Effect of Electrode Type for SMAW Welding on ASTM A36 Steel to Reduce Bio-corrosion Rate in Marine Environment

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Keywords: Bio-corrosion Rate, SMAW Welding, ASTM A36 Steel.

Abstract: The construction of the maritime industry, especially the manufacture of offshore building, at the moment mostly use the technique of metal welding. Weld joints on steel materials cannot be separated with the corrosion. Corrosion can cause a decrease in strength of materials and damage to construction. Corrosion is the degradation of metal caused by an electrochemical reaction between the metal with the surrounding environment. One of the causes of corrosion was bacteria, it was called as bio-corrosion. The bacteria live in the marine environment were widespread in their habitat and form a colony and then stick on the metal surface in the form of a thin layer. The aim of the research was to determinate the corrosion rate of the weld type SMAW on steel ASTM A36 with variations of the electrode. The variations of the electrode were AWS E6010, AWS E6013, AWS E6019. The corrosion test was conducted using immersion corrosion test method. The welded joints of materials were be soaked in artificial sea water with a salinity of 35‰ with Thiobacillus ferrooxidans addition and without bacteria addition as a control. The resistance on bio-corrosion rate was determined using weight loss method. The results showed the lowest of bio-corrosion rate with the addition of the Thiobacillus ferrooxidans on welded joints of materials was AWS E6013 compared with other electrodes. It reached 9.79757 mpy. Similarly, the lowest of corrosion rate (7.48178 mpy) without Thiobacillus ferrooxidans addition was AWS E6013. Based on microstructure results, uniform and pitting corrosion occurred on all welded joint specimens with the addition of bacteria or without the addition of bacteria. However, the corrosion rates were different. It indicated that AWS E6013 as a electrode on SMAW welding on ASTM A36 steel has a high effect to reduce the corrosion and bio-corrosion rate in marine environment.

1 INTRODUCTION

The construction of the maritime industry, especially the manufacture of building offshore at the moment mostly use the technique of metal welding. This welding technique is not a new knowledge but it is something of basic needs. Therefore, the welding process should be conducted with the right method to get maximum results and satisfactory. Welding is a technique of connection between the metal become one and strong. Based on the definition of DIN (Deutch Industrie Normen) welding is a metallurgical bonding on the connection of a metal alloy was carried out in the circumstances of the melt or liquid. At this time, there are 40 types of welding, one of which is Shielded Metal Arc Welding (SMAW) or welding electrodes encased. However, the weld joints on steel materials cannot be separated with the name of corrosion. Corrosion can cause a decrease in strength of materials and damage to construction.

Corrosion is the degradation of metal caused by an electrochemical reaction between the metal with the surrounding environment (Trethewey and Chamberlain, 1991). Corrosion can also be interpreted as the events of nature that occured on the material and is the process of the return of the material to its original condition when the material is found and processed from nature (Supriyanto, 2007). Quickly than a material corroded is closely related to the corrosion rate while the corrosion rate itself on the environment is neutral normally is equal to 1 mpy or less. The rate of corrosion is influenced by several

Pratikno, H., Titah, H. and Azdkar, M.
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DOI: 10.5220/0008649801650169
In *Proceedings of the 6th International Seminar on Ocean and Coastal Engineering, Environmental and Natural Disaster Management (ISOCEEN 2018)*, pages 165-169
ISBN: 978-989-758-455-8

factors, among others: water, gas content and dissolved solids, temperature, material selection, pH, reducing bacteria or Sulfate Reducing Bacteria (ASM, 2003).

In the marine environment the corrosion rate is quickly increased, it is because the sea water contains dissolved substances that are able to dissolve other substances in larger quantities than other liquids. Dissolved substances include inorganic salts, organic compounds derived from living organisms (bacteria) and dissolved gases. One of the causes of corrosion is bacteria. The live bacteria in the marine environment are widespread in their habitat and form a colony and then stick on the metal surface in the form of a thin layer. Microorganisms that affect the process of corrosion is divided into two types, namely aerobic and anaerobic bacteria. The bacteria form a colony on the surface of the metal to the place of their lives. These colonies form a layer (biofilm) on the surface of the material so that the material becomes corroded a result of life activity of microorganisms.

The purpose of the research was to determinate the corrosion rate of the weld type SMAW on steel ASTM A36 with variations of the electrode. In this study, the sea water used artificial sea water with a salinity of 35 ‰ with the addition of bacteria (Thiobacillus ferrooxidans).

2 MATERIALS AND METHODS

2.1 Preparation of Steel Material of ASTM A36

The material that was used in this study was a steel material ASTM A36 mild steel. Test specimens were made in the shape of a rectangle with the size dimensions as follows length of 300 mm, width of 150 mm and thickness of 6 mm, and the shape of the weld groove was Single V-Groove with 60o. The variations of the electrode were AWS E6010, AWS E6013, AWS E6019.

2.2 Preparation of Welding

WPS (Welding Procedure Specifications) was prepared based on the welding procedures (Standard AWS D1.1, 2015). It was conducted to get results of the welds in accordance with the desired. Making WPS refers to the about the procedure of welding steel.

2.3 Hardness Testing

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.

2.4 Preparation of Bacteria

The preparation of bacteria was conducted based on Pratikno and Titah (2016). The pure culture of Thiobacillus ferrooxidans was be inoculated onto nutrient agar (NA) media using streak plate technique based on 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.

2.5 Preparation of Bio-corrosion Test

This research used a chemical solution instead of sea water with a salinity of 35 ‰. The chemical composition of seawater replacement is in accordance with ASTM D1141-90 (2004). The specimen was tested by immersion technique in a prepared seawater solution with salinity of 35‰ using ASTM G31-72 standard (2004). Immersion testing was conducted in beaker glass with size of 300 mL and the artificial seawater was 250 mL for each beker glass. The welded joints of materials were be soaked in artificial sea water with a salinity of 35 ‰ with Thiobacillus ferrooxidans addition and without bacteria addition as a control for 1 week.

2.6 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 (2002) as follows:

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

With

K = Constanta

T = Time of exposure (h)

A = Surface area (cm2)

W = Weight loss (gram)

D = Material density (gram/cm3)

2.7 Microstructure Observation

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

3.1 Hardness Test

Figure 1 depicted the results of hardness test on welded ASTM A36 with variations of the electrode. The highest hardness value on welded ASTM A36 was 164.00 VHN with electrode E6013. In the area of heat influence (Heat Affected Zone), the highest hardness value occurred in welding with E6019 electrode, it reached 157.43 VHN. Whereas in the base metal, the highest hardness value occurs in welding with E6019 electrode (150.19 VHN). The average of hardness value of the specimens in all electrode variations increased when compared with the parent metal. However, the type electrode of E6013 has the highest hardness value. According to Allen (Allen, 2018), the material was more harder can cause more higher of the tensile strength, higher of the level of brittleness (brittle) and less of the ductile. The hardness of a material was directly proportional to strength and brittleness, but it was inversely proportional to its ductility.

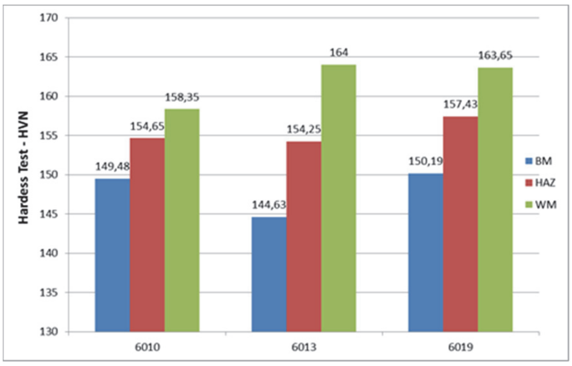


Figure 1: Results of hardness test on ASTM A36 with variations of the electrode.

3.2 Bio-corrosion Test

Figure 2 showed the bio-corrotion rate on welded ASTM A36 with variations of the electrode. According to Figure 2, the bio-corrosion showed the higher value when compared with corrosion rate without Thiobacillus ferroxidans addition. The variation type of electrode showed the difference on corrosion rate on welded joints of materials. The bio-corrotion rate with electode of AWS E6013 reached 9.79757 mpy. Similarly, the lowest of corrosion rate (7.48178 mpy) without Thiobacillus ferrooxidans addition was AWS E6013. Based on Pratikno and Titah (2016), 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 Pseudomonas fluorescenson 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). Based on the resultas of corrotion rate and bio-

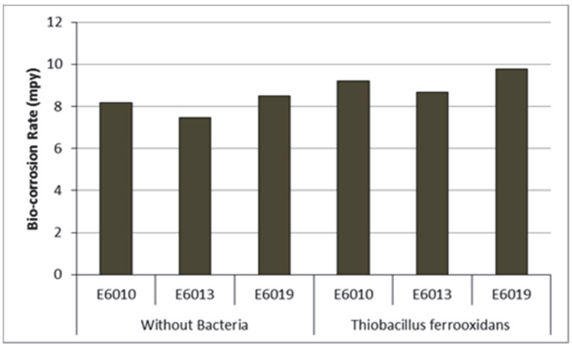
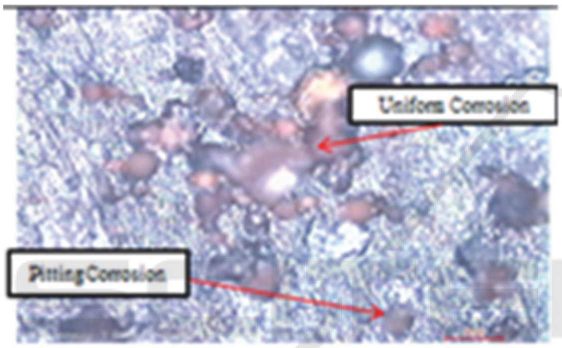


Figure 2: Bio-corrosion rate on ASTM A36 with variations of the electrode.

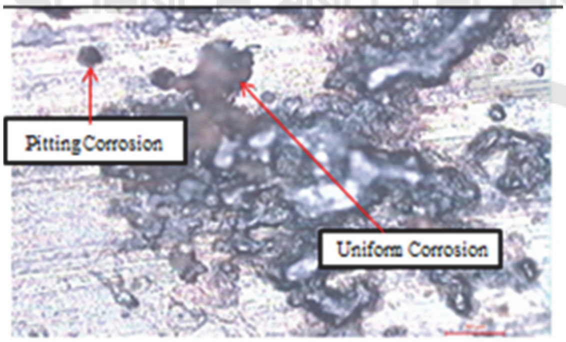
corrotion rate (7,48178 - 9,79575 mpy), it can be concluded that all the material included in the category of good (better). According to Fontana (1987), the level of corrosion resistance based on corrosion rate of 5 – 20 mpy was good.

3.3 Microstructure Observation

Microstructure showed that appearance of corrosion on specimen. According to Figure 3, the corrosion on the specimens test were pitting and uniform corrosion. There was a difference of pitting corrosion in specimens immersed at difference of electrode type. However, uniform and pitting corrosion occurred on all welded joint specimens with the addition of bacteria or without the addition of bacteria. Although the corrosion rates were different.



(a)



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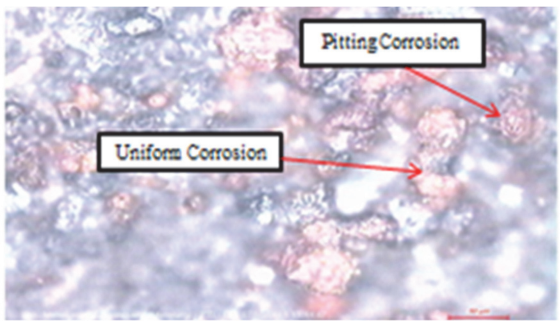

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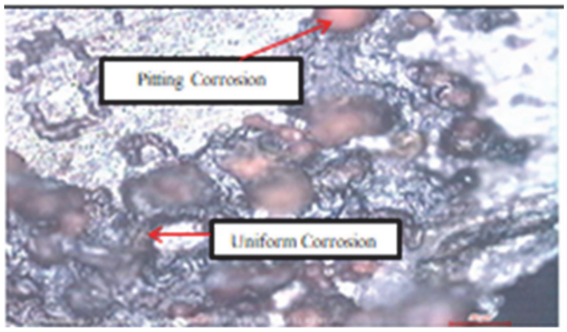
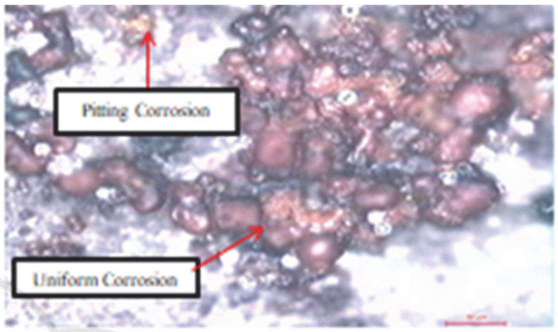
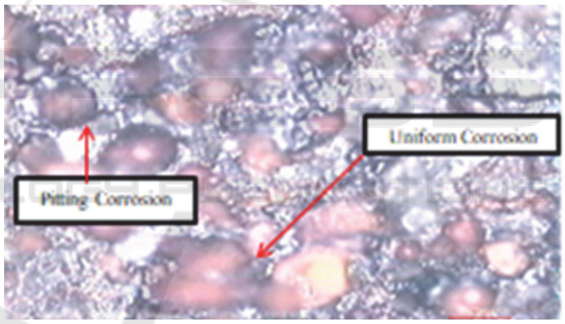


(d)



(e)



(f)

Figure 3: Microstructure on welded ASTM A36 with variations of the electrode, (a) non bacteria, (b) with bacteria with electrode of E6010, (c) non bacteria (d) with bacteria with electrode of E6013, and (e) non bacteria , (f) with bacteria with electrode of E6019.

4 CONCLUSION

The results showed the lowest of bio-corrosion rate with the addition of the Thiobacillus ferrooxidans on welded joints of materials was AWS E6013 compared with other electrodes. Similarly, the lowest of corrosion rate or without Thiobacillus ferrooxidans. The value of bio-corrosion and corrosion rate were 9.79757 mpy and 7.48178 mpy, respectively. The type electode of E6013 has the highest hardness value (164 HVN). Based on microstructure results, uniform and pitting corrosion occurred on all welded joint specimens with the addition of bacteria or without the addition of bacteria. However, the corrosion rates were different. It indicated that AWS E6013 as a electrode on SMAW welding on ASTM A36 steel has a high effect to reduce the corrosion and bio-corrosion rate in marine environment.

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