Aging Treatment on Aluminium AA6063 against Bacterial Corrosion Resistance in Marine Environment

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Abstract: The corrosion is a natural occurrence of metal damage caused by electrochemical interactions with the environment. One of the causes of corrosion is the attachment of bacteria to the material. The hazard caused by corrosion, especially on ship, corrosion can cause a failure on ship's structure which causes the ship to not operate properly. The purpose of the research was to determine the effects of Aluminium AA6063 aging treatment on bacterial corrosion. The material was be treated by heat treatment (Aging Treatment) before the bacterial corrosion test was conducted. The bacterial corrosion test was carried out in artificial seawater with salinity of 33‰, 35‰ and 37 ‰. The addition of three species of bacteria, i.e. Thiobacillus ferrooxidans, Pseudomonas fluorescens and Escherichia coli were applied in all salinity with 5% (v/v). The bio-corrosion rate was determined using weight loss method and the microstructure of material was conducted at pre and post bacterial corrosion to determine the differences in the microstructure of the material before and after the bacterial corrosion test. The results showed the non aging treatment material has a higher corrosion rate when compared with the material with aging treatment. The non aging treatment material has the highest corrosion rate of 1.189 mmpy with the addition of Thiobacillus ferrooxidans at salinity of 37‰ and the lowest corrosion rate of 0.186 mmpy at salinity of 33‰. However, the aging treatment material has the highest corrosion rate of 0.770 mmpy and the lowest corrosion rate of 0.175 mmpy at similary condition. Based on microstructure results, uniform and pitting corrosion occurred on all specimens with the addition of bacteria or without the addition of bacteria. However, the bacterial corrosion rates were different. It was identified that aging treatment on Aluminium AA6063 can reduce the bacterial corrosion rate or increase the bacterial corrosion resistance.

1 INTRODUCTION

The usage of aluminium in maritime industry as one of the supporting materials has considerable role. Aluminium with 6xxx series is aluminium alloys in which magnesium and silicon are the principal alloying elements, commonly used for architectural extrusions and automotive components (Davis, 2001). Aluminium with 6xxx series have a high strength when used for building structures in the marine environment and more corrosion resistant when compared with other aluminium series. However, many factors can cause the decreasing of aluminium metal. One of the factor is corrosion. Alloys in the 6xxx series contain silicon and magnesium approximately in the proportions required for formation of magnesium silicide (Mg_2Si), thus making them heat treatable. Although not as strong as most 2xxx and 7xxx alloys, 6xxx series alloys have good formability, weldability, machinability, and corrosion resistance, with medium strength (Davis, 2001).

Corrosion is considered a significant factor in the failure and damage of metals (Nuhia, et.al, 2011). Corrosion is a material damage that was caused by the influence of the surrounding environment. Corrosion can cause many losses due to the reduction of relatively large dimensions per unit time and also reduce the age of the building. Aluminium with erosion corrosion can accelerate or increase the destruction due to relative movement and corrosive media on metal surface.

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In the marine environment, the rate of corrosion increase rapidly, due to the seawater contain solution that are able to dissolve other substances in greater quantities than other liquids. Those substances include inorganic salts, organic compounds derived from living organisms (bacteria) and dissolved gases. One of the causes of corrosion is bacteria. Bacteria live in the marine environment extensively in their habitats and form colonies and attach to the metal surfaces in the form of thin layers. Factors that affect the occurrence of bio-corrosion are temperature, pH, and oxygen levels. Based on our previous study, 3 species of bacteria Escherichia coli, Pseudomonas fluorescens, and Thiobacillus ferroxidans can caused bio-corrosion on steel structures of ASTM A106 and A53 in deep seawater (salinity of 33‰), medium seawater (salinity of 35‰), and shallow seawater (salinity of 37‰) (Pratikno and Titah, 2016). The bio-corrosion rate by P. fluorescens on Aluminium Alloy 6063 at salinity of 37‰ increased by one point six-fold compared with the condition without bacteria addition at the same salinity (Pratikno and Titah, 2016).

Corrosion can occur rapidly if neither environmental control or prevention. The usage of aluminium in the maritime industry is high such as in ship building. So that aluminium should treat with suitable treatment to increase the resistance of corrosion or decrease the corrosion rate. The aim of the research was to determine the effects of Aluminium AA6063 aging treatment on bacterial corrosion. The material was be treated by heat treatment (Aging Treatment) before the bacterial corrosion test was conducted.

2 MATERIALS AND METHODS

2.1 Preparation of Specimen

Material cut with area of ± 2 cm2 with diameter ± 1mm with thickness 1-2 mm. After that, the hardening process was conducted by heating the specimen with temperature of 535 ºC for 6 h. This process was called as Solution Heat Treatment. After that, the specimen was immersed in water or quenching phase, then re-heat it at 200 ºC for 5 h. This process was called as Aging Treatment. After the aging treatment, the hardness test was conducting to all specimens using Vickers method. Vickers Hardness Test is the standard method for measuring the hardness of metals, particularly those with extremely hard surfaces: the surface is subjected to a standard pressure for a standard length of time by means of a pyramid-shaped diamond. The diagonal of the resulting indention is measured under a microscope.

2.2 Preparation of Artificial Seawater

This research used a chemical solution instead of sea water with a salinity of 35 ‰. Salinity of 35‰ is the salinity in the ocean of medium depths, where in the microorganism commonly found at this depth, including bacteria. The chemical composition of seawater replacement is in accordance with ASTM D1141-90, 1994 (ASTM, 2004).

2.3 Preparation of Bacteria

The preparation of bacteria was conducted based on Pratikno and Titah (Pratikno and Titah, 2017). The pure culture of Thiobacillus ferrooxidans, Pseudomonas fluorescens and Escherichia coli, were be inoculated onto nutrient agar (NA) media using streak plate technique based on Harley and Prescott (Harley and Prescott, 2002). The age of bacteria for the test was 24 h. After that, one colony of bacteria was transferred to nutrient borth (NB) and keep in shaker incubator of Innova 2000 (New Brunswick-Eppendorf, Germany) at 150 rpm and room temperature, 33 oC for 24 h. The cell suspension of selected bacteria was prepared by harvesting the cells at the middle of the logarithmic phase, based on the typical of growth rate graph for the selected bacteria. At this time, the OD at 600 nm was 1.0 was determined using UV spectrophotometer Genesys 20 (Thermo, USA). The cells were harvested through centrifugation of Jouan E82 (Thermo, USA) at 4,000 rpm for 15 min. The obtained pellet was then washed twice using 8.5 g NaCl/1000 mL solution.The suspension of bacteria was ready to be used in bio-corrosion test.

2.4 Immersion Method for Bio-corrosion Test

The specimen was tested by immersion tehnique in a prepared seawater solution with salinity 33‰, 35‰ and 37‰ using ASTM G31-72 standard (ASTM, 2004). There were two different treatments, namely treatment without bacterial addition as a control and treatment with bacterial addition Testing was carried out for 4 weeks. Immersion testing was conducted in beaker glass with size of 300 mL and the artificial seawater was 250 mL for each beker glass.

2.5 Calculation of Corrosion Rate

Running rate of corrosion is a rapid propagation of material quality decline against time. There is a formula for calculating the corrosion rate based on the ASTM G1-03 standard (ASTM, 2002) as follows:

$$Corrosion\ rate\ (mpy) = \frac{K \times W}{A \times T \times D} \quad (1)$$

With:

K = Constanta

T = Time of exposure (h)

A = Surface area (cm2)

W = Weight loss (gram)

D = Material density (gram/cm3)

2.6 Macrostructure and Microstructure Testing

After corrosion testing was conducted, the microstructure of specimens were determined using a microscope for detailed morphology of the specimen structure. It was used for documentary evidence and it can be known that the specimen differences between before and after testing.

3 RESULTS AND DISCUSSION

Figure 1 showed the results of hardness test on AA6063 before and after aging treatment. Based on the Figure 1, the value of hardness test on AA6063 increased after aging treatment. The high value of Vickers hardness was 52.02 HVN after aging treatment. It indicated that aging treatment can accelerate the hardness value. According to Abel-Rahman et al. (2010), the Vickers hardness of 6066 alloy has a maximum value of 80 HVN after 10 days of quenching at 530oC which is the solution temperature of this alloy. The hardness of 6063 alloy has a maximum value of 40 HVN after 14 days of quenching at 520 oC. A tremendous increase in hardening of the Al-Mg-Si alloys is caused by precipitates formed from solution with merely 1 wt% of Mg and Si added to aluminum. During natural or artificial aging, Al-Mg-Si alloys first produce clusters of a few nm sizes. These clusters are an enrichment of the Mg and Si precipitates (Abdel-Rahman, et.al, 2010). Extrudability of the alloy is strongly influenced by the amount of Mg and Si and the size and distribution of Al-Mg2Si precipitate particles (Andersen, et.al, 1998).

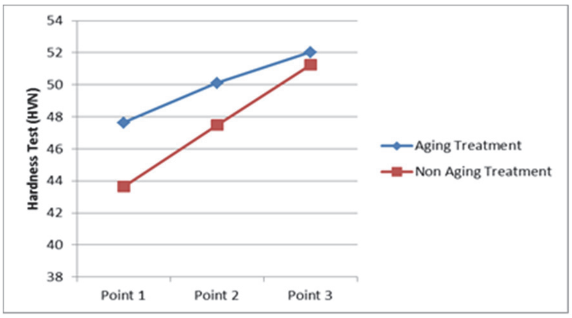


Figure 1: Hardness test.

Based on Figure 2 and 3, the higher of salinity can accelerate the rate of corrosion. The higher of salinity contain chloride ions due to cause pitting corrosion and other damage to the material. The corrosion rate on alumnium alloys with the highest heat treatment at salinity 33 ‰ with addition of Thiobacillus ferroxidans was 0.565 mmpy, meanwhile the lowest corrosion rate in the control specimens was 0.175 mmpy. At salinity 35 ‰, the highest corrosion rate occurred in specimens with the addition of Thiobacillus ferroxidans (0.692 mmpy), and the lowest corrosion rate in control specimens was 0.178 mmpy. Similarly, the highest corrosion rate in specimens with the addition of Thiobacillus ferroxidans was 0.770 mmpy at salinity 37 ‰ and the lowest corrosion rate on the specimen with the addition of Escherichia coli (0.175 mmpy).

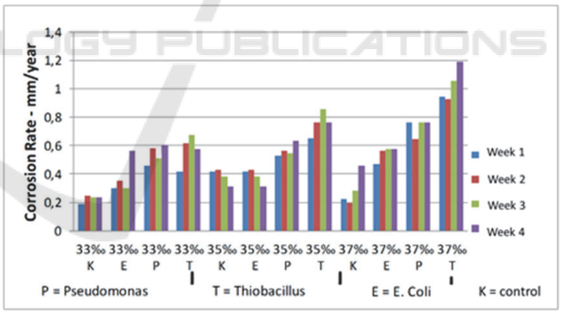


Figure 2: Corrosion Rate on AA6063 without aging treatment.

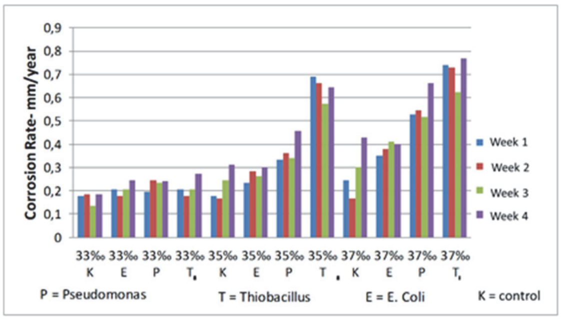


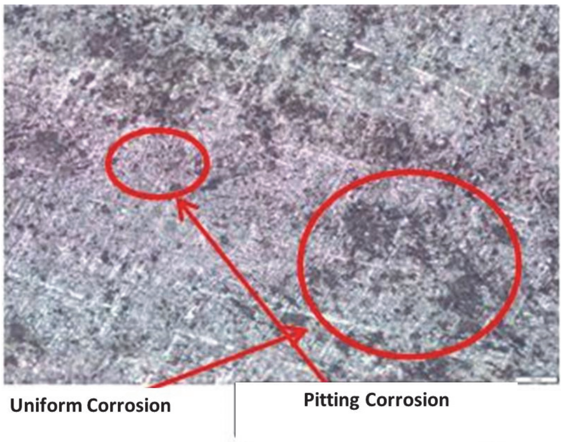
Figure 3: Corrosion Rate on AA6063 with aging treatment.

Based on graph, the most corrosive bacteria to test specimens on corrosion rate of aging material and non aging treatment was Thiobacillus ferroxidans. Thiobacillus ferroxidans has the highest corrosion rate due to this bacteria can produce more organic acids, pigments, H2S ligands that can remove heavy metal ions from the material. The non aging treatment material has a higher corrosion rate when compared with the material with aging treatment. The non aging treatment material has the highest corrosion rate of 1.189 mmpy and the lowest corrosion rate of 0.186 mmpy, meanwhile the aging treatment material has the highest corrosion rate of 0.770 mmpy and the lowest corrosion rate of 0.175 mmpy.

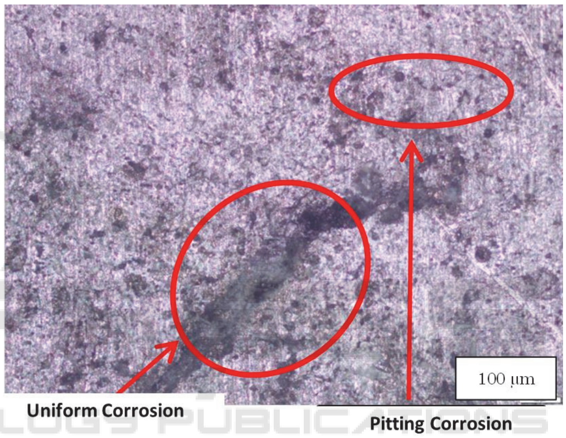
3.1 Macro Structure and Microstructure

Macrostructure showed that appearance of specimen before and after corrosion test. Based on Figure 4 (a), the specimen was clear, however the appearance of specimen was different after corrosion test Figure 4 (b). Microstructure were determined on two sides of the specimen's surface to detect the characteristics of corrosion forming on each surface. Based on the microstructure results, the corrosion on the specimens test were pitting and uniform corrosion. There was a difference of pitting corrosion in specimens immersed at difference of bacteria species. The observation of the visible side of the specimen soaked in E. coli bacteria, the pitting corrosion was a small holes clumped. The pitting corrosion in Pseudomonas was slightly larger and not clustered. The last of pitting corrosion in Thiobacillus ferroxidans addition was hole tends to be large and not clustered. However, all the shape of corrosion was a pitting corrosion. The observations on the bottom side showed no difference, however it have a relatively similar form of pitting corrosion.

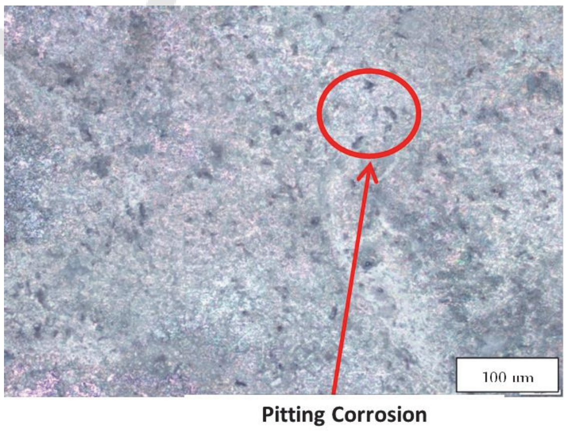
Figure 4: Image of macrostructure aging treatment material (left) before corrosion test (rigth) after corrosion test.



(a)

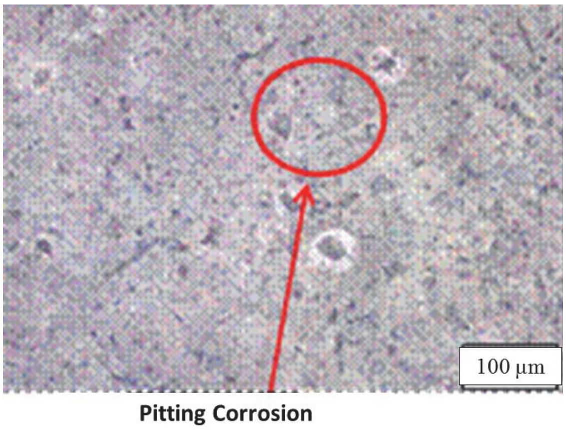


(b)

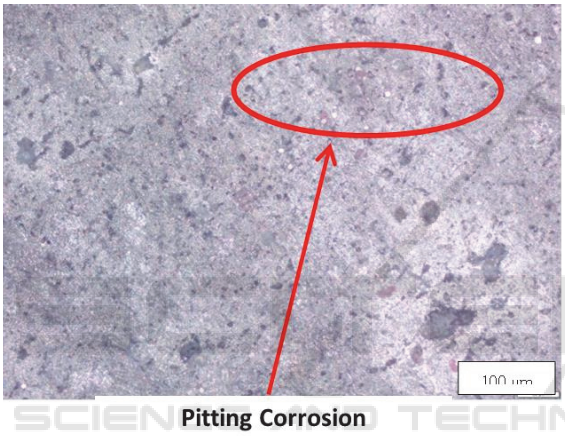


(c)

Figure 5: Microstructure of top of material aging treatment with (a) kontrol, (c) Escherichia coli (e) Pseudomonas fluorescens (g) Thiobacillus ferrooxidans, and on bottom of specimen with (b) kontrol, (d) Escherichia coli (f) Pseudomonas fluorescens (h) Thiobacillus ferrooxidans.



(d)



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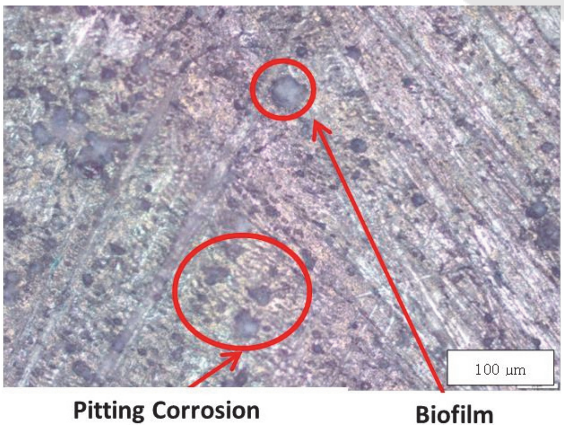
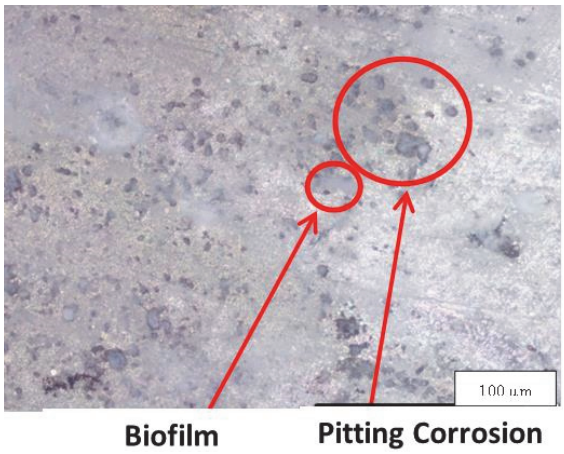
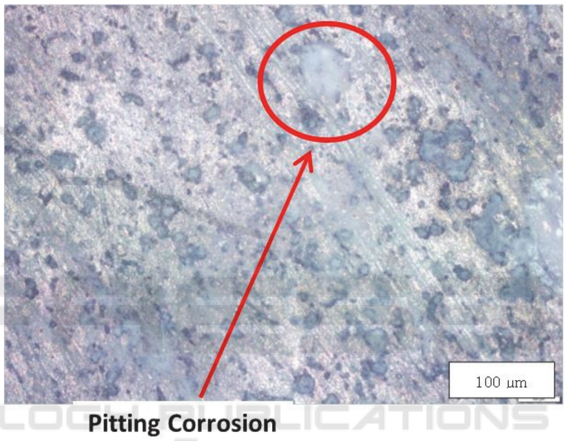


(f)



(g)



(h)

Figure 5: Microstructure of top of material aging treatment with (a) kontrol, (c) Escherichia coli (e) Pseudomonas fluorescens (g) Thiobacillus ferrooxidans, and on bottom of specimen with (b) kontrol, (d) Escherichia coli (f) Pseudomonas fluorescens (h) Thiobacillus ferrooxidans (cont.).

4 CONCLUSION

The non aging treatment material has the highest corrosion rate of 1.189 mmpy with the addition of Thiobacillus ferrooxidans at salinity of 37‰ and the lowest corrosion rate of 0.186 mmpy at salinity of 33‰. However, the aging treatment material has the highest corrosion rate of 0.770 mmpy and the lowest corrosion rate of 0.175 mmpy at similary condition. Based on microstructure results, uniform and pitting corrosion occurred on all specimens with the addition of bacteria or without the addition of bacteria. However, the bacterial corrosion rates were different.

It was identified that aging treatment on Aluminium AA6063 can reduce the bacterial corrosion rate or increased the corrosion resistance.

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