

2. Corrosion cost and the challenges with infrastructure

In this modern age of technological advancement corrosion has proven to be an engineering problem that is very serious. It leads to damages of structures that cannot be reversed and accounts for heavy economic losses. According to the National Association of Corrosion Engineers (NACE) Corrosion costs globally accounted for about 3.4% of the global Gross Domestic Product as at 2013, which amounts to $2.5 Trillion US Dollars [13, 14]. According to NACE with current day technology about a third of costs incurred by Corrosion can be saved, and there are various methods that help implement corrosion control. The harmful effects of corrosion can be felt on society in both direct and indirect ways. Direct ways being that it affects how long we use our possession and indirect being that incurred costs obtained by manufacturers through corrosion are passed to consumers. Corrosion endangers lives taking for example is the collapse of the “Silver bridge” in Ohio due to corrosion. It took the lives of 46 people and severely injured 9 people. The cost to fix the bridge was in millions of dollars [26].

These are some of the negative economic impact that corrosion has in society:

- When it concerns appearance devaluation of a building, structure or antique.
- Contamination of product; such as the case when corroded pipelines carry liquid.
- Reduction in efficiency; as the case when heat exchangers are corroded
- Unable to use materials that were desirable
- Equipment adjacent to point of corrosion are damaged.
- Equipment that has corroded needs to be replaced.
- Corrosion failure that leads to the stoppage of equipment.
- Corrosion causes the need to overdesign to compensate for corrosion that would occur.
- Corrosion causes the need for preventive maintenance practice such as: painting.

Corrosion also has some social effects which include the endangerment of human safety, which involves fires or explosions due to corrosion as well as the collapse of a structure. Concerns such as health hazards arise due to the pollution produced by the corroded products [27].

Corrosion is an unavoidable process nevertheless it is a process that can be limited and controlled. To control this natural phenomenon, it needs to be understood by its mode of activation and propagation. The mechanisms that enable the corrosion must be known so as to prevent their activity or their effects. These studies lead to various methods of corrosion control:

- Material Selection
- Change of environment
- Use of Inhibitors
- Use of surface coats
- Design of equipment
- Electrical Protection [15]

Each of the above methods of corrosion protection has applications for where they are best suited. Material Selection is the most common method of corrosion prevention. This simply deals with selecting materials that satisfy the best criteria when it comes to the performance and efficiency of the operation [24-26]. Change of environment deals with the altering certain factors in the environment that slows down the corrosion process; for example, removing oxygen from the solution. Inhibitors are substances or a combination of substances that are added in low concentrations to reduce or eradicate the corrosive effect of the environment on a material [7]. Surface coats are simply coverings applied to a material to protect it from corrosion. There are different ways surface coats can be applied namely: Electrodeposition, Flame spraying, and Cladding etc. The design of equipment has to do with the design measures taken to reduce the effect of corrosion. Ensuring homogeneity throughout design is one of the design measures. Electrical protection deals with using electrical currents to protect a material. This can be done by a process called galvanic coupling which uses a sacrificial anode where the material itself serves as the cathode in the process or by using an external power supply to protect the material [21-23]

The use of inhibitors is the major focus of this study. The classes of inhibitors can be split into 2: Organic and Inorganic Inhibitors. Inorganic inhibitors have been in use over the years and have proven to be the source of ecological and health problems due to its toxicity. The search for Organic inhibitors as an alternative has been on the increase due to its lower cost and it is ecologically friendly to the environment [28]. This study is based on the use of Organic inhibitors as a solution to Stress Corrosion Cracking on Mild Steel. The toxicity of Inorganic inhibitors has harmful effects on human health and they affect the environment in a negative way. Costs incurred by the use of Inorganic inhibitors can be checked by the use of eco-friendly organic inhibitors which are of low cost [28].

3. From steel to stress corrosion cracking

Mild steel is a very versatile material that has applications in many areas of industry and compared to other materials is of a low cost [4]. Mild steel is used extensively in the use of construction because of its ease of machinability and its strength. Mild steel is used extensively in the handling of salt, alkali and acidic solutions. Its tendency to corrode when exposed to acidic environments is a problem and involves the need of corrosion control techniques to mitigate the effect of corrosion on mild steel [5].

Corrosion is a problem that is experienced all over the world and it is a process that is unfortunately unavoidable. Its effects is prevalent on many industries and its problems cause constant replacement of corroded materials and other maintenance or preventive measures that control corrosion [20-23]

Stress corrosion cracking is a phenomenon that occurs because of the simultaneous action of a specific corrosive environment and applied tensile stress. It has led to the sudden failure of many structural members and endangers the lives of people. In fact you can say stress corrosion cracking is the major cause of unforeseen failures of structures in industry. The government of the United States of America spends billions of US dollars every year managing the effects of stress corrosion cracking [10].

Conclusion

This study has established the need to vital corrosion mechanism, ways toward improving the life-span of structures against failure and effects of stress corrosion cracking. Moreso, the overview affirmed that provision of an alternative to toxic and non-environmentally friendly inorganic inhibitors with eco-friendly organic inhibitors is require for effective and efficient mitigation.

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