Experimental study of corrosion rate on st60 steel as a result of immersion in HCl, NaOH, and NaCl solutions

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Abstract. The purpose of this study is to calculate corrosion rate (CR) of ST60 steel. A wet corrosion test was conducted by dipping ST60 steel in the solution of HCl, NaOH, NaCl. Use weight loss Method to calculate CR. It was found that the highest corrosion rate occured when the specimen of ST60 steel dipped on HCl0.1M solution. Corrosion that occurs for all corrosion tests is immersion in HCl, NaOH, and NaCl solutions produces uniform corrosion

1. Introduction

ST60 steel means that steel has a tensile strength of 60 kgf / mm^2 or 600 N/mm^2, including in the medium carbon steel group with a carbon content of 0.464%. ST60 steel is widely used for general construction because it has weld ability and sensitivity to good weld cracks and has excellent working properties and strength. It also applies to the railroad shaft, car axle and ship propeller shaft. When ST 60 steel is given the right treatment, hardness and tenacity will be obtained as desired. However, the main weakness of steel is corrosion. Corrosion is the destruction or damage of material due to reaction with the environment [1]. Corrosion can result in a decrease in the quality of the steel resulting in weak and damaged steel.

Research on low carbon steel for ship hulls coated with two layers using Alkyd paint and three-layer system using Epoxy paint, then calculated the corrosion rate using the electrochemical method, the results show that the thicker the coating does not guarantee the coating can protect perfectly. The thicker a coating has a greater risk of coating failure, such as reduced flexibility, shrinkage or imperfect drying [2].While research on steel ST 40 which is widely used in industry and household appliances, with chrome (Cr) electroplating, it can increase the hardness of the steel and prevent direct contact with the outside environment. The corrosion rate of ST 40 steel metal obtained the highest value in specimens with a coating time of 5 minutes, amounting to 235.37 mpy. While the lowest corrosion rate on specimens with a 20 minute coating duration of 50.02 mpy [3].

The purpose of this study was to calculate the corrosion rate (CR) of ST60 steel without coating with wet corrosion treatment (dipped in HCl, NaOH, and NaCl solutions).

2. Experimental Studies

Method procedure of experimental studies is prepare of ST60 Steel as material study in the form of a solid cylinder with a diameter of 25 mm and a thickness of 5 mm. The composition of ST60 Steel was observed using a spectrometer device. Corrosion test were dipped in a solution of HCl, NaOH, and NaCl solutions with concentrations of 0.1 Molar for 6 hours (interval 2 hours). The method used for measuring the corrosion rate (CR) was Weight Loss Method [4]. CR can be calculated by the equation:

$$CR = \frac{KW}{ADT} \quad (1)$$

CPR is Corrosion Penetration Rate (mpy) or reduction in the thickness of the material per time unit.
Unit: mile per year (mpy) or millimeter per year (mm/yr).
W is weight loss during testing = mo – m,
m is weight after corroded,
$m_o$is weight before corroded.
K is constant depends on unit used, when K = 534 the mpy will be used. When K = 87.6, mm/yr will be used.
D is density (gr/cm3),
T is time (hours),
A = surface area (cm^2) (same units other such as CPR wear mpy).

When the value of CPR was less than 20 mpy (0.5 mm/yr), the value/coefficient was still acceptable. Microstructure of ST60 steel before and after corroded was observed by using an optic microscope. Clearly shown in flow chart **Figure 1.**

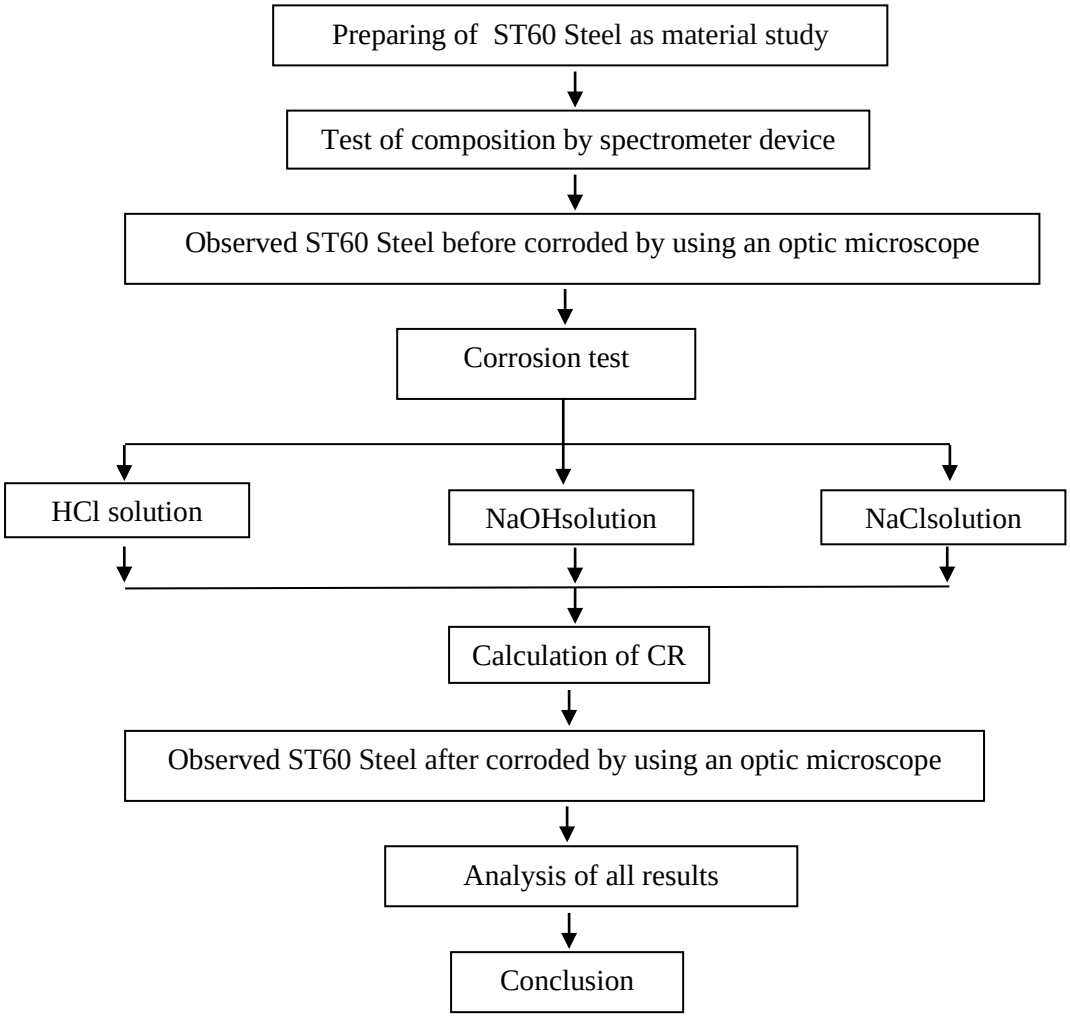


Figure 1. Flow chart of study

3. Result and Discussion

3.1 ST60 Steel Composition Test Results

Testing the composition to determine the elemental content in ST60 Steel using a spectrometer machine. The results obtained are shown in Table 1. It is seen that carbon content (C) is 0.4% indicating that ST60 Steel is medium carbon steel.

Tabel 1. The composition of ST60 Steel

C	Mn	P	S	Si	Ni	Cr	Mo
0.400	.700	.019	0.017	0.181	.90	0.680	.25

3.2 Wet Corrosion Test (Dipped in HCl, NaOH, and NaCl solutions)

The result for CR data obtained from effect of time in wet corrosion test when dipped in solution of0.1MHCl, 0.1MNaCl and 0.1 M NaOH, shown in Figure 2 respectively. The fastest of corrosion rate for six hours to weeks was occurred in solution of HCl. While the slowest was happened in NaOH and NaCl solution. All corrosion rate data are shown in the Table 2. In Figure 3, ST60 Steel in the solution of HCl have the highest CPR compared with the solution of NaOH and NaCl. When ST60 Steel was dipped in solution of HCl, it will be easily eroded, since HCl had no oxygen. HCl in the absence of oxygen will lead to a reaction at the cathode side of the galvanic cell, allowing the formation of a galvanic cell pairing in the micro structure of these samples have led to very easily affected, so the corrosion rate when the samples were stored in HCl became very fast. The fastest corrosion rate values during dipped for 6 hours is 130,12 mm/yr. This value of the CPR was dangerous because it exceeds the maximum allowable CPR (0.5mm/yr). To reduce the corrosion rate, steel needs to be coating with chrome (Cr), copper (Cu), and nickel (Ni) [5].

Table 2.CR obtained by wet corrosion test

Sampel	Solutions Time (T)	W(mg)	CR (hours)	(mm/yr)
X_1 HCl 0,1 M	2312.3127.634	629.2128. 6	955.2	130.12
X_2 NaOH 0,1 M	20.40.16	410.26	1.6	0.22
X_3 NaCl 0,1 M	20.90.37	5.51.12	611	1.5

3.3 Observed ST60 Steel using an Optic Microscope (MO)

Microstructure of ST60 Steel was observed using optical microscope magnification of 100x and 200x. **Figure3(a)** shows sample of ST60 Steel before before wet corrosion test. While Figure 3(b) and (c) were microstructure of ST60 Steel magnification of 100x and 200x. **Figure 4(a)** shows sample of ST60 Steel after corrosion in 0.1MHCl. **Figure 4(b) and (c)** were microstructure of ST60 Steel magnification of 100x and 200x after corrosion in 0.1 M HCl. **Figure 5(a)** and **(b)** show microstructure magnification of 100x and 200x of ST60 Steel after corrosion in 0.1M NaOH. **Figure 6(a)** and **(b)** show microstructure magnification of 100x and 200x of ST60 Steel after corrosion in 0.1 M NaCl.

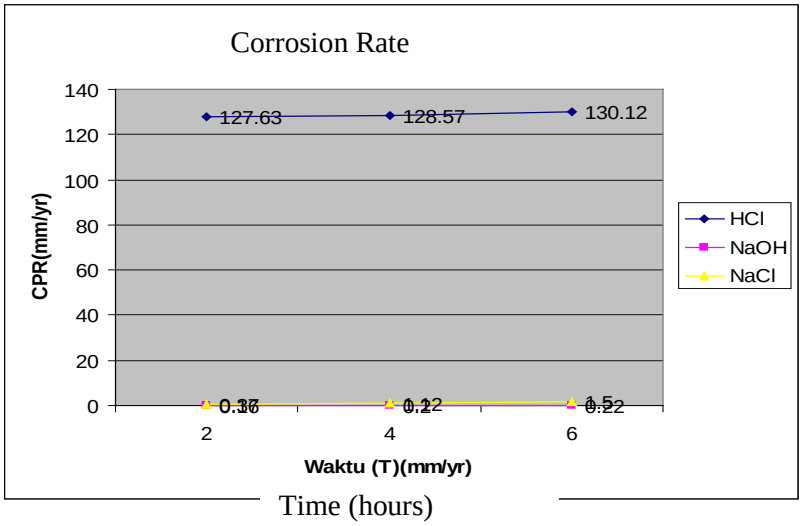
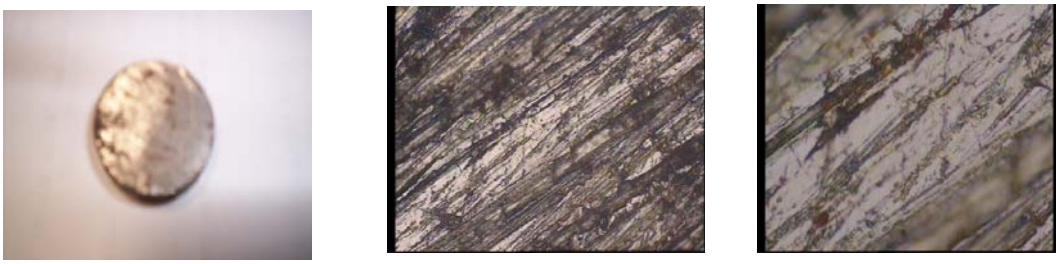


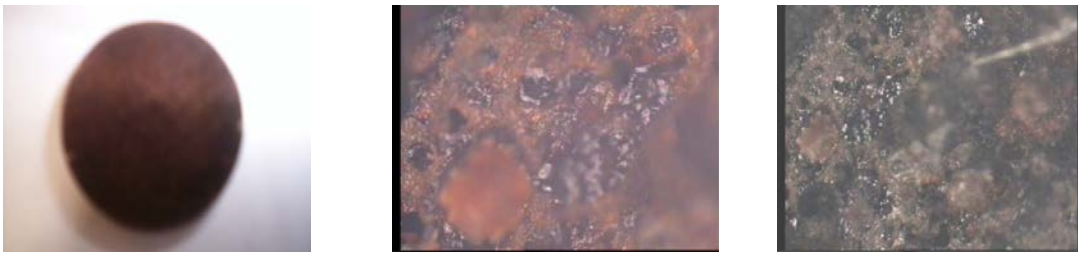
Figure 2 Graph of CPR comparison of solution HCl, NaCl andNaOH

From these figures, corrosion attacks the grain boundaries, can be seen in the presence of white and grows grain boundaries. The observe dimages show that the corrosion in HCl, seems fairly having sharp attack because of the environmental HCl is an acidic environment, which is strong enough to attack the samples. Corrosion in NaOH, which is alkaline the environment oxygen species, causing a delay in the process of corrosion in the alkaline environment. Corrosion that occurs for all corrosion tests is immersion in HCl, NaOH, and NaCl solutions produces uniform corrosion. Even corrosion is corrosion that occurs on all metal surfaces that come into contact with electrolytes, with the same intensity. This type of corrosion is the corrosion that most removes metals. ST40 carbon steel plate and stainless steel (SS) 304 which were tested for corrosion on sulfuric acid (H_2SO_4) 1M for 48 hours were carried out in 72 hours, obtained CR average value of 3.69 mm/ year for ST40 carbon steel plate and 0.18 mm/year for stainless steel (SS) 304 plates. Corrosion that occurs in carbon steel and stainless steel plates is uniform corrosion and pitting corrosion [6].



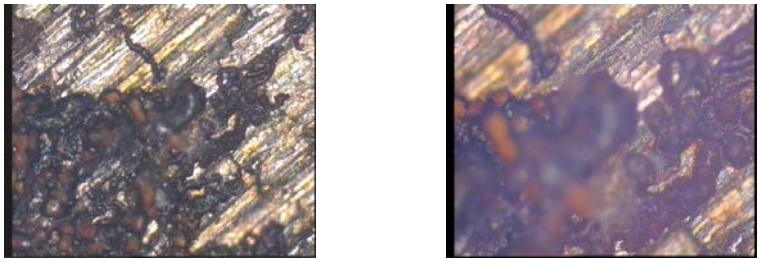
(a) (b) (c)

Fig. 3 (a) Sample of ST60 Steel before before wet corrosion test.
(b) Microstructure of ST60 Steelmagnification of 100x before before wet corrosion test
(c) Microstructure of ST60 Steelmagnification of 200x before before wet corrosion test



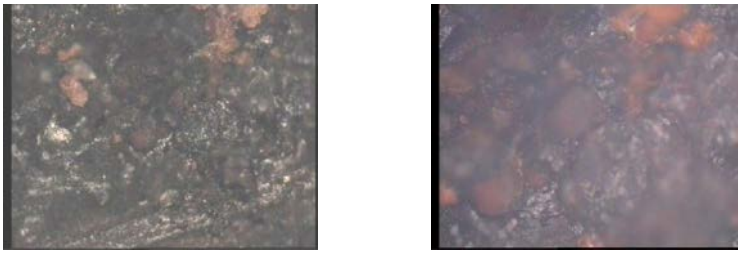
(a) (b) (c)

Fig.4 (a) Sample of ST60 Steel after corrosion test in 0.1MHCl
(b) Microstructure of ST60 Steel magnification of 100x after corrosion test in 0.1MHCl
(c) Microstructure of ST60 Steel magnification of 200x after corrosion test in 0.1MHCl



(a) (b)

Fig. 5(a) Microstructure of ST60 Steelmagnification of 100x after corrosion test in 0.1 MNaOH
(b) Microstructure of ST60 Steelmagnification of 200x after corrosion test in 0.1 MNaOH



(a) (b)

Fig. 6 (a) Microstructure of ST60 Steel magnification of 100x after corrosion test in 0.1 M NaCl
(b)Microstructure of ST60 Steel magnification of 200x after corrosion test in 0.1 M NaCl

4. Conclusion

From the discussion above, it can be concluded thatcorrosion rate of ST60 Steel in the solution of HCl have the highest corrosion rate compared with the solution of NaOH and NaCl. Corrosion that occurs for all corrosion tests is immersion in HCl, NaOH, and NaCl solutions produces uniform corrosion.

Acknowledgment

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