THE EFFECT OF TIME VARIATION ON CORROSION BEHAVIOR ASTM A36 IN SWAMP WATER FROM THE VILLAGE OF RAMBUTAN SOUTH SUMATRA PROVINCE, INDONESIA

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ABSTRACT

Most of Indonesia's land is covered in swamps, and many infrastructure projects, including bridge construction, factory construction, and pipe installation, are completed in swampy environments. Swamp water typically has a high acid content and higher than normal concentrations of sulfates and chlorides, which are known to be more active in producing corrosion under normal conditions. This study aims to analyze and understand the corrosion rate and changes in the physical and mechanical properties of ASTM A36 steel that has undergone quenching heat treatment. Compared to steel ASTM A36 as received immersion in corrosive media using swamp water from The Village of Rambutan, South Sumatra Province, which has a pH of 3.00 with variations in immersion time of 48 hours, 96 hours, and 144 hours. The method used to determine the hardness value was the Brinell method, the corrosion rate was determined by the weight loss method, and SEM tests were carried out to determine the surface morphology of the specimens after immersion and XRD tests. The results showed that ASTM A36 steel specimens with quenching heat treatment had a higher hardness value than the as-received specimens; the greatest value was obtained in specimens with quenching treatment with immersion time. 48 hours, which is 497.97 BHN. The immersion test results showed that the highest corrosion rate occurred in the as-received specimen with a 144-hour immersion time of 17.6 mpy. Observation of the microstructure on the surface of the specimen found uniform corrosion and fitting corrosion; this was evidenced by the detection of iron oxide (Fe_2O_3), known as iron rust which is brownish-yellow in XRD testing.

Keywords: ASTM A36, Corrosion Rate, Immersion Time, Swamp Water, Fe_2O_3

1 INTRODUCTION

Corrosion is a material destruction process caused by chemical, physical and biological environmental influences. Corrosion is one of the problems faced by many parties, especially factories that use a lot of metal equipment, machines, and buildings. The problem that often occurs in using metals is the corrosion attack that befalls the metal [1]. Corrosion occurs due to the presence of chemical elements in an acidic environment. Chemical elements that have corrosive properties include sulfate (SO_4^{2-}), chloride (Cl-), and nitrate (NO3-); where these substances are known to be more aggressive in causing corrosion. Corrosion is a very important problem because it is detrimental; corrosion can cause damage that makes the construction lose its strength.

Table 1. ASTM A 36 Steel Chemical Composition Requirements

(%)	Plates Width (mm)				
	≤ 20	20-40	40-65	65-100	100
Carbon (c), max	0.25	0.25	0.26	0.27	0.29
Mangan (Mn)	…	…	0.18-1.20	0.18-1.20	0.18-1.20
Fosfor (P), max	0.04	0.04	0.04	0.04	0.04
Sulfur (S) max	0.05	0.05	0.05	0.05	0.05
Silicon (Si)	0.40 max	0.40 max	0.15-0.40	0.15-0.40	0.15-0.04
Copper (Cu)	0.20	0.20	0.20	0.20	0.20

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Based on previous research has investigated the corrosion rate of carbon steel in swamp water environments. Has analyzed the impact of corrosion in swamp water on losses in infrastructure development that uses steel as a raw material. The result is that the corrosion rate in a swamp water environment is approximately two times faster than in a clean water environment. [3] .

In addition, it is also based on research conducted that examines the effect of cooling rate on the microstructure and mechanical properties of medium carbon steel. Heated at 850^0C with a holding time of 30 minutes and cooled using different cooling rates: quenching, normalizing, and annealing. The results showed that the hardness of medium carbon steel using the quenching cooling method was higher than that of normalizing and annealing. The microstructure generated on the surface of the specimen after being heat treated by cooling quenching deformed the ferrite structure into pearlite and martensite.

This study aimed to analyze and understand the corrosion rate and changes in the physical and mechanical properties of ASTM A36 steel that underwent quenching heat treatment compared to ASTM A36 steel as received.

2 METHODOLOGY

The implementation of this research was carried out experimentally in the laboratory. In this study, the steel used was ASTM A36, commonly used as a general construction material. ASTM A36 steel specimens in the form of plates are cut to the desired size with a length of 100 mm, a width of 50 mm, and a thickness of 0.96 mm. Then the specimen is cleaned with sandpaper and immersed in an alcohol solution to remove dirt and grease. After drying, the specimens' dimensions were measured and weighed using digital scales.

Table 2. Chemical composition of swamp water

Parameter	Unit	Analysis result	Method	(c^0)	Humi dity	PH
Chloride	mg/L	9.30	Argento metri	22,7	68%	3
Sulfate	mg/L	91	Sulfate meter	22,7	68%	3

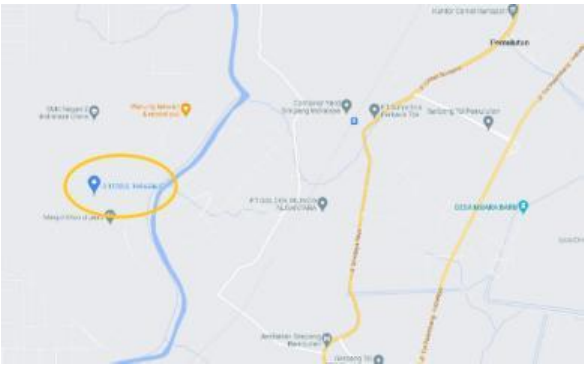


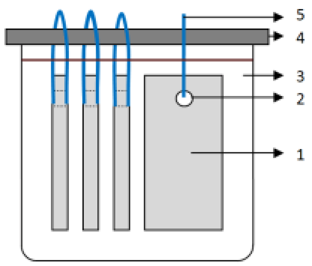
Figure 1. Location of swamp water corrosive media

In this study, the corrosive medium used was swamp water is taken from the KTM Rambutan Indralaya Utara area, Ogan Ilir Regency, South Sumatra, a peatland area. Wetlands such as swamp water and mud contain sulfate, chloride, and nitrate elements. These elements are factors that cause the corrosion of metals. Swamp water and mud contain organic matter and high humus, so the pH is low, which causes swamp water to be acidic. Swamp water quality measurements were carried out in the Chemistry Laboratory of the Faculty of Mathematics and Natural Sciences, Sriwijaya University.

Brinell hardness test was carried out by applying pressure using an indenter in the form of a steel ball with a diameter of 10 mm on the surface of the material being tested with a load of 3000 kgf. The following formula formulates the Brinnel hardness test.

$$BHN = \frac{2F}{\pi D(D-\sqrt{D^2-d^2})} \quad (1)$$

Treatment (Heat Treatment) begins with the preparation of specimens and heating chambers. The specimens were heated to a temperature of 750° C and then held at that temperature for 120 minutes. The aim was to determine the effect of heat treatment on the hardness value and microstructure of ASTM A36 steel. After heat treatment, the specimen is immersed in swamp water as a corrosive medium by immersing all parts of the specimen, with variations in immersion time of 48 hours, 96 hours, and 144 hours. Refers to the standard ASTM G31-72 concerning Laboratory immersion corrosion testing standards for metals.



Information:
1. Specimens
2. Holes for yarn
3. Swamp water (electrolyte)
4. Buffer
5. Yarn

Figure 2. The process of immersing specimens in swamp water media vessels

In this study, specimens were weighed before and after the immersion process in corrosive media with various immersion times of 48, 96, and 144 hours. The corrosion rate can be calculated using the following formula.

$$CR(mpy) = \frac{(K \ x \ \Delta W)}{A \ x \ T \ xD} \qquad (2)$$

3 RESULTS AND ANALYSIS

ASTM A36 material corrosion analysis begins by comparing the initial weight of the specimen before immersion in the corrosion medium with the weight of the specimen after immersion. Comparative data for the initial and final weights of ASTM A36 materials are shown in Table 3.

Table 3. Comparison of the initial and final weight

Specimens	Immersion Time (Hours)	W_0 (gr)	W_1 (gr)	Δw (gr)
As received (AR)	48	358.90	358.55	0.20
	96	353,54	353,11	0.45
	144	362.01	361,40	0.75
Quen-ching (Q)	48	363.04	362.96	0.10
	96	356,46	356,32	0.25
	144	365.02	364.81	0.34

The results of the study were carried out on ASTM A36 steel with a heating temperature of 750° C with a holding time of 120 minutes, with heat treatment using the quenching cooling method and without heat treatment as received which immersion in swamp water media pH 3.0 with variations in immersion time of 48 hours, 96 hours and 144 hours, it was obtained data that there was a large decrease in weight in the as receive specimens with an immersion time of 144 hours which was equal to 0.75 gram, while the specimen quenching The lowest weight loss occurred at 48 hours of immersion, namely 0.10 grams. This weight loss occurs because the specimen undergoes an electrochemical process (the process by which rust occurs in water). Electrochemistry occurs because steel metal will dissolve into Fe2+ ions; these ions will diffuse into the water (water acts as the cathode) and will form $Fe(OH)^{2,}$ which will then be oxidized contained in water and precipitate to form (Fe_2O_3) which is brown.

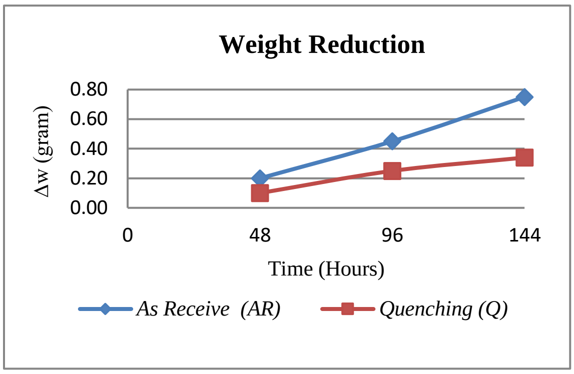


Figure 3 Graph of the weight loss of ASTM A36 steel after immersion in swamp water

Figure 3 shows that immersion time affects weight loss. The longer the immersion time, the greater the weight loss that occurs. [7]. Corrosion rate calculation data that occurs in ASTM A36 can be seen in table EL 4.

Table 4 ASTM 36 Brinnel hardness values

Specimen	BHN (Hours)		
	48	96	144
As receive	277.94	303,28	212.90
Quenching	497.97	326,69	262.50

Results of hardness test data. The hardness value obtained the largest was found in specimens with quenching treatment with an immersion time of 48 hours, with a hardness value of 497.97 BHN.

Heating the test sample at 750^0 C for 120 minutes and rapidly cooling it using aqueous media resulted in a hard steel structure. Cooling Against Mechanical Properties and Microstructure. In his research, he stated that the hardness value of the steel test sample treated with high quenching was due to the increased austenite grain size because the area of grain boundaries per unit volume decreased [6].

Table 5. CR Corrosion Rate Test Results (mpy)

Specimen	T (Hours)	A (cm^2)	K	ΔW (gram)	D (g/cm^3)	CR (mpy)
AR	48	131,92	3,45 x10^6	0,20	7,85	13,88
	96	128,98	3,45 x10^6	0,45	7,85	15,97
	144	131,08	3,45 x10^6	0,75	7,85	17,46
Q	48	130,89	3,45 x10^6	0,10	7,85	7,00
	96	128,75	3,45 x10^6	0,25	7,85	8,89
	144	133,63	3,45 x10^6	0,34	7,85	7,77

In this study, the corrosion rate calculation was calculated based on the ASTM G31-72 corrosion rate calculation formula, with variations in quenching cooling, and receiving with immersion times of 48 hours, 96 hours, and 144 hours. The results of each variation are then graphed and linked to the others so that the effect of immersion time and specimen cooling variations can be analyzed.

In table 4 and Figure 4 it can be known the value of the corrosion rate (mpy) of each test specimen. The highest corrosion rate in the as-received specimen with 144 hours of immersion time was 17.46 mpy, and the specimen with the lowest corrosion rate was found in ASTM A36 steel with variations of quenching cooling with 144 hours of immersion time of 7.00 mpy. The data also illustrates that the specimens that underwent quenching heat treatment have a lower corrosion rate than the as-received specimen. Thus heat treatment is effective in inhibiting corrosion attacks on ASTM A36 steel.

In Figure 4, it can be seen that in the swamp water immersion medium pH 3.0, the corrosion rate value of ASTM A36 steel tends to increase at each immersion time; this illustrates that there is an effect of the length of immersion time on the corrosion rate that occurs [8]. The longer the immersion time of the specimen, the higher the corrosion rate that occurs.

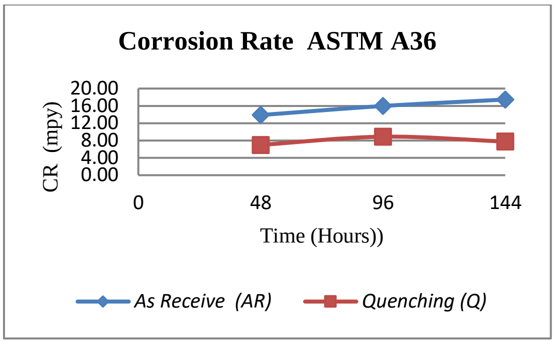


Figure 4 Comparison of the corrosion rate of ASTM A 36 steel

The corrosion rate of the quenched specimens with 144 hours of immersion decreased compared to the quenched specimens with 48 hours and 96 hours of immersion-this was due to the formation of black passivation, which occurred due to the reaction of the test specimen material with the immersion medium, this black color is iron sulfate which forms layer protection from corrosion products as well as from the metal part itself thereby reducing the value of the corrosion rate that occurs in carbon steel specimens [9].

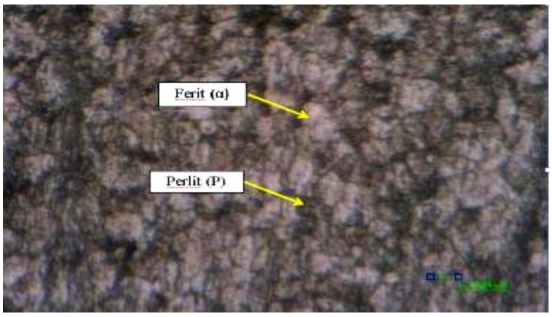
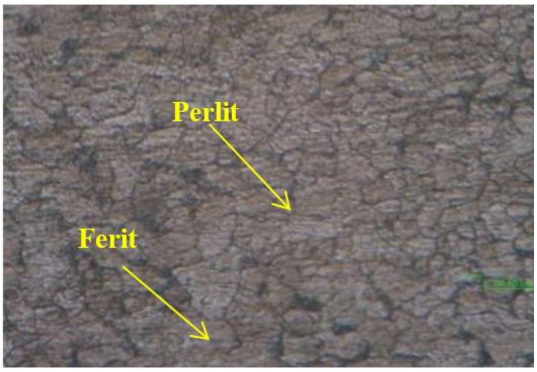


Figure 5 ASTM A36 steel microstructure as received before immersion

As-receive ASTM A36 steel microstructure shown in Figure 5 explains that two phases predominate in ASTM A36 steel, namely the ferrite (α) and perlite (P) phases. The ferrite (α) phase, which is white, is a metal component that has a maximum carbon solubility limit of 0.025% C at a temperature of 723°C, the crystal structure is BCC (Body Center Cubic), and at room temperature, it has a carbon solubility limit of 0.008%. The properties of ferrite are soft, ductile, and medium corrosion resistance. While the black Perit (P) phase occurs at a temperature of

723°C, contains 0.8% carbon with strong properties, and is resistant to corrosion [10].



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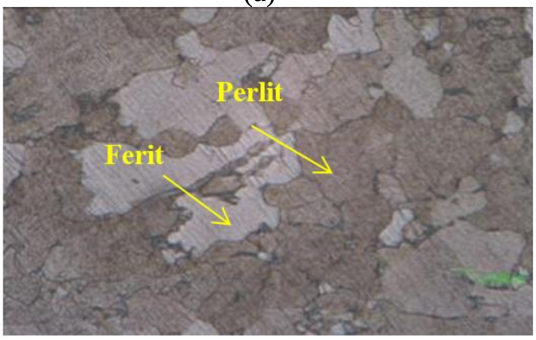

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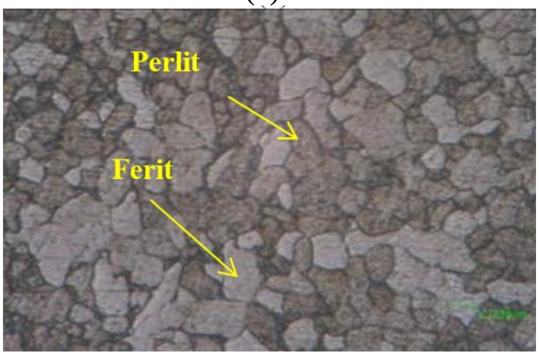
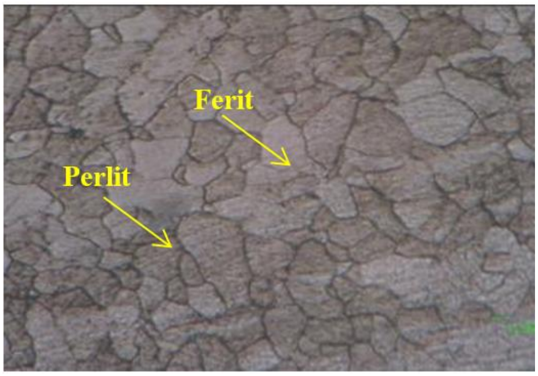


(c)

Figure 6 ASTM A36 steel microstructure as received with immersion time (a) 48 hours (b) 96 hours (c) 144 hours

Scanning Electron Microscope (SEM) observations were carried out on steel specimens ASTM A36 as received, and quenched immersion in swamp water medium with a immersion time of 144 hours. The results of the observations are as follows.



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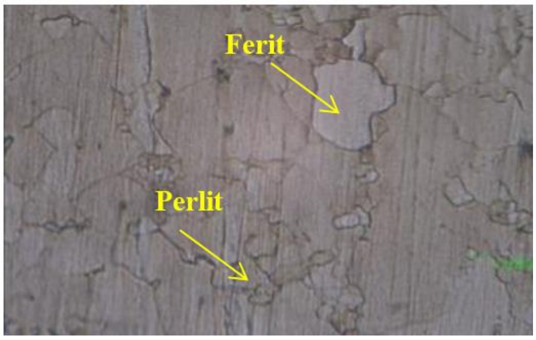

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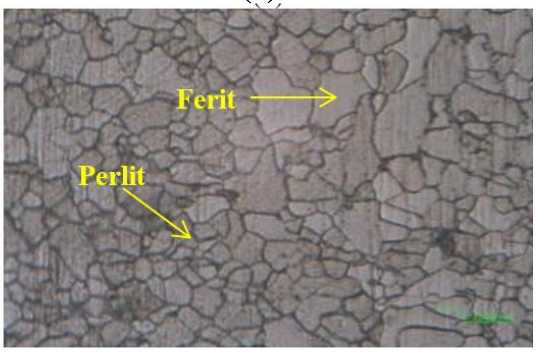

(c)

Figure 7 ASTM A36 steel microstructure quenching with immersion time (a) 48 hours (b) 96 hours (c) 144 hours

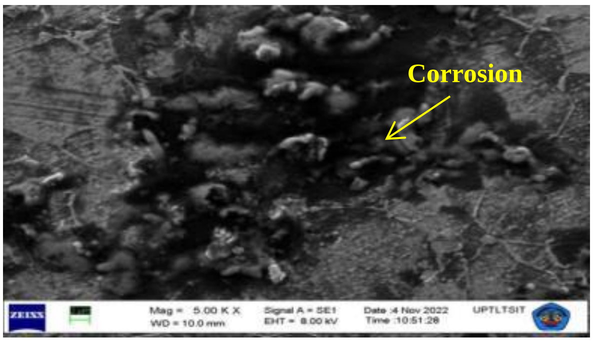

Figure 8 Corrosion Observation of ASTM A36 Using a Scanning Electron Microscope (SEM) As Receive Immersion Time 144 Hours Magnification 5000x.

As received steel specimens were immersed in a swamp water medium for 144 hours of immersion. The steel surface experiences corrosion which is characterized by damage to the steel surface with the appearance of rust crystals, this is due to the interaction between the swamp water containing chloride and sulfate with the steel causing corrosion to occur. The surface of the as-received specimen shows uniform corrosion and well corrosion fitting corrosion which is characterized by the presence of small holes on the surface of the specimen.

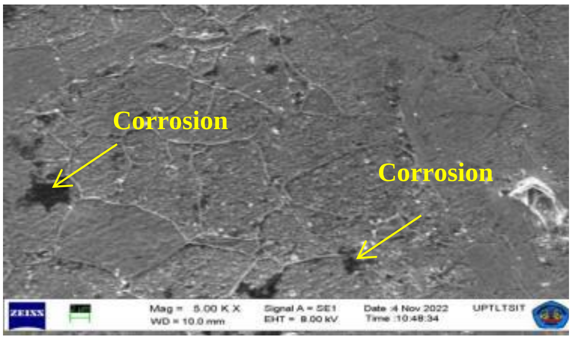

Figure 9 Corrosion Observation of ASTM A36 Using Scanning Electron Microscope (SEM) Quenching Immersion Time 144 Hours Magnification Data Filtering 5000x

Figure 9 is the surface morphology of ASTM A36 steel specimens heats treated at 750^0 C with a holding time of 120 minutes, variations of cooling quenching using clean water immersion in swamp water medium with a immersion time of 144 hours. It appears that there are non-uniform metal grains that fill the material, and there are large metal grains as a result of very fast recrystallization. The surface morphology of the quenched specimens appears flatter, this is because in this study the results of calculating the corrosion rate of the quenched specimens that occurred were lower than those of the as-received specimens. Forms of corrosion on ASTM A36 steel which is quenched with water media are fitting corrosion and uniform corrosion.

From the results of observations of ASTM A36 as -received steel specimens immersed in swamp water medium with a immersion time of 144 hours using the Rigaku Miniflex 600 XRD with the PDXL analysis software at the Physics Laboratory, Sriwijaya University, the presence of iron (Fe) and iron oxide (Fe_2O_3) compounds was detected which is known as brownish yellow iron rust. From Figure 10, it can be seen that there are 4 peaks (peaks) that describe the characteristics of a compound or element when it is shot with electrons at an angle of 2theta (deg) to the specimen.

At an angle of 2theta (deg) 8.634 a compound of unknown type was detected, at an angle of 17.7832 it was detected Fe_2O_3 compound was, at an angle of 44.5695 the highest peaks were detected for Fe and Fe2O3 compounds, and at an angle of 51.5191 it was detected the presence of Fe_2O_3, From Figure 11 it can be seen that the Fe_2O_3 compound was detected almost all over the surface, this shows that uniform corrosion occurred on the surface of the specimen.

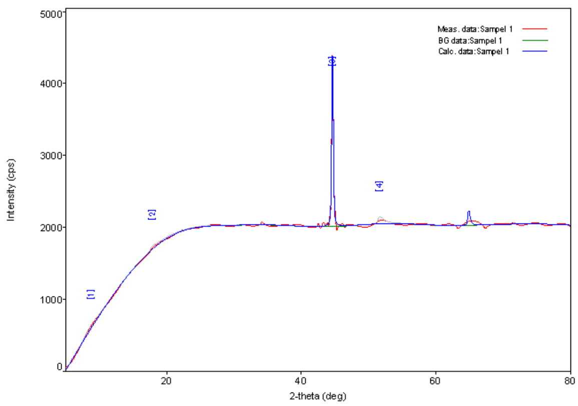

Figure 10 Graph of the dominant compounds detected by the XRD test results

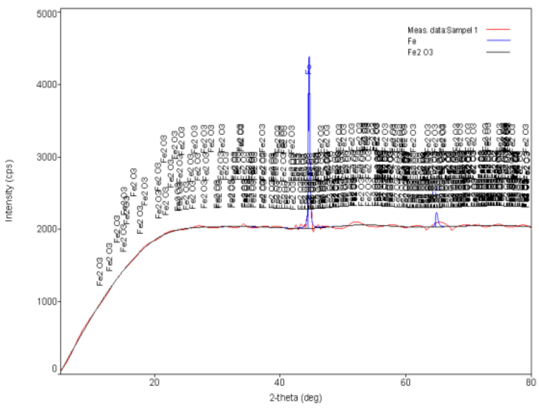

Figure 11 Graph of Fe and Fe2O3 compounds detected by XRD test results

4 CONCLUSION

The heat treatment process can affect the hardness value of the specimen, the greatest hardness value is obtained in the specimen by quenching treatment 48 hours of immersion time of 497.97 BHN, rapid cooling using water media has produced a hard steel structure caused by the austenite grain size (austenite grain size) increases. Meanwhile the lowest value is owned by the as-received specimen with a 144-hour immersion time of 212.90 BHN.

The higher corrosion rate occurred in the as-received specimen with a 144-hour immersion time of 17.46 mpy and the lowest corrosion rate occurred in the quenching specimen with a 48-hour immersion time with a corrosion rate of 7.00 mpy. Thus, heat treatment is effective in inhibiting corrosion attack on ASTM A36 steel.

Observation of the microstructure of ASTM A36 steel specimens shows that two phases predominate, namely pearlite, which is strong and resistant to corrosion. and ferrite with the dominating properties of softness, ductility, and medium corrosion resistance.

On the surface of the specimens found uniform corrosion and well corrosion fitting corrosion, this was evidenced by the detection of iron oxide (Fe_2O_3), known as iron rust which is brownish yellow in XRD testing.

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