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The Effect of Protective Coatings using L-5A Type toward Corrosion Rate on Mild Steel Grade a Material (Case Study in Indonesia Warship)

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Abstract

The Indonesian Navy requires warship as the main component of defense. It most of the material used are plates. There are several materials or materials that are vulnerable when exposed to corrosive attack on the marine environment. The aim of this paper is to determine the influence of coating, characteristics and compounds corrosion mild steel material A grade toward corrosion rate in seawater environment. Characteristics and corrosion compounds, used salt spray, immersion corrosion method, and X-ray method for analyzing corrosion compounds. The result of salt spray method showed highest corrosion rate (average 7,228 mpy for 20 days). The result of highest without coating showed corrosion rate (average 52,781 mpy for 20 days). The immersion test method with painting has the highest corrosion rate (average 1,892 mpy for 10 days). The highest unpainted corrosion rate (average 4,608 mpy for 20 days) after identified using x-ray obtained analysis and element that cause corrosion. In salt sprays produce corrosion product that is Fe (CO_3).

Keywords: Coating; Corrosion rate; Salt spray; Immersion corrosion testing method X-ray

Introduction

Indonesian Navy requires warship as the main component of defense. Indonesia Warship most of the material used is mainly made of ferros, non ferros, composite materials or other materials. There are several materials or materials that are vulnerable when exposed to corrosive attack on the marine environment. In various literature states that corrosion rates are various ways: how many milligrams per square centimeter per day, what percentage of weight is lost, and how many grams per square inch per hour are calculated from the weight of the corrosion [1]. Corrosion is a natural process involving oxidized metals by reducing the binding energy in metals to obtain the final result caused by most metals losing one or more electrons [2]. Some studies define that metals should be limited but often corrosion engineers provide a solution for considering metals and nonmetals for the problem [1]. Corrosion is the damage to metal caused by reaction with environment [3]. Corrosion is the environmental interaction that occurs due to material degradation [4]. In corrosion control there are five basic methods used, among others, namely: using a protective layer method, the use of cathodic or anodic protection, appropriate changes to the materials used, the modified environment, and the use of design on the modified system or component [5]. One of method to controlling corrosion is coating. The current condition of iron plate in Indonesia Warships already many who experience corrosion and porous, so readiness of operation of Warships very constrained and can not maximal in operational implementation, while operational warships is high preparedness that must be driven at any time against current background conditions for background research for the effect of protective coating using L-5A type lattice paint against corrosion rate on mild steel grade *A* material in warships. This research was conducted to determine the influence of coating, characteristics and compounds corrosion mild steel grade material A against corrosion rate in seawater environment in determining the effect of coatings. This research used three methods of salt spray testing method, immersion corrosion testing method to know the resultant corrosion and X-ray method to find out the corrosion product that produced. Characteristics and corrosion compounds, used salt spray, immersion corrosion method, and x-ray method for analyzing corrosion compounds.

This paper have many literature to support the research about it, such as Research Conducted on The Effect of Mild Steel Corrosion in 5 Different Environments [2]. Research on corrosion of Galvanic Interactions On Galena Flotation Using Milling Medium [6]. Research on The Corrosion. The induced voltage can be a determination to affect the rate of medium carbon steel in the salt environment [7]. Research Carried Out by Means of Low Pressure Cold Spraying to be able to protect the Corrosion and Electrical Conductivity of stored Copper Layers [8]. Ellectrodeposition Research that Replaces Zinc-Zinc Alloy Coating to be able To Know The Measurement of Corrosion Rate [9]. Research on Nano Composite Epoxy-Graphene Oxide Composide Based On Mils Steel to be able to Explore The Properties of Protective Corrosion Protection [10]. The Ultrasonic Irradiation Effect On Micro That Becomes The Determination In Coating The Construction Of High-Level Performance By To Determine The Corrosion Rate Of Zn-4.8% Al Alloys [11]. With In Situ (3D) X-Rays To Test The AA7075 Inclusion Particles To Determine Localized Corrosion Rates [12]. Research on Corrosion Resistant Coating to Evaluate The Effects Tested in Liquid Copper Chloride Salt Immersion [13]. Research on Dynamic Potentiometric Polarization Test in NaCl Solution And With Immers Test To Determine Comparative Behaviour of AZ31B Magnesium Alloy Corrosion [14]. Research on Correlations That Occur On The Meassurement of Silver Corrosion Field And Modification of Salt Spray Salt Test ASTM B117 [15]. Examines The Modification of Accelerated Corrosion Space And Its Effect on The Corrosion of The Silver Atmosphere Occuring In The External Environment [16]. Studied About Alluminum Alloys With an

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Intergranular Corrosion Case Study Using in situ Radiographic X-rays [17]. Research On Salt Spray With New Tin-Brass Alloys with Slightly Different Zn Environment To be Known For Its Corrosion Behaviour [18]. Research Undertaken by Way of Immersion and Salt Spray Environtment on an As-Cast AM60 Magnesium Alloy To Determine The Quantification Of The corrosive Pitting That Occurs [19]. Research By Combining Converted Alluminum Alloys Conversion To Correlate Between Salt Spray and Electrochemical Impedance Spectroscopy Test Results [20]. Testing Performed on EN19 & EN8D Alloy Steel Using Salt Spray Method To Determine its Effect [21]. Research to Find Out The Corrosion Product Formed On Iron Surface By Using In-situ Method X-ray Diffraction [22]. Research By Case Studies SEM-EDX and Inhibitation of Corrosion of 2205 grade Duplex stainless steel in 4M HCl by L – Glutamine - Weight Loss, ICP-OES [23]. The benefit from this paper is a literature for Indonesian Navy about plate material for use in ship construction and provides an explanation of the results obtained from the calculation process of corrosion rate using salt spray method and immersion corrosion testing. This paper is organized as follow. The basic concept of corrosion is described in section 2, for the results of research can be seen in section 3. whereas for the conclusion of this research can be found in section 4.

Materials and Methods

Corrosion

Corrosion is a natural process involving oxidized metals by reducing the binding energy in metals to obtain the final result caused by a metal that is mostly one electron or more [2]. In base incubators are usually protected steel rods that have been combined with a protective layer, ie the exposure as a cover, and/or to reduce the deterioration tendency of inhibitor use in the event of exposure to harsh environments [24]. moisture involving two electrochemical reactions, will usually lead to corrosion of the material in the presence of oxygen where an oxidation occurs which results in a reduction in the cathodic site and on the anodic site [25]. Some studies define that metals should be limited but often corrosion engineers provide a solution for considering metals and nonmetals for the problem [1]. The environmental reaction to the metal material is called corrosion [3]. Corrosion is the environmental interaction that occurs due to material degradation [4].

Reduction of the oxygen occurring which occurs due to some metal reduction reactions and the consumption of electrons involved by the corrosion process of electron (oxidation) removal [4].

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

$$O_2 \rightarrow 2H_2O^{+}+4^{e-} \quad (2)$$

$$2Fe+O_2+2H_2O \rightarrow 2Fe^{2+}\ 4OH^{-} \quad (3)$$

An anodic reaction or also called an oxidation reaction (1) and the reduction reaction (2) is called the cathodic reaction. Corrosion will occur when both reactions undergo an electrochemical process. Metals lost due to oxidation reactions that arise due to lack of oxidation reaction (3) of electrons, the enduring charge of neutrality. if it does not happen, then a large negative charge between the metal develops and will stop its corrosion process. Half-cell reactions and may occur locally or so-called oxidation and reduction or physical reactions may be separated. ie a process called a differential corrosion cell due to a separate electrochemical reaction physically [4].

Corrosion rate

The rate of corrosion is corrosion amount per unit time. Such corrosion level indications include from wide variations in rainfall, temperature fluctuations, humidity, wind, and to prevent classification schemes by using pollutants [5]. One of them, it can use electrical method. It calculations with equation (Table 1) [26].

$$Corrosion\,rate = mpy = \frac{534W}{DAT} \quad (4)$$

Salt spray testing

In the ASTM B117 salt spray test execution, the data used to stand on its own by using the results of the salt spray. parts of the spray salt spraying (fog) comprising a reservoir for salt dissolving, a salt reservoir, compressed air supply to adjust consumption requirements, one or more atomization nozzles, specimen support, provision for heating the room, and the necessary control means (Figure 1). Salt spray instrument consists of 5 components:

(a) Fog chamber/internal reservoir;

(b) Salt solution reservoir;

(c) Compressed air;

(d) Atomizing nozzle;

(e) Spesimen support.

Immersion corrosion testing

A. In ASTM B895 consists of 2 methods, that is when immersion is applied in sodium chloride solution (5% NaCl) to evaluate the ability of stainless steel parts. In the first method, the appearance of the first rust is used to indicate the end point so that the test piece is checked regularly. While the 2nd method, to monitor the corrosion rate as a function of time by using advanced exposure using sodium chloride. of a few glass beads and 5% NaCl solution added to each bottle. A minimum of at least five times the test specimen in grams of at least 25 mm in determining the distance from the tube. The volume of the solution in the tube is about 1: 2 to 1: 3 to get the air volume ratio. In Figure 1 is an example of his experimental. By way of gentle twisting the solution then the air bubbles are removed. Bar test is checked every time interval according to the time specified. After the rust appears, then the time interval will be extended. Prior to the observation of the rust is the last checking time used for method 1, which continues with periodic checks outside the rust that appears. While Method 2 is given a degree of staining to give the rankings according to the following:

Relative Corrosion Resistance	Approximate Metric Equivalent				
	mpy	mm/yr	µm/yr	nm/yr	pm/s
Outstanding	< 1	< 0.02	< 25	< 2	< 1
Excellent	1-5	0.02-0.1	25-100	2-10	1-5
Good	5-20	0.1-0.5	100-500	10.50	5-20
Fair	20 - 50	0.5-1	500-1000	50-150	20-50
Poor	50 - 200	1-5	1000-5000	150-500	50-200

Table 1: Value of Corrosion Rate.

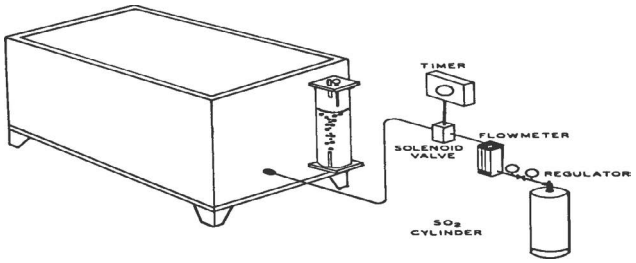

Figure 1: Salt spray (ASTM, 2003).

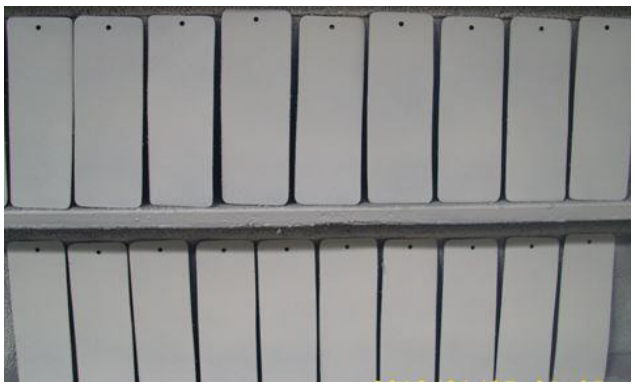

Figure 2: Specimen to be tested.

A: Sections or specimens free from stains or rust

B: Rust marks appear up to 1% covered or 1%

C: Carat. Up to 25% covered with corrosion

D: Over 25% covered with rust [27].

Material specimen

The material used in the research is a class A soft steel plate or commonly referred to as Mild Steel Grade A (Figure 2). With the following specifications:

Maksimum Tensile Strength	: 41-53 kg/mm²
Yield point	: 24 kg/mm²
Elongation	: 22%.

Tools and method

The Tools use for research such as pH indicator, micrometer, weight scales, Optical Emission Spectrometer, and electrolyte solution. And method used is by testing the plate material dissolved using immersion corrosion testing and spraying electrolyte solution with salt spray method and identify it with X-ray method.

Steps

The steps taken are first to cut the plates to fit the specimen plate for testing. The carry out the painting of 3 layers in accordance with the standard painting. After which the plate is tested by using electrolyte solution which uses sea water media. The test is done by comparison of time parameters. Where the time used is 10 days, 20 days, and 30 days by using the test with immersion and salt spray. After emerging corrosion product then identify the product of compound corrosion result by using X-ray.

Goal

The goal of the final project is:

a. Analyze the protective effect of coatings in terms of their corrosion resistance to sea environment.

b. Analyzing the process of corrosion rate on mild grade A material due to corrosion process in sea water environment.

c. Identify the material content of the test material content of the corrosion proof process by immersion of 30 days using X-ray method.

Results and Discussion

Based on the image above some differences from the plate that has been tested for 10 days, where the plate shows physical change where there is corrosion product is formed from the testing process for 10 days (Figure 3 and Table 2).

Based on the image above some differences from the plate that has been tested for 20 days, where the plate shows physical change where there is corrosion product is formed from the testing process for 20 days (Figure 4 and Table 3). And if compared with a 10 day test theres is difference on which to base the initial calculation for the corrosion rate.

Based on the image above some differences from the plate that has been tested for 30 days, where the plate shows physical change where there is corrosion product is formed from the testing process for 30 days (Figure 5 and Table 4). And compared with testing 10 and 20 days theres is a difference that becomes the basic for the initial calculation for the corrosion rate and for the corrosion product will be tested using X-rays.

Based on the above salt spray graph shows that a 20-day without paint test show the highest corrosion rate when compared to test at 10 and 30 days (Figure 6). So the test using the protective test at 20

Figure 3: Test results for 10 days.

Figure 4: Test results for 20 days.

Testing	10 days			
	Sample 1	Sample 2	Sample 3	Avg Sample
Salt spray				
Paint (before)	25.4732	25.3773	25.9652	
Paint (after)	25.8172	25.8343	26.3831	
Weight change (g)	0.344	0.457	0.4179	
Weight change (mg)	344	457	417.9	
Result of corrosion rate (mpy)	4.149	5.512	5.04	4.9
Without paint (before)	25.8608	26.0278	25.1701	
Without paint (after)	24.0265	25.1585	21.4132	
Weight change (g)	1.8343	0.8693	3.7569	
Weight change (mg)	1834.3	869.3	3765.9	
Result of corrosion rate (mpy)	22.124	10.485	45.313	25.974
Immersion test				
Paint (before)	24.9809	25.5057	25.8877	
Paint (after)	25.1968	25.6731	25.975	
Weight change (g)	0.2159	0.1674	0.0873	
Weight change (mg)	215.9	167.4	87.3	
Result of corrosion rate (mpy)	2.604	2.019	1.053	1.892
Without paint (before)	25.3501	25.5599	25.3398	
Without paint (after)	25.2028	25.5034	25.1032	
Weight change (g)	0.1473	0.0565	0.2366	
Weight change (mg)	147.3	56.5	236.6	
Result of corrosion rate (mpy)	1.777	0.681	2.854	1.771

Table 2: Test data within 10 days.

Testing	20 days			
	Sample 1	Sample 2	Sample 3	Avg Sample
Salt spray				
Paint (before)	25.2426	25.9238	24.9322	
Paint (after)	26.3832	27.0702	26.241	
Weight change (g)	1.1406	1.1464	1.3088	
Weight change (mg)	1140.6	1146.4	1308.8	
Result of corrosion rate (mpy)	6.879	6.914	7.893	7.228
Without paint (before)	25.8494	24.9795	25.2416	
Without paint (after)	17.1564	15.8672	16.7903	
Weight change (g)	8.693	9.1123	8.4513	
Weight change (mg)	8693	9112.3	8451.3	
Result of corrosion rate (mpy)	52.424	54.953	50.967	52.781
Immersion test				
Paint (before)	25.9134	25.8993	25.1206	
Paint (after)	25.7934	25.7094	24.9076	
Weight change (g)	0.12	0.1899	0.213	
Weight change (mg)	120	189.9	213	
Result of corrosionn rate (mpy)	0.724	1.145	1.285	1.051
Without paint (before)	25.1114	24.5322	24.7594	
Without paint (after)	24.3156	23.7621	24.0328	
Weight change (g)	0.7958	0.7701	0.7266	
Weight change (mg)	795.8	770	726.6	
Result of corrosion rate (mpy)	4.799		4.382	4.608

Table 3: Test data within 20 days.

Figure 5: Test results for 30 days.

Testing	30 Days			
	Sample I	Sample 2	Sample 3	Avg. Sample
Salt spray				
Paint (before)	25.5425	25.7247	25.4818	
Paint (after)	27.1312	27.1239	27.067	
Weight change (cram)	1.5887	1.3992	1.585.2	
Weight change (me)	1588.7	1399.2	15852	
Result of corrosion rate (mpy)	6.387	5.625	6.373	6.129
Without paint (before)	25.311	26.0882	24.427	
Without paint (after)	12.7334	13.0076	11.9625	
Weight change (gram)	12.5776	13.0806	12.4645	
Weight change (mg)	12577.6	13080.6	12464.5	
Result of corrosion rate (mpy)	50.567	52.590	50.113	51.09C
Immersion test				
Paint (before)	25.0655	25.9465	26.5235	
Paint (after)	24.9357	25.7099	26.2963	
Weight change (gram)	0.1298	0.2366	*o.22n*	
Weight change (mg)	129.8	236.6	2272	
Result of corrosion rate (mpy)	0.522	0.951	0.913	0.796
Without paint (before)	25.5064	25.9163	24.8253	
Without paint (after)	25.0338	25.3456	24.4099	
Weight change (gram)	0.4726	0.5707	0.4154	
Weight change (mg)	472 .6	570.7	415.4	
Result of corrosion rate(mpy)	1.900	2.294	1.670	1.955

Table 4: Test data within 30 days.

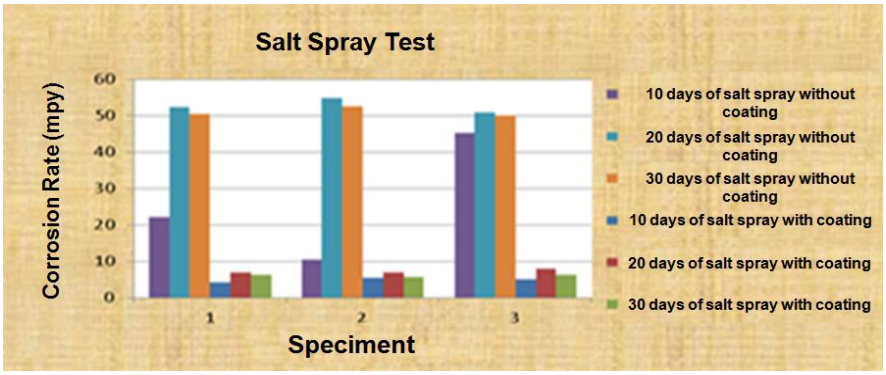

Figure 6: Salt spray.

days showed the highest corrotion rate also the corrosion rate when compared to the test when 10 and 30 days.

Based on calculation of corrosion rate above and graph shows that (Figure 7):

a. In general, salt spray is higher than immersion under various conditions.

b. The sample specimen without coating (no paint) higher corrosion rate compared to using coating.

c. The highest salt spray corrosion rate was tested on 20 days than immers, except the immersion test with coating (paint on the 10th day of the highest test when compared to immers with paint on 20 days and 30 days).

From the test results using XRD it can be identified that the corrosion product from the salt spray test is Fe (CO_3) and the immersion corrosion test is Fe O (OH) (Figures 8 and 9, Tables 5 and 6).

Conclusion

The salt spray method with the highest corrosion rate (average 7,228 mpy for 20 days). The highest unpainted corrosion rate (average 52,781 mpy for 20 days) The immersion test method with painting has the highest corrosion rate (average 1,892 mpy for 10 days). The highest unpainted corrosion rate (average 4,608 mpy for 20 days)

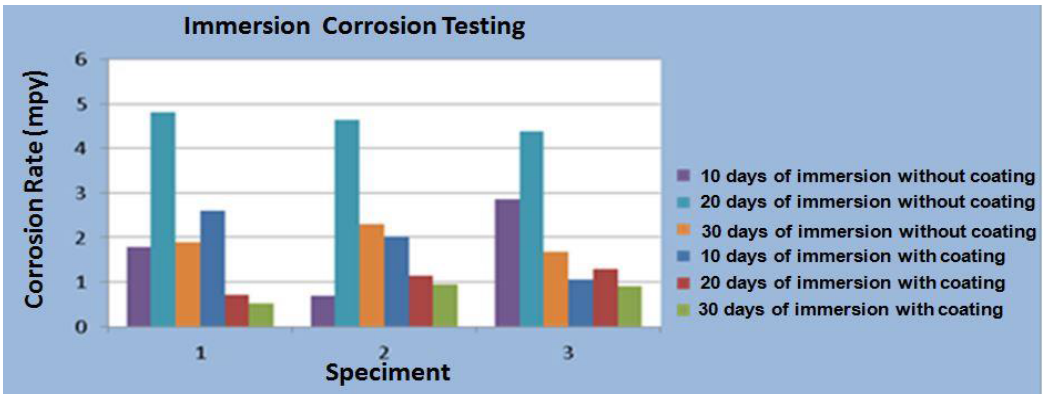

Figure 7: Immersion Corrosion Testing.

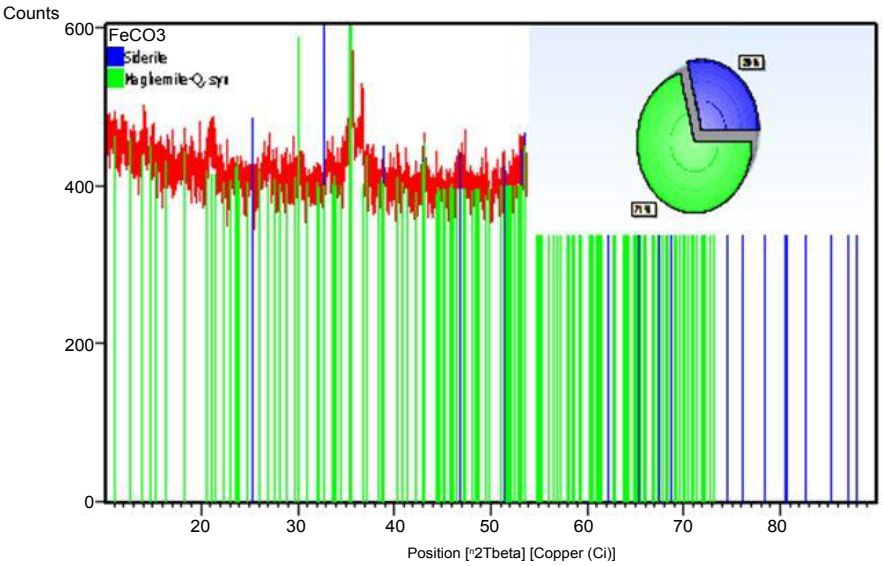

Figure 8: Salt Spray using XRD.

Visible	Ref. Code	Score	Compound Name	Displacement [°2Th]	Scale Factor	Chemical Formula
*	01-083-1764	10	Iron Carbonate	0.621	0.413	$Fe(Co_3)$
*	01-076-3169	45	Iron Oxide	-0.17	0.75	Fe_2O_3

Table 5: XRD test idntification data for salt spray.

Visible	Ref Code	Score	Compound Name	Displacement [°2Th]	Scale Factor	Chemical Formula
*	01-075-1594	4	Iron Oxide Hydroxide	-0.061	0.049	FeO(OH)
*	03-065-4899	84	Iron	-0.165	0.721	Fe

Table 6: XRD test idntification data for Immersion Corrosion Testing.

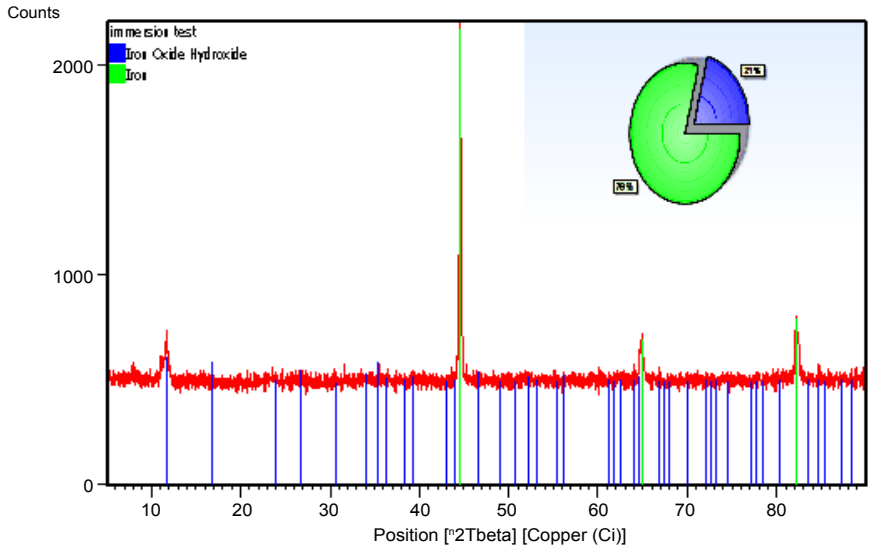

Figure 9: Immersion Corrosion Testing using XRD.

after identified using X-ray obtained analysis and element that cause corrosion. In salt sprays produce corrosion product that is Fe (CO_3).

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