CORROSION INHIBITION OF 6061 ALUMINIUM ALLOY IN MARINE ENVIRONMENTS BY MILK

MOHD ZULKARNAIN BIN ZULKIFLI

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We certify that the project entitled "*Corrosion Inhibition of 6061 Aluminium Alloy in Marine Environments by Milk"* is written by *Mohd Zulkarnain Bin Zulkifli.* We have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. We herewith recommend that it be accepted in partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering.

Luqman Hakim Bin Ahmad Shah

Examiner Signature

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature

Name of Supervisor : JULIAWATI BINTI ALIAS

Position : LECTURER

Date :

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature

Name	: MOHD ZULKARNAIN BIN ZULKIFLI
ID Number	: MA07067
Date	:

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ABSTRACT

6061 aluminium alloy is an important material with wide ranges of industrial applications and marine technology. This study examines the use of milk for improvement of corrosion resistance of 6061 aluminium alloy in sodium chloride. Weight loss method and potentiodynamic polarization measurement were employed to study the corrosion behavior of 6061 aluminium alloy in sodium chloride. The weight loss method showed that the presence of milk significantly decreases the corrosion rates of 6061 aluminium alloy 6061 in the test solutions. Pitting corrosion take places in all the specimens during immersion test and the pitting can be seen through surface analysis by using optical microscope 200x magnifications. With the presence of milk in the sodium chloride, the pitting growth is smaller and lesser compare to no milk added. The electrochemical measurements also showed the similar finding that the presence of milk reduces the corrosion rates, and that corrosion current densities (i_{corr}) simultaneously increases the values of polarization resistance R_p. The inhibition efficiencies increase with increasing of milk concentration. The nature of adsorption of milk on the metal surface has also been examined. Scanning electron microscope (SEM) and energy dispersive x-ray spectroscopy (EDS) confirmed the formation of thin film on the metal surface, which reduces the overall corrosion reaction.

ABSTRAK

Aloi aluminium 6061 merupakan bahan penting yang diaplikasikan secara meluas dalam industri dan teknologi marin. Kajian ini meneliti penggunaan susu untuk peningkatan ketahanan pengaratan aloi aluminium 6061 di dalam larutan natrium klorida. Kaedah kehilangan berat dan pengukuran polarisasi potensiodinamik digunakan untuk mempelajari perilaku pengaratan aloi aluminium 6061 di dalam natrium klorida. Kaedah kehilangan berat menunjukkan bahawa kehadiran susu secara signifikan mengurangkan kadar pengaratan aloi aluminium 6061 di dalam larutan uji. Pengaratan jenis lubang mengambil tempat di semua spesimen selama ujian perendaman dan lubang dapat dilihat melalui analisis permukaan dengan menggunakan mikroskop 200x pembesaran. Dengan kehadiran susu dalam larutan natrium klorida, pertumbuhan lubang adalah kurang dan saiz lubang lebih kecil berbanding dengan tanpa susu ditambah ke dalam larutan uji. Pengukuran elektrokimia juga menunjukkan penemuan yang sama bahawa kehadiran susu mengurangkan kadar pengaratan, arus kakisan (i_{corr}), secara bersamaan meningkatkan nilai rintangan polarisasi $R_{p.}$ Kecekapan penghalangan meningkat seiring dengan peningkatan kepekatan susu. Sifat serapan susu pada permukaan logam juga telah diperiksa dengan menggunakan mikroskop pengimbas electron (SEM) dan spektroskopi x-ray pemancar tenaga (EDS) mengesahkan pembentukan lapisan tipis di permukaan logam, yang mengurangkan proses pengaratan secara keseluruhan.

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LIST OF SYMBOLS

A	Area
Al	Aluminium
Al^{3+}	Aluminium dissolves to 3 electron
Al_2O_3	Aluminium oxide
$Al(OH)_3$	Hydroxide
AlOOH	Oxyhydroxide
b_a	Anodic Tafel slopes
b_c	Cathodic Tafel slopes
C	Carbon
-COOH	Carboxyl
d	Diameter
e	electron
E_{corr}	Corrosion potential
H_2	Hydrogen gas
H^+	Hydrogen ion
H_2O	Water
i_{corr}	Corrosion current density
K	Corrosion constant
Si	silicon
W	Weight loss
&	And
°C	Celcius

LIST OF ABBREVIATIONS

ASTM	American Standard Testing Method
EDS	Energy Dispersive X-Ray Spectroscopy
FYP	Final year project
NaCl	Sodium Chloride
SEM	Scanning Electron Microscope
UMP	University Malaysia Pahang

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

The corrosion of aluminium and its alloy is the subject of critical technological importance due to the increasing industrial application of these materials. Aluminium and its alloy represent an important category of materials due to their high technological value and wide range of industrial applications, especially in aerospace, household industries, automotive, transportation and marine technology. Mainly is because of their good specific strength, excellent formability and corrosion resistance. Therefore the understanding of the corrosion resistance and electrochemical behavior of aluminium for the future industrial applications and development is vital.

Corrosion is defined as destruction or deterioration of a material because of its chemical reaction with its environment. One example of aggressive environments is seawater. Seawater systems are used by many industries such as shipping, offshore oil and gas production, power plants and coastal industrial plants. Exposure of these structures in marine environments will cause corrosion that finally leads to total damage. Therefore, it is very important to study on corrosion prevention in this environment.

With the fact of corrosion represent a tremendous economic loss and much can be done to reduce it. There are many ways to reduce corrosion rate and one of the most popular and acceptable practice is the use of inhibitors. Large numbers of organic compound was studied and are being studied to investigate their corrosion inhibition potential. All these studies reveal that organic compounds especially those with N, S, and O showed significant inhibition efficiency.

An inhibitors is a substance that, when added in small concentrations to an environment, decreases the corrosion rate. In a sense, an inhibitor can be considered as a retarding catalyst. There are numerous inhibitor types and compositions. Most inhibitors have been developed by empirical experimentation, and many inhibitors are proprietary in nature and thus their composition is not disclosed. Inhibition is not completely understood because of these reasons, but it is possible to classify inhibitors according to their mechanism and composition.

The safety and environmental issues of corrosion inhibitors arisen in industries has always been global concern. In recent days, many alternative eco-friendly corrosion inhibitors have been developed. The growing needs for the corrosion inhibition becomes increasingly necessary to delay or stop the attack of metal in aggressive solution. Many efforts made to find suitable natural source to be used as corrosion inhibitor in various corrosion media. This study considered this particular issue when applying selected 6061 aluminium alloy to its application which would be suitable with our natural environment for instance tropical seawater. Milk offers interesting possibilities for corrosion inhibitor due to its safe use, low cost, availability and the most important is the potential usages of milk discussed in this research are in line with the recent trend of environment-friendly concept (Rosliza et. al., 2009).

1.2 PROBLEM STATEMENT

This organic inhibitor can be applied in some practical areas such as:

(i) The main uses of seawater are for cooling purpose, fire fighting, oil field water injection and desalination plants. 6061 aluminium alloy can be used as container for these applications and the organic inhibitor may add to the container to retard the corrosion cause by the seawater.

(ii) Marine corrosion includes the immersion of components in seawater, equipment and piping that use seawater or brackish water, and corrosion in marine atmospheres. Exposure of components can be continuous or intermittent. Ships, marinas, pipelines, offshore structures, desalination plants, and heat exchangers are some examples of system that experience marine corrosion.

The corrosion problems in these systems have been well studied over many years despite several published information on materials behavior in seawater, failures still occur. Therefore, more investigations need to carry out to obtain better understanding on material corrosion behavior.

1.3 OBJECTIVES OF STUDY

The objectives of this study are:

(i) To study the corrosion behavior of 6061 aluminium alloy in NaCl.
(ii) To investigate the effect of variation concentration of milk as inhibitor, on the corrosion rate of 6061 aluminium alloy in NaCl.

1.4 SCOPES OF PROJECT

The scope of this study includes:

(i) Preparation for specimen and inhibitor.
(ii) Exposure of specimen in sodium chloride (NaCl).
(iii) Cleaning process of corrosion product.
(iv) Weighing sample by digital weighing scale.
(v) Analysis corrosion rate by using weight loss method and electrochemical technique.
(vi) Surface morphology examination using scanning electron microscope.
(vii) Compositional features characterization using energy dispersive x-ray spectroscopic

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Corrosion is a very serious problem. There are several examples that show how corrosion cost is very high when doing the maintenance. Corrosion of bridge is a major problem as they age and require replacement, which costs billions. One large chemical company have to spent a lot of budget for corrosion maintenance in its sulfuric acid plants, the petroleum industry spends a million dollar per day to protect underground pipelines and another spends on painting steel to prevent rusting by a marine atmosphere. Corrosion engineering is the application of science and art to prevent or control corrosion damage economically and safely. In solving corrosion problems, the corrosion engineer must select the method that will maximize profit.

Corrosion is the chemical transformation of metal due to chemical reactions. The most common form of corrosion is oxidation, where metal atoms combine with oxygen atoms to form oxides. Iron rust is the most recognizable form of corrosion, and appears when iron oxide forms on iron or steel components that are exposed to air or water, however, virtually all metals and alloys are susceptible to corrosion. Technically, corrosion can occur in other types of materials, such as ceramics or polymers, but the process is either rare or different enough that the term “corrosion” is generally not used.

2.2 FORMS OF CORROSION

Engineers often take their specific environment into effect and try to understand the types of possible corrosion when designing metal components and structures. There are several types of corrosion, depending on the metal, corrosive agent, geometry, and environment: (Jones et. al., 1982)

(i) General Corrosion: Uniform corrosion is characterized by corrosive attack proceeding evenly over the entire surface area, or a large fraction of the total area. General thinning takes place until failure. On the basis of tonnage wasted, this is the most important form of corrosion. However, uniform corrosion is relatively easily measured and predicted, making disastrous failures relatively rare. In many cases, it is objectionable only from an appearance standpoint. As corrosion occurs uniformly over the entire surface of the metal component, it can be practically controlled by cathodic protection, use of coatings or paints, or simply by specifying a corrosion allowance.

(ii) Pitting Corrosion: Pitting corrosion is a localized form of corrosion by which cavities or holes are produced in the material. Pitting is considered to be more dangerous than uniform corrosion damage because it is more difficult to detect, predict and design against. Corrosion products often cover the pits. A small, narrow pit with minimal overall metal loss can lead to the failure of an entire engineering system. Pitting corrosion, which, for example, is almost a common denominator of all types of localized corrosion attack. Pitting is initiated by:

a. Localized chemical or mechanical damage to the protective oxide film; water chemistry factors which can cause breakdown of a passive film are acidity, low dissolved oxygen concentrations which tend to render a protective oxide film less stable and high concentrations of chloride such as in seawater.

b. Localized damage to, or poor application of, a protective coating.

c. The presence of non-uniformities in the metal structure of the component, for instance nonmetallic inclusions.

(iii) Galvanic Corrosion: Galvanic corrosion is refers to corrosion damage induced when two dissimilar materials are coupled in a corrosive 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. For galvanic corrosion to occur, three conditions must be present:

a. Electrochemically dissimilar metals must be present.
b. These metals must be in electrical contact.
c. The metals must be exposed to an electrolyte.

The relative nobility of a material can be predicted by measuring its corrosion potential. The well known galvanic series lists the relative nobility of certain materials in sea water. A small anode or cathode area ratio is highly undesirable. In this case, the galvanic current is concentrated onto a small anodic area. Rapid thickness loss of the dissolving anode tends to occur under these conditions. Galvanic corrosion problems should be solved by designing to avoid these problems in the first place.

(iv) Stress Corrosion: Stress corrosion cracking is the cracking induced from the combined influence of tensile stress and a corrosive environment. The impact of this type of corrosion on a material usually falls between dry cracking and the fatigue threshold of that material. The required tensile stresses may be in the form of directly applied stresses or in the form of residual stresses.

(v) Crevice Corrosion: Crevice corrosion is a localized form of corrosion usually associated with a stagnant solution on the micro-environmental level. Such stagnant microenvironments tend to occur in crevices shielded areas such as those formed under gaskets, washers, insulation material, and clamps.

(vi) Intergranular Corrosion: The microstructure of metals and alloys is made up of grains, separated by grain boundaries. Intergranular corrosion is localized attack along the grain boundaries, or immediately adjacent to grain boundaries, while the bulk of the grains remain largely unaffected. This form of corrosion is usually associated with chemical segregation effects which means impurities have a tendency to be enriched at grain boundaries or specific phases precipitated on the grain boundaries. Corrosion then occurs by preferential attack on the grain-boundary phase, or in a zone adjacent to it that has lost an element necessary for adequate corrosion resistance. In any case the mechanical properties of the structure will be seriously affected.

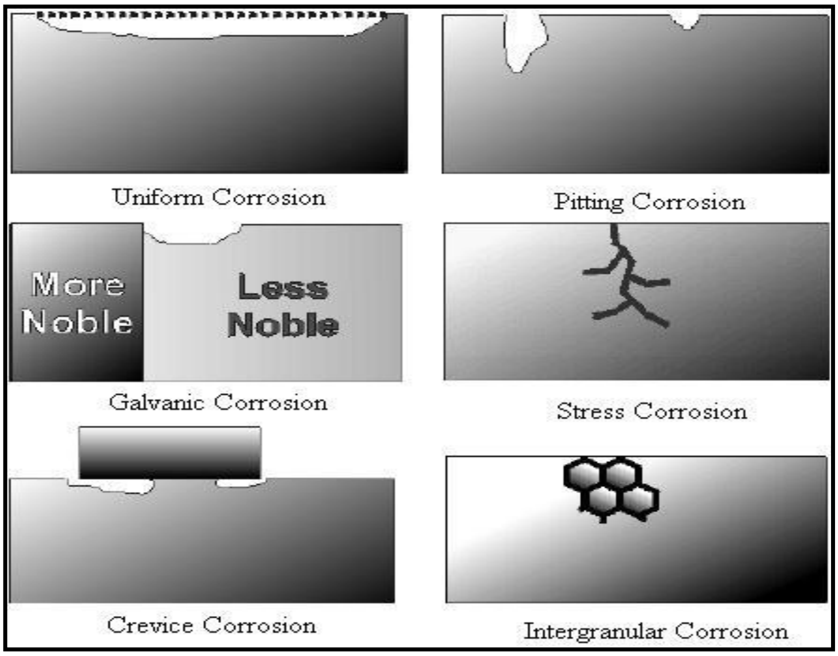

Figure 2.1 Forms of corrosion

Source: Roberge (1999)

2.3 MARINE CORROSION

The corrosion of metals and alloys in chlorinated seawater has long presented challenges for those responsible for materials selection and has been much studied. Marine corrosion is of particular interest to designers of ships and shoreline facilities because most metals used in these structures are vulnerable to damage from seawater. Maintenance cost for ships, offshore structures and other related equipment are dependent on how marine corrosion issues and failures are managed.

In addition to the salt (NaCl) in seawater, there are other commonly occurring constituents, dissolved gases, living organism, and various other materials found in seawater. Rives, temperature, dissolved oxygen and pollutants are some examples of issues that may affect the corrosion of a given component in seawater. Marine atmospheric corrosion is generally considered to be one of the more aggressive atmospheric corrosion environments. Some factors that affect corrosion rates in marine atmosphere are humidity, wind, temperature, location, airborne contaminants and biological organism. Alloy selection, metallic coatings, organic coatings (inhibitor) and cathodic protection are commonly used methods for providing proper corrosion protection to various components.

The choice of an appropriate material for seawater service is a difficult decision that has to be mad by a designer prior to specification of the system. A number of alloys have been successfully used in seawater services. Marine grade aluminium can form an oxide on the surface that excludes contaminants and prevents corrosion. Marine grade here mean 5000 or 6000 series aluminium alloys, such as 5058 and 6061. Aluminium forms an oxide on the surface thus it will not corrode unless the oxide is damage or washed away. In marine environments, the presence of aggressive anions which is chloride leads to pit formations and film breakdown. Pitting is one of extreme localized attack that results in holes in the metal. These holes may be small or large in diameter, but most cases they are relatively small. Pitting is particularly vicious because it is a localized and intense form of corrosion, and failures often occur with extreme suddenness (Fontana, 1986).