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The Effect of Ultrasonic Waves on the Rate of Corrosion in Low Carbon Steel with Hydrochloric Acid Solution

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Abstract— Low carbon steel can be applied in various fields of manufacturing industry, pipes, machine parts. The problem that is often faced is that corrosion often occurs, resulting in changes in the properties and characteristics of the steel material, requiring very high costs for prevention and maintenance of equipment due to corrosion. The use of ultrasonic waves to measure the rate of corrosion can identify defects and damage to the material. This study used a completely randomized design method with variations in immersion time of 6 hours, 7 hours, 8 hours, 9 hours, 10 hours and variations in hydrochloric acid concentration of 4%, 5%, 6% while the specimen dimensions were 30 mm in diameter and specimen thickness 20 mm. From the research results, it was found that the best corrosion rates at 10 hours of hydrochloric acid concentration were 0.2233 mmpy, 0.2664 mmpy and 0.3294 mmpy.

Keywords— Ultrasonic; Low Carbon Steel; Corrosion Rate; Hydrochloric Acid.

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I. INTRODUCTION

Low carbon steel is widely applied in various fields because it has low production costs. Carbon steel besides carbon has other elements such as manganese, silica and nickel. Based on the outline, carbon steel is divided into three parts, low carbon steel <0.25%, medium carbon steel 0.25 – 0.7% and high carbon steel 0.7- 0.1% [1]. The problem often faced by using metal materials is corrosion, especially in high temperature environments [2] resulting in damage and failure of the material [3]. In developed countries, 5% of state income is allocated for prevention or maintenance and replacing products or equipment due to corrosion[4]. Corrosion is the destruction of materials (especially metal) due to the environment. In metals, this occurs due to chemical reactions, namely at high temperatures between metal and gas or electrochemical corrosion occurs in water or wet air environments. Basically, the metal corrosion reaction takes place electrochemically [5], which occurs in the cathode and anode areas by forming a closed current circuit. There are several factors that influence the rate of corrosion, namely temperature, fluid flow speed or stirring speed, concentration of corrosive materials, oxygen and contact time.

The corrosion rate is defined as the amount of metal released per unit time on a certain surface, where by knowing the corrosion rate, it is possible to inhibit the corrosion rate or predict the life of the component [6]. Factors that influence the rate of corrosion are water and air humidity. Judging from the reactions that occur in the corrosion process, water is an important factor for corrosion to take place. Humid air containing a lot of water vapor will speed up the corrosion process. The use of ultrasonic waves to measure the rate of corrosion can identify defects and damage to the material. Similar research shows that with variations in ultrasonic time of 2 hours, 4 hours and 6 frequencies of 40 kHz with a 3.5% hydrochloric acid (HCl) solution on carbon steel. Rate measurement can use the weight loss method and electrochemical methods [7].

Table 1. The relationship between corrosion rate and corrosion resistance [8]

Relative corrosion resistance	Corrosion rate (mmpy)
Extraordinary	< 0.02
Very well	0.02 - 0.15
Good	0.15 - 0.5
Enough	0.5 - 1.25
Bad	1.25 – 5
Ugly as hell	> 5

By using the weight loss method, the corrosion rate equation can be calculated using the equation below.

$$CR = \frac{534W}{\rho AT} \quad \text{(mpy)} \qquad (1)$$

Where, *CR* Corrosion rate (mpy), *W* Weight loss during corrosion (mgr), *ρ* Specimen density (gr/cm3), *A* Cross-sectional area (cm2), *T* Corrosion process time (hours)

Ultrasonic waves are propagations of mechanical energy and momentum that interact with the solid, liquid and gas media through which they pass [9]. The vibration of air particles is caused by ultrasonic waves passing through the air. Periodic changes in the air during ultrasonic waves through a medium cause a continuous process to occur so that there is density and strain in the medium [10]. The method of utilizing ultrasonic waves is a method that uses acoustic waves with a frequency above 40 kHz[11]. In this method, ultrasonic waves formed from micro cavitation around the material cause heating and damage to the walls of the material, then the kinetic energy followed by the formation of cavitation bubbles is passed to all parts of the liquid so as to increase mass transfer between the solid and liquid surfaces [12]. Several mechanisms that can be used in ultrasonic extraction have been identified. One of them is fragmentation which is associated with collisions between particles and ultrasonic waves, which causes a reduction in particle size thereby facilitating mass transfer[13].

Hydrogen chloride (HCl) solution is a chemical liquid that is very corrosive, has a strong smell and is very irritating and toxic, HCl solution is a dangerous chemical or B3. The danger to health depends on the concentration of the solution, < 5% is a weak irritant, 5 – 10% is a strong irritant, > 10% is corrosive [14].

II. Material And Methods

A. Tools and Materials

- Glasses or test containers are used to test specimens.
- Hand grinders are used to cut specimens.
- Sandpaper is used to clean the initial specimen before testing for corrosion from attached scale and dirt.
- Digital scales are used to weigh the initial weight of the sample before the immersion test process and the final weight of the sample after the immersion test process.
- A ruler is used to measure the specimen.
- A stopwatch is used to help calculate the sample immersion time.

a. Tool

- Ultrasonic batch

b. Material

- Low carbon steel AISI 1018 with dimensions of 30 mm diameter and 20 mm thickness
- Hydrochloric acid solution
- Aquades is used to rinse the specimen being tested

B. Methods

In this study, a completely randomized design (CRD) research method was used with variations in the immersion time of the specimens in hydrochloric acid solution (HCl). By using the method above, the corrosion rate value for low carbon steel can be determined. In the research process, a circular specimen was first made with a diameter of 30 mm and a thickness of 20 mm. Next, the specimens were soaked in a solution of 4%, 5%, 6% hydrochloric acid HCl with variations in soaking each specimen for 6 hours, 7 hours, 8 hours, 9 hours, 10 hours with ultrasonic waves. After the process is complete, the corrosion rate is calculated using the weight loss method.

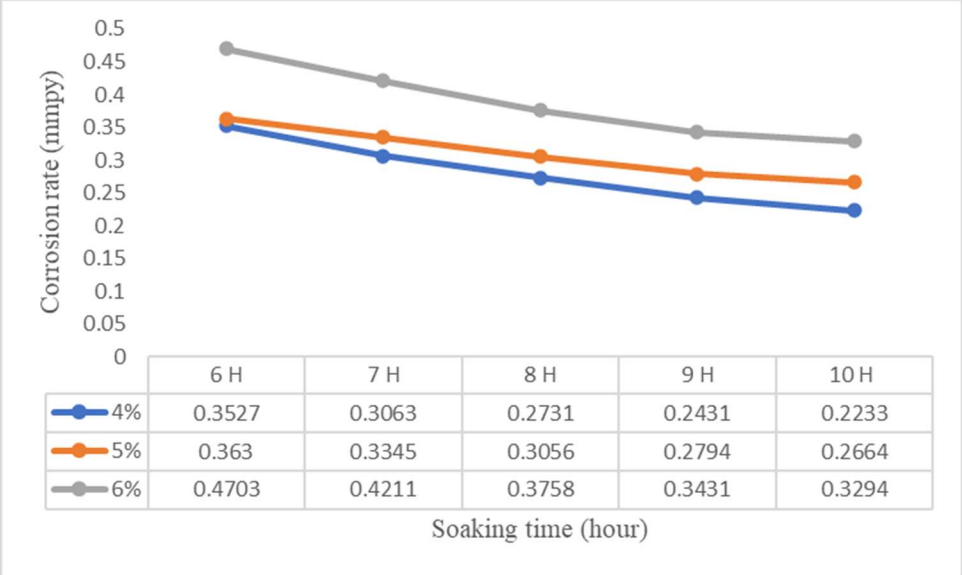
By using equation (2), the weight of the specimen can be calculated before and after immersion.

$$\Delta W = W_1 - W_2 \qquad (2)$$

Where, ΔW Difference in weight lost (g), W_1 Initial weight of specimen (g), W_2 Final weight of specimen

III. Results And Discussion

Weight measurements on low carbon steel specimens are carried out using digital scales which will be carried out at two times, namely before immersion (W_1) and after immersion (W_2). Next, the weight loss of the specimen will be calculated using varying concentrations of 4% hydrochloric acid (HCl) solution. 5%, 6% and variations in immersion time of 6 hours, 7 hours, 8 hours, 9 hours and 10 hours with the help of ultrasonic waves at a frequency of 40 kHz can be seen in Figure 1 below.



	6 H	7 H	8 H	9 H	10 H
4%	0.3527	0.3063	0.2731	0.2431	0.2233
5%	0.363	0.3345	0.3056	0.2794	0.2664
6%	0.4703	0.4211	0.3758	0.3431	0.3294

Figure 1. Graph of the relationship between corrosion rate and soaking time

From Figure 1. Above, the best results are at respective hydrochloric acid concentrations of 4%, 5%, 6% and soaking time of 10 hours respectively. Corrosion rate results are 0.2233 mmpy, 0.2664 mmpy and 0.3294 mmpy respectively. The longer the immersion time with the help of ultrasonic waves, the corrosion rate becomes smaller or decreases. This is due to the increased influence of ultrasonic waves which can propagate in liquids and gases, as well as in solid materials which causes density and tension in the medium caused by periodic vibrations of particles as the ultrasonic waves pass through them [15].

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References

[1] I. Alenenezi, “Effects of Heat Treatment on The Corrosion Behavior of ASTM A-36 Steeel,” Enginnering, Technology & Applied Science Research, Vol.10, No.1, 2020.

[2] A. Rahaman, Abubakne, A.Kaneen, Tijane, Aliyu and A. Samuel, “Effects of Coating Mild Steel Wit CNTs on Its Mechanical Properties and Corrosion Behavior in Acidic Medium” Adv. Nat. Sci. Nanotechnol. 2017

[3] A. Philip, “Fundamental of Corrosion: Mechanism, Cause and Preventive Method” Boca Raton Fl: CRC Press. PP 14-25, 2010.

[4] B. Rani and Basu, “ Int. J Corros” 2011

[5] K. R. Trethewey and J. Chamberlain, “Korosi” 1st Jakarta: Gramedia Pustaka Umum

[6] Siregar, M. Batu, Mutia, “Analisis Laju Korosi Mild Steel pada Lingkungan dengan Kelembaban Tinggi Selama 24 Jam. Jurnal Sistem Teknik Industri, Vol.6, No.5, PP 66-70, 1991.

[7] I. J. Kang, K.T. Kim, Y.R. Yoo and Y.S. Kim, "Ultrasonic Aplitude on Electrochemical Properties During Cavitation of Carbon Steel in 3.5% NaCl Solution" Corrosion Science and Technology, Vol. 19, No.4, PP 163-173, 2020

[8] Jones, A. Denny, "Principles and Preventation of Corrosion" Maxwell Mac Millan, Singapura, 1992.

[9] R.J. Bueche, "Introduction to Physics for Scientist and Engineers" New York, Mc. Graw-Hill, 1989.

[10] Giancoli and C. Douglas, "Fisika" Jilid 1 Edisi ke-5, 2001

[11] K. S. Suslick, "Ultrasound :Its Chemical, Physical and Biological Effect" VHC Publisher, New York, 1988.

[12] B. Susilo, "Pengaruh Pretreatment dan Lama Waktu Ekstraksi Terhadap Karakteristik Ekstrak Kulit Jeruk Purut (Citrus Hystris D.C) Menggunakan Ultrasonic Assisted Exstraction (UAE)" Jurnal Pertanian Tropis dan Bioristem, Vol.4, No.3, PP. 230-241, 2016.

[13] N. M. Torres and T. A. Talavera, H. E, Andrew, A. S. Contreras and N, Pacheo, "Ultrasound Assisted Extraction for The Recovery of Phenolic Compounds for Vegetable Sources" Agronomy, Vol.7, No. 47, PP 1-19, 2017.

[14] D. W. Green, "Perrys Chemical Engineering Handbook" 9th ed, Mc Graw-Hill, 2008.

[15] D. Halliday, R. Resnick and K. S. Krane, Physics" 4th ed, Vol.1, John Wiley and Sons, New York, 1992.