



Performance Assessment of Ship Hull Metal in Seawater Media

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This research was undertaken to determine the effects of corrosion on material performance using mild steel and Aluminum as selected material in seawater media. The result from the experiment showed higher corrosion rate in uncoated mild steel coupon as higher corrosion rate ranges from 0.0494 mmpy, 0.0565 mmpy, and 0.0656 mmpy was evident, while a reduction in corrosion rate from 0.0369mmpy, 0.0432 mmpy and 0.0452mmpy was observed in the fourth week, fifth week and sixth week. Corrosion rate for coated mild steel ranges from 0.0396 mmpy in the first week and reduces to 0.0333 mmpy and continually reduces to 0.0206 mmpy in the sixth week. From the hardness testing device using MITECH 320, uncoated Mild steel metal specimen gave an average Brinell hardness reading of 112 before immersion and 105 after immersion to seawater. Also, the tensile strength of the uncoated mild steel specimen deteriorated from 414 Mpa before immersion to 403Mpa after immersion to seawater media. Also, uncoated Aluminum specimen gave a brinell average reading of 163 before immersion and 152 after immersion to the seawater media. Likewise, the tensile strength result of the aluminum specimen gave 776M pa before immersion and 744 Mpa after immersion to the seawater media. The overall result from weight loss technique and metal hardness using MITECH 320 showed aluminum metal is more resistive to corrosion attack.

Keywords: *Corrosion; aluminum; mild steel; performance; ship hull.*

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1. INTRODUCTION

Corrosion by definition is the destructive attack on a metal by its environment (surrounding) or with sufficient damage to its properties, such that it can no longer perform its required function. In the case of a ship hull, corrosion can be defined as deterioration of the ship hull metal. Corrosion remains a big challenge to the maritime world, due to its environmental hazard both to human and aquatic life and its economic implications. According to Koster [1], consistent dry docking has revealed a lot of astonishments on ship hull deterioration rate contrary to evaluations.

Ikechukwu and Pauline [2] cited that corrosion takes place in the presence of an electrolyte like water, salt water, or soil. The danger in corrosion is that it reduces the metallic properties of the affected metals Rajendran et al [3]. The corrosion rate of Ship hull and offshore facilities produced from mild steel have been found to be high [1]. Study by Anyawu and Agberegba [4], showed that other corrosion accelerating factors include; pH values, the amount of oxygen in the fluid, the chemical make-up of the fluid, the velocity of the fluid in the pipe and high temperature which increase virtually all chemical reactions. According to Clement et al [5], corrosion rate is higher in cast steel metal compared to copper metal in 0.0015 M and 0.002 M of saltwater.

Ship hull design material refers to the metal used as the outer shell or covering, which forms the part of a vessel which is largely immersed in the water. Material used for ship hull design are wood, iron and steel. Carlos et al. [6] cited that failures in ship hull and oil spill disasters are caused by excessive corrosion. According to Vander [7], 20% of steel produced every year is used to replace metal lost to corrosion. The difficulties associated with corrosion due to seawater have been studied for many years, however; despite published information about the behaviour of materials in seawater, failures still occur. According to Schweitzer [8], the rate of corrosion of carbon steel range from 0.20 to 2.0 mm/year depending on several factors, such as oxygen, pH, contaminants, macro-, and micro-organisms. According to Roberge [9], some of these factors are interrelated and depend on physical, chemical, and biological variables, such as depth, temperature, nearby rivers, contamination by industrial effluents, and the availability of nutrients.

However, the behaviour of metal in a corrosive media differs from metal to metal, hence proper material selection is necessary to control or reduce the spread or rate of corrosion in metals. Material selection is crucial especially when they are subjected to marine environment that is harsh, rough and corrosive in nature. It is therefore of utmost importance that a vital focus should be placed on material selection and their characteristics. According to Oliver, et al. [10], when selecting materials for a particular fluid system, it is imperative to take first into consideration the characteristics of the system, giving special attention to all factors that may influence corrosion.

This study is aimed at assessing the performance reliability of two selected materials used for ship hull design in seawater media. The essence of the study is to demonstrate the metals reliability performance in seawater media.

2. MATERIALS AND METHODS

Selected materials of mild steel and Aluminium was used for the study in seawater media. According to Oliver et al. [9], in design the selection of materials to be used dictates a basic understanding of the behavior of materials and the principles that govern such behavior. Furthermore, if proper design of suitable materials of construction is incorporated, the equipment should deteriorate at a uniform and anticipated gradual rate, which will allow scheduled maintenance or replacement at regular intervals.

2.1 Weight Loss Gravimetric Technique

The selected material (metal) of mild steel and Aluminium used for the study were cut into rectangular shape of six part each; where their weight, area and density was assessed using a weighing balance in order to determine their weight. Mild steel and aluminum metal has a length and width of 30.5 mm, 14.8 mm and 16.0 mm and 29.8 mm respectively. The density of mild steel and aluminum was 7.828 g/m³ and 7.218 g/m³. Mild steel and aluminum metal was classified into two category (coated/uncoated), two of the metal (aluminum and mild steel) was coated while the others was uncoated.

Weight loss technique involves a gravimetric method which assess metal weight. It is recognized as the simplest and easiest method to determine metal weight loss in order to assess their corrosion rate in plant and process

equipment. A weighed sample (coupon) of the metal or alloy under consideration is introduced into the process, and later removed after a reasonable time interval. Two mild steel and aluminum (coated and uncoated) was used for the weight loss experimental set up while one sample of uncoated mild steel and aluminum was used to check the metal hardness before and after immersion using MITECH 320 hardness testing machine.

The metal specimen is cleaned of all corrosion products and is re-weighed. The loss in metal weight is converted to a corrosion rate (CR) with unit in millimeter per year (mmpy). It is usually expressed as:

$$\text{Corrosion rate (C.R.)} = \frac{87.6 \times \Delta W}{\text{density} \left(\frac{\text{g}}{\text{m}^3}\right) \times \text{Area} (\text{m}^2) \times \text{Time of exposure (yrs)}} \quad (1)$$

ΔW is the change in weight of the metal specimen in grams

K is rate constant = (87.6),

D is the density of the metal specimen in (g/m^3)

T is time of exposure and

A is the area of the metal specimen

$$\Delta W = W_R - W_L \text{ (g)} \quad (2)$$

W_R is the original weight of the metal specimen before immersion to the corrosion media and W_L is the weight loss of the metal after immersion into the corrosive media.

The rectangular specimen of mild steel and Aluminium was then clean mechanically with the use of emery cloth to ensure they are in fine shape. The apparatus used in the study were Vernier caliper, weighing machine, beaker, iron-brush, file and, sand paper. One of the mild steel and Aluminium was coated while the other (mild steel and aluminium) was uncoated. Equipment used are emery cloth, supporting iron rod and string. Some of the sample preparation processes include grinding and polishing. The grinding process is done to ensure smooth finish and uniformity of the surface of the specimen. Abrasive papers were used ranging from P220,

320, 400, 600 and 800. Figs. 1 and 2 shows the experimental setup for the weight loss technique and MITECH 320 testing device for the metal hardness procedure.



Fig. 1. Experimental set up



Fig. 2 Mitech 320 testing device

2.2 Metal Hardness

Macro hardness testing was conducted on both selected materials (uncoated mild steel and aluminum) to determine the hardness of the metal. The equipment used for this test is MH 320. By description, a hardness tester is used to test the standard test block downward vertically for 3 times, the arithmetic average value compare with the value of standard test block. In the preparing sample surface, the hardness effect of being heated or cold processing on the surface of sample should be avoided as too large roughness of the sample surface being measured could cause measurement errors.

The seawater used for this study was obtained from Elia-Gina River, Ogonokom Abua/Odurl L.G.A. Rivers State. Constituent of seawater is shown below in Table 1.

Table 1. Seawater constituent obtained from Niger Delta University Biological Science laboratory (2019)

Constituent	P ^H	Salinity	NO ₃	Cl	SO ₃	Ca	Mg	Na	Fe	K
Seawater	8.11	4.24	7.641	975	54.60	568	142	264	0.54	72

3. RESULTS AND DISCUSSION

3.1 Presentation of Results

The corrosion rate of Aluminium was calculated using the weight loss formula for a period of six (6) weeks in seawater media. The corrosion rate of both coated (painted) and uncoated aluminum was analyzed in a comparative manner after six weeks of immersion. Table 2 and Fig. 3 shows the corrosion rate of aluminum metal specimen

from week 1 to week 6 accordingly. The behaviour of the coated and uncoated metal coupon differs as their corrosion rate varies from week to week in the seawater media. Table 3 and Fig. 4 shows the corrosion rate for uncoated and coated mild steel metal in seawater media while Fig. 5 shows the corrosion rate versus immersion time for both metal in coated and uncoated perspective to give a general view of their response or behaviour in a corrosion media.

Table 2. Corrosion rate of uncoated and coated aluminum in seawater media

Metal	1 st week	2 nd week	3 rd week	4 th week	5 th week	6 th week
Uncoated AL	0.0011 mmpy	0.0014 mmpy	0.0016 mmpy	0.0018 mmpy	0.0025 mmpy	0.0022 mmpy
Coated AL	0.0000 mmpy	0.0000 mmpy	0.0004 mmpy	0.0003 mmpy	0.0005 mmpy	0.0009 mmpy

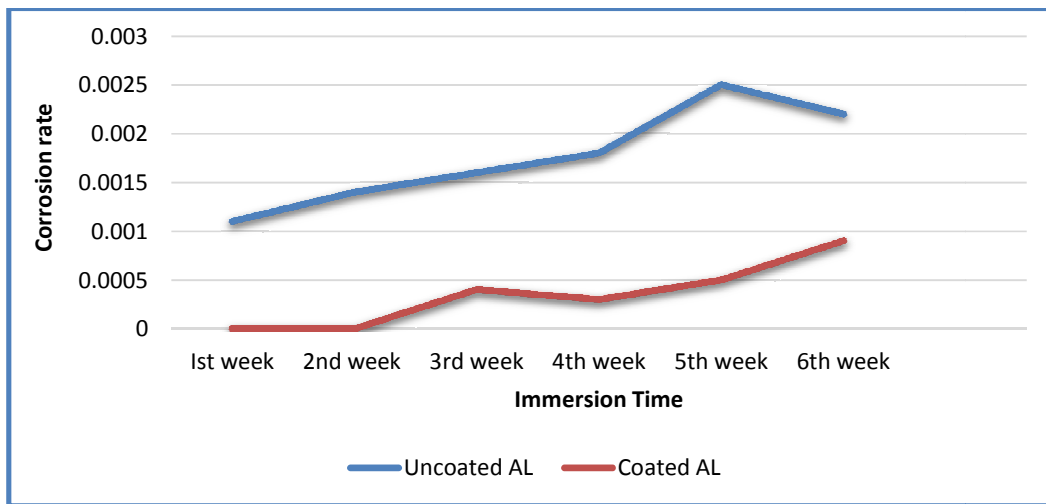


Fig. 3. Corrosion rate versus immersion time for coated/uncoated Aluminium (AL) in seawater

Table 3. Corrosion rate of uncoated and coated mild steel in seawater media

Metal	1 st week	2 nd week	3 rd week	4 th week	5 th week	6 th week
Uncoated MS	0.0494 mmpy	0.0565 mmpy	0.0658 mmpy	0.0369 mmpy	0.0432 mmpy	0.0452 mmpy
Coated MS	0.0369 mmpy	0.0333 mmpy	0.0267 mmpy	0.0271 mmpy	0.0216 mmpy	0.0206 mmpy

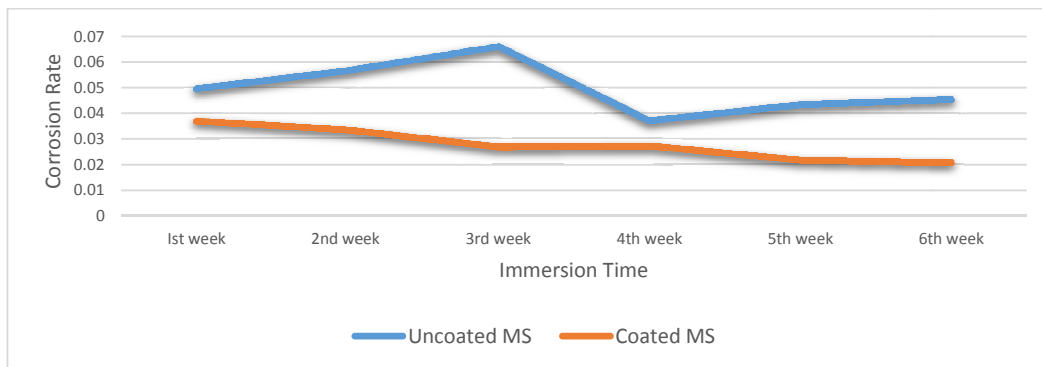


Fig. 4. Corrosion rate versus immersion time for both coated and uncoated mild steel metal

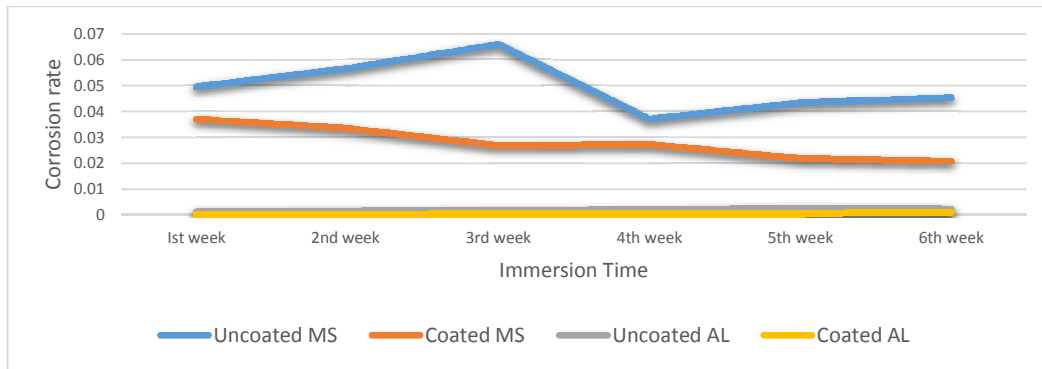


Fig. 5. Corrosion rate versus immersion time for Aluminum (AL) and Mild Steel (MS)

3.2 Discussion of Finding's

3.2.1 Uncoated and coated aluminium corrosion rate

The behaviour of coated aluminum and uncoated aluminum differs as higher corrosion rate ranging from 0.0011 mmpy to 0.0025 mmpy was observed. In coated aluminum metal, no corrosion rate was observed during the 1st and 2nd week while a corrosion rate of 0.0004 mmpy was observed in the third week and 0.0009 mmpy was observed in the 6th week. Fig. 3 and Table 2 showed that coated (painted) aluminum is more reliable and resistive to corrosion attack compared to uncoated aluminum where the film strength is weak.

3.2.2 Uncoated and coated mild steel

Mild steel in generally is prone to corrosion attack in nature. The result from the experiment showed higher corrosion rate in uncoated mild steel coupon as corrosion rate ranges from 1st week to 3rd week 0.0494 mmpy, 0.0565 mmpy, 0.0656mmpy then reduces to 0.0369 mmpy in the 4th week and again increased to 0.0432 mmpy and 0.0452 millimeter per year (mmpy) in the 5th and 6th week. However, corrosion rate for coated mild steel ranges from 0.0396 mmpy in the 1st week and reduces to 0.0333 mmpy after the 2nd week and continually reduces to 0.0206 mmpy in the 6th week as shown in Fig. 4. The overall result showed that, coated (painted) mild steel metal possess higher resistive nature to corrosion than uncoated mild steel metal. Thus, coated mild steel metal possess better film strength than uncoated mild steel.

The overall corrosion rate result from Tables 2 and 3 showed evidently that aluminum is more resistive to corrosion attack in both coated and uncoated perspective. This shows the performance reliability of aluminum metal as a better material selection in ship hull design compared to mild steel. Also, the idea or concept of painting and repainting metals that are used in corrosive environment is very important as it helps to improve material film strength to resist corrosion attack. Furthermore, the need of maintenance and inspection is very important and crucial in ensuring metal performance is optimal.

3.2.3 Metal hardness results

The Brinell hardness and tensile strength of the selected materials before and after immersion in seawater was tested using MH320. The result for both uncoated mild steel and aluminum is shown in Table 4.

Results from the metal hardness before and after immersion gives an indication of the metal behaviour in seawater. Average Brinell hardness test reading of Mild steel metal specimen before immersion gave a reading of 112 and later reduced to 105 after immersion to seawater. Also, the tensile strength of the mild steel specimen before immersion gave 414 Mpa to 403 Mpa after immersion in seawater media. Similarly, Brinell hardness value of Aluminum specimen before immersion gave a reading of 163 to 152 after immersion to seawater media. Likewise, the tensile strength result of the aluminum specimen gave a reading from 776Mpa before immersion and 744 Mpa after immersion in the seawater media.

Table 4. Metal hardness result for aluminum and mild steel

S/N	MITECH 320 LEEB hardness tester	BRINELL hardness reading				Tensile strength (Mpa)			
		HB1	HB2	HB3	Average	σ_1	σ_2	σ_3	$\sigma_{average}$
1	Uncoated Mild steel before immersion	95	124	118	112	433	418	391	414
2	Uncoated Mild steel after immersion	84	116	114	105	425	395	390	403
3	Uncoated Aluminum before immersion	68	167	153	163	789	771	768	776
4	Uncoated Aluminum after immersion	148	165	142	152	746	752	734	744

Source: Turret engineering services Limited, 2019

This shows the obvious effects and impact of corrosion attack in both selected material used in the study. However, the impact of corrosion on both metal specimen showed evidently that mild steel specimen is more susceptible to corrosion attack than aluminum. Hence, affirming aluminum metal is to be reliable in seawater media than mild steel which is in agreement with the corrosion rate results obtained via weight loss method.

4. CONCLUSION

The Marine environment by nature is rough and possesses huge risk to the safety of crew member's onboard, marine machineries onboard the vessel and so also the design material used in ship. The concept and destructive nature of corrosion is overwhelming, however it can be maintained or controlled by utilizing proper material selection and enforcing good maintenance culture.

The paper has investigated the effects of corrosion on material performance using mild steel and Aluminum as selected material in seawater media. The results obtained via weight loss method and metal hardness using MITECH 320 has revealed beyond doubts the destructive nature and impact of corrosion on metals. The study also pointed and highlighted the significant behaviour of aluminum metal in seawater media compared to mild steel; as it is more reliable and resistive in nature to corrosion attack than mild steel metal.

5. RECOMMENDATIONS

In view of the findings, it is imperative that the following recommendation should be adopted

1. Proper maintenance of ship hull especially during dry docking

2. Proper material selection in the design of ship hull that is highly resistive to corrosion
3. Organization of programs and workshop that gives awareness on the impact of corrosion and applicable control measures

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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