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Effect of seawater flow velocity in South Malang on the corrosion rate of low carbon steel with a corrosion coupon rack

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Abstract

Corrosion is a phenomenon of damage to metal that can be influenced by several factors, including environmental factors, namely pH, humidity, temperature, and impurity factors. Corrosion that occurs due to the flow of a fluid is known as erosion-corrosion. One type of metal that is susceptible to corrosion is carbon steel which is very commonly used in the industrial world. An application of carbon steel is in piping systems that transport fluids; thus, fluid flow velocity affects the corrosion resistance of carbon steel. This research aimed to determine the effect of seawater flow on the corrosion rate of low-carbon steel (ST 37) with variations in seawater velocity. This research was a type of laboratory-scale experimental research using coupon rack corrosion test equipment. The variations in seawater velocity used were 0 L/min, 15 L/min, 20 L/min, and 25 L/min. Observations of each experiment were carried out every 6 and 12 hours. The corrosion rate was analyzed using the weight loss method, by calculating the initial and final weight of the specimen before and after the experiment. The results showed that increasing seawater flow velocity also increases the corrosion rate on steel specimens, with the lowest corrosion rate at 10.262 mpy on specimens with a variation of 0 L/min, while the highest corrosion rate was 48.743 mpy on specimens with a variation of 25 L/min. It can be concluded that the velocity of the fluid flow and the type of particles contained in the flow affected the rate of erosion-corrosion.

Keywords:
Corrosion rate, seawater, flow velocity, low carbon steel, corrosion coupon rack.

1 Introduction

The development of science and technology is increasing rapidly, supported by modern and sophisticated equipment, many of which are made of metal. The use of metal has disadvantages, one of which is the problem of corrosion [1]. Corrosion is a natural phenomenon of metals that occurs due to electrochemical reactions between metals and their environment. The environment in question is humidity, acidity, and pH, of course, coastal and highland environments will have different corrosion rate values [2]. Metal in the coastal environment will be exposed to corrosion more quickly because the salt solution is more conductive, causing corrosion more quickly[3].

Corrosion can reduce the quality of the metal itself, causing buildings, vehicle frames, the shipping industry and, others to quickly become damaged[4]. One type of metal that is widely used and susceptible to corrosion is low-carbon steel [5]. Low-carbon steel is often applied in piping systems [4]. Piping systems are often found on ships which are often in an acidic environment [6]. The acidic environment in the marine environment is caused by the sea absorbing more carbon dioxide from the atmosphere [7], so this can affect the corrosion rate of metals. An environment that experiences an increase in pH can reduce the rate of corrosion in low carbon steel [8].

Corrosion that occurs due to the flow of a fluid causes erosion corrosion type. The velocity of fluid flow and the type of particles contained in the flow affects the rate of erosion-corrosion [9]. The higher the flow velocity and the more abrasive the particles contained in the flow, the faster the rate of erosion-corrosion [10].

Therefore, corrosion prevention methods are very important to minimize the occurrence of corrosion. Apart from that, testing for corrosion of metal is also needed, thus, efficient prevention methods can be determined. One type of corrosion testing on metal can be done using a corrosion coupon rack [11]. The working principle of this tool is that the metal test object is placed on a corrosion coupon rack, after which the test object will be flowed with water at a certain velocity and pH level, after that, it will be possible to observe over time how quickly the corrosion occurs. A corrosion coupon rack can be installed on the pipe system found on the ship, which can be used as a control. In this study, we observed the flow velocity of South Malang seawater on the corrosion rate and pH value of seawater [12].

2 Research Methods

The method used in this research is laboratory-based experimental research [13], where the tools used in this research are also laboratory-scale tools designed and made by students for corrosion testing. The tool used in corrosion testing was the corrosion coupon rack which was supplied with water.

Fig. 1 shows the design and final results of the tool resulting from the corrosion coupon rack design. This tool consists of several series of pipes equipped with several supporting components.

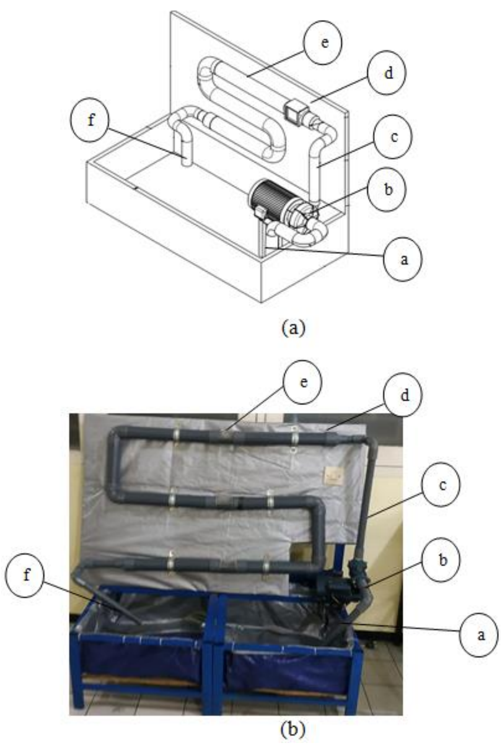

Fig. 1. Corrosion coupon rack (a) design, (b) final product.

Component (a) is an input pipe, component (b) is a pump, which is used to drain water, component (c) is a fluid/water distribution pipe, component (d) is a flow meter which is used to regulate the velocity of fluid/water flowing in the pipe, component (e) is a clamp, functions to place the specimen, where the clamp is placed on a transparent pipe so that it is easy to monitor during observation, and component (f) is the output pipe.

The settings for the corrosion coupon rack before being used as a corrosion test tool are as follows:

1. Checking that all components are installed properly,
2. Placing the specimen on the clamp located on the top pipe,
3. Making settings on the flow meter,
4. Turning on the pump,
5. Observing on the specimen every 6 hours.

The specimen tested in this research was a low-carbon steel plate (ST 37), cut with dimensions of 50 mm × 30 mm × 3 mm (Fig. 2). The dimensions of the specimen are cut according to the size of the pipe, namely the minimum dimensions of the specimen that can be submerged by the fluid in the pipe [8]. The specimen is tested by placing it on the top pipe with a clamp so that in the process the specimen is exposed to water which causes the specimen to corrode. The variation used in this research was the water velocity which was regulated via a flowmeter, where the variations in water velocity were 0 L/min, 15 L/min, 20 L/min, and 25 L/min. Specimens were observed every 6 hours for 12 hours.

Fig. 2. Specimen.

After the corrosion test on the specimen is carried out, the corrosion rate test is carried out based on the ASTM G1-03 standard, namely using the weight loss methods [14].

3 Results and Discussion

In the corrosion test, experiment on a strip plate was placed in a pipe flowing with seawater using 4 variations of flow velocity for 12 hours.The test results are shown in Table 1.

Table 1. Results of corrosion test on strip plates

Strip plate dimensions (cm)	Initial weight (g)	Final weight (g)	Weight losses (g)	Initial pH	Final pH	Water flow velocity (L/min)
5.0×3.0×0.3	31.635	31.631	0.004	6.0	7.6	0
5.1×3.0×0.3	33.784	33.769	0.015	6.0	7.8	15
5.1×3.0×0.3	34.350	34.334	0.016	6.0	7.9	20
5.1×3.0×0.3	35.200	35.181	0.019	6.0	7.9	25

Based on the results in Table 1, the corrosion rate can be calculated using the Eq. 1[15].

$$CR = \frac{k \times w}{A \times t \times \rho} \quad (1)$$

Where:

CR = Corrosion rate (mpy)

k = Constant of CR (3.45×10^6)

w = Weight losses (g)

A = Cross-sectional area (cm^2)

Based on ASTM G3-01, the constants in the corrosion rate calculation can vary according to the units used [14]. In this research, the corrosion rate was expressed in units of miles per year (mpy), so a constant value used was 3.45×106. The results of the corrosion rate are shown in Table 2.

Table 2. Corrosion rate value on low carbon steel strip plate

Seawater flow velocity(L/Min)	Weight losses (g)	Cross-sectional area (cm^2)	Density (g/cm^3)	Constant	Exposure time (hours)	Corrosion rate (*mpy*)
0	0.004	15.0	7.5	3.45×10^6	12	10.262
15	0.015	15.3	7.5	3.45×10^6	12	38.481
20	0.016	15.3	7.5	3.45×10^6	12	41.047
25	0.019	15.3	7.5	3.45×10^6	12	48.473

Fig. 3 shows the relationship between the flow velocity of South Malang seawater and the corrosion rate value on low-carbon steel strip plates which shows that the higher the flow velocity, the higher the corrosion rate. The specimen without a flow velocity of 0 L/min for 12 hours resulted in a corrosion rate of 10.262 mpy, while with the highest flow velocity of 25 L/min for 12 hours, the specimen experienced a corrosion rate of 48.743 mpy,which was an increase in the corrosion rate of 375%. This is the same as research on low carbon steel using Gresik seawater as a medium with a flow velocity of 1.28 knots for 96 hours [10]. The specimen experienced a corrosion rate of 0.9862 mmpy. At a flow velocity of 2.31 knots for 96 hours, the specimen experienced a corrosion rate of 2.7472 mmpy which was an increase in the corrosion rate of 179%. This was also supported by the research without a flow velocity of 0 m/s for 5 days at pH 5 where the specimen experienced a corrosion rate of 0.1208 mmpy, while a flow velocity of 1.328 m/s for 5 days at pH 5 resulted in the specimen experienced a corrosion rate of 0.6716 mmpy. There was an increase in the corrosion rate of 450% so that the flow velocity was directly proportional to the corrosion rate[16], [17]. This happens because the higher the velocity, the more seawater will pass through the plate and cause the plate to lose more weight, thus affecting the corrosion rate value [18]. This is the same as research on corrosion that occurs on ship hulls due to the velocity of seawater movement. The faster the seawater moves, the faster the corrosion rate [4], [19].

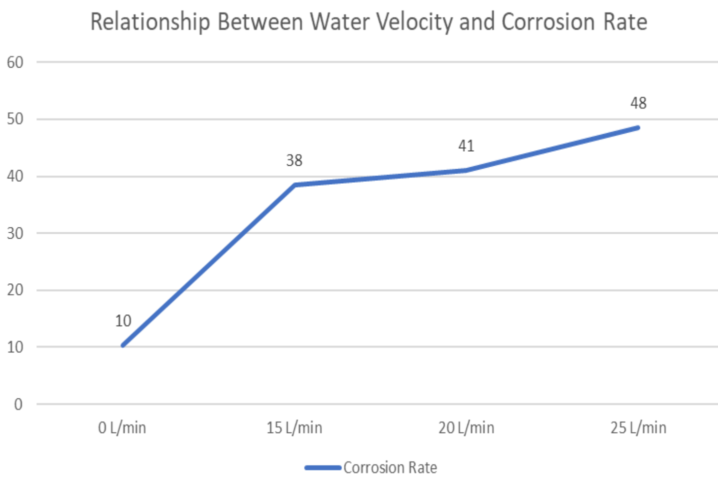

Fig. 3. Seawater flow velocity on corrosion rate.

Fig. 4 shows the result of specimens at several variations which were (a) flow velocity of 0 L/min, (b) flow velocity of 15 L/min, (c) flow velocity of 20 L/min, (d) flow velocity of 25 L/min. All of them were categorized as uniform corrosion.

Fig. 5 shows the relationship between flow velocity and the pH value of seawater. It can be seen in Fig. 1 that the corrosion rate value is directly proportional to the flow velocity of seawater, but at seawater flow velocities of 20 L/min, and 25 L/min it shows the same value, namely pH. 7.9. The increase in seawater pH can occur due to several factors, one of which is the carbonate concentration that occurs when strip plates are eroded due to corrosion which is influenced by flow velocity [12]. The higher the flow velocity causes the higher the corrosion rate or the higher the weight lost due to corrosion. A higher carbonate concentration was a factor in increasing the pH value. At a flow velocity of 25 L/min, the pH is stagnant. The pH value of 4 -10 does not affect the corrosion rate, so that the corrosion rate was only influenced by the seawater flow velocity[8], [20].

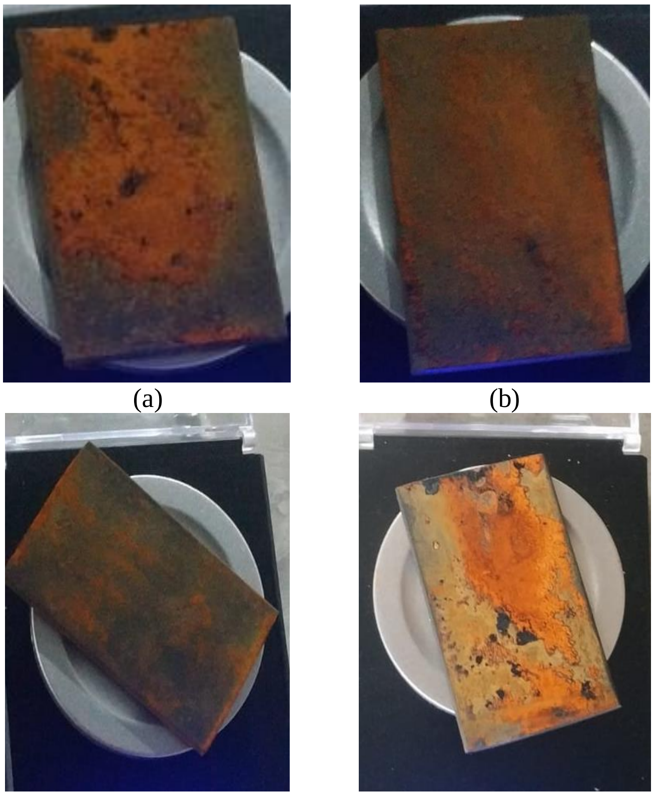

Fig. 4. Specimens at variation of (a) flow velocity of 0 L/min, (b) flow velocity of 15 L/min, (c) flow velocity of 20 L/min, (d) flow velocity of 25 L/min.

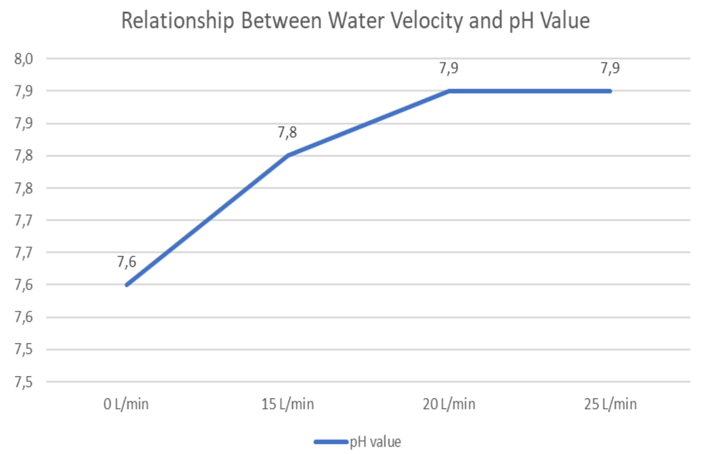

Fig. 5. The relationship between flow velocity and seawater pH value.

4 Conclusion

Based on the research results, it can be concluded that the corrosion rate value obtained in the experiment is directly proportional to the velocity of seawater flow. At a flow velocity of 0 L/min, the corrosion rate value was 10.262 mpy. At the flow velocity of 15 L/min, the corrosion rate value was 38.481 mpy. At the flow velocity of 20 L/min, the corrosion rate value was 41.047 mpy, and at the flow velocity of 25 L/min resulted in the corrosion rate value of 48.743 mpy. At the flow velocity from 0 to 25 L/min, the corrosion rate was increased by 375%. The pH value was directly proportional to the velocity of seawater flow. At athe velocity of 0 L/min, the pH value was 7.6. With the flow velocity of 15 L/min, a pH value was 7.8. At the flow velocity of 20 L/min, a pH value was 7.9 and the flow velocity of 25 L/min showed that the pH value was 7.9. At this point, stagnation occured. . The results of this research show that corrosion coupon racks can facilitate control in piping systems.

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