International Journal of Marine Engineering and Applications
Volume 1, Number 1, September 2024
e-ISSN: 3063-640X

Date of Received: June 27, 2024 | **Date of Accepted:** July 4, 2024 | **Date of Published:** September 1, 2024
DOI: doi.org/10.30649/ijmea.v1i1.370

THE EFFECT OF FLUID FLOW RATE ON THE CORROSION RATE OF THE PIPE OF SEAWATER SYSTEM

Kriyo Sambodho[1*] Kurnia Kusherminto Priyo Pratomo[2*]

[1] Ocean Engineering 1, Sepuluh Nopember Institute of Technology, Surabaya, Indonesia
[2] Nissandi Kompresindo, Cilegon, Indonesia
*Corresponding Author: kriyosambodho@gmail.com

ABSTRACT

Corrosion is a process of decreasing the quality of a material because it reacts with the environment. The corrosion process takes place spontaneously and is a natural event that cannot be avoided. This research was carried out to determine the relationship between the fluid flow rate of seawater flowing in the channels of API 5L grade B standard galvanized pipe and seamless pipe specimens on the corrosion rate using flow modeling for 4 months. The research variations used were variations in flow rate, namely 50%, 75%, and 100%. Corroded pipe specimens were cleaned, weighed, and photomicrography. From this research, it was found that the higher the flow rate, the higher the corrosion rate that occurs, and the corrosion that occurs is abrasion corrosion and pitting corrosion.

Keywords: Abrasion corrosion, corrosion rate, erosion corrosion, galvanized and seamless pipe

Introduction

Corrosion is an event that reduces the quality of metal materials due to interaction with the environment [1]. The operation of a large ship is always equipped with a cooling system and a ship balancing system with fluid using seawater, so a piping system is needed to circulate the cooling fluid [2]. The flow rate of a corrosive fluid can initially increase the corrosion rate by bringing a lot of oxygen to the surface of the material. At high speeds, only a few oxygen ions can reach the surface of the material, resulting in a slowdown in the corrosion rate. If this happens, the corrosion rate will decrease after the initial increase. On the other hand, high flow rates can also increase the rate of corrosion by damaging the protective layer or causing mechanical damage [3].

Since there is no discussion regarding the relationship between the rate of seawater fluid flowing in steel pipes and the rate of corrosion in steel pipes transmitting seawater, for this reason, the author examines this relationship.

Corrosion comes from the Latin word "Corrodere," which means metal destruction or rust due to the environment [4]. Corrosion is a process of degradation/deterioration/destruction of materials caused by chemical, physical, and biological environmental influences [5]. The corrosion mechanism cannot be separated from electrochemical reactions, which involve the transfer of electrons as a result of reduction-oxidation (redox) reactions. The main elements of corrosion are anode, cathode, electrolyte, and conducting medium [6].

Factors that influence corrosion:

1. Material factors, including material purity, material structure, crystal form, material trace elements, and material mixing techniques.
2. Environmental factors, including the level of air pollution, temperature, humidity, and the presence of corrosive substances.

3. Electrical factors that influence metal elements in chemical processes that will produce corrosion.

Erosive corrosion or abrasion is a combination of corrosive fluids and high flow speeds. Erosive corrosion occurs because erosion and corrosion support each other [7]. Erosive corrosion can also be caused by impingement corrosion as a result of very fast fluid speeds and eroding the protective layer on the metal. Damage to pipes in systems that use seawater caused by corrosion can cause various bigger problems, both in construction, such as ship hulls or other marine construction, and in systems on ships, including engines that use seawater cooling, which is very dependent on pipe resistance to corrosion [8].

Methodology

This study used flow rate variations of 0%, 50%, 75%, and 100% for 4 months. Each treatment is marked with the type of pipe, valve opening size, and test duration. For example: PG.075.04, which means PG for galvanized pipe and PN for seamless pipe, 075 is the size of the valve opening, and 04 is the length of the month of testing.

a. Specimen

The specimens used are galvanized pipe and seamless pipe standard API 5L grade B, NPS ¾ inch, SCH 40.

b. Test equipment

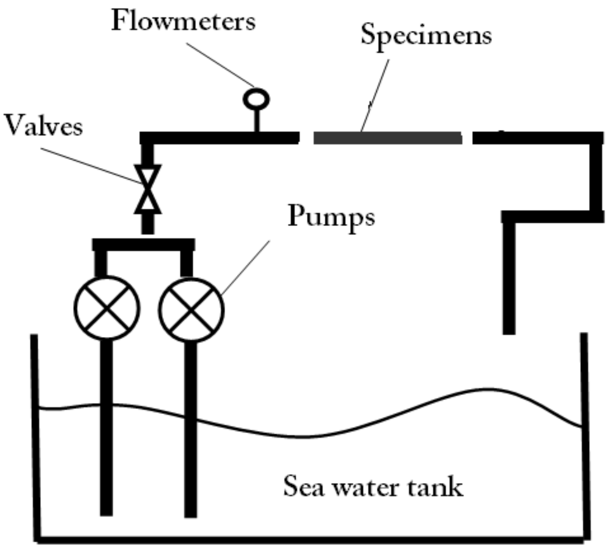


Figure 1. The side view of the scheme of corrosion test equipment

c. Fluid Flow Calculations

Flow rate:

$$V = \frac{Q}{A}$$

where:

V: flow rate (m^2/sec)
Q: flow rate (m^3/sec)
A: surface area (m^2)

Reynolds number:

$$\mathrm{Re} = \frac{VxD}{\nu}$$

where:

V: flow speed (m^2/sec)
D: pipe diameter (mm)
v: viscosity of water
- Re < 2300, laminar flow
- 2300 < Re < 4000, transition flow
- Re > 4000, turbulent flow

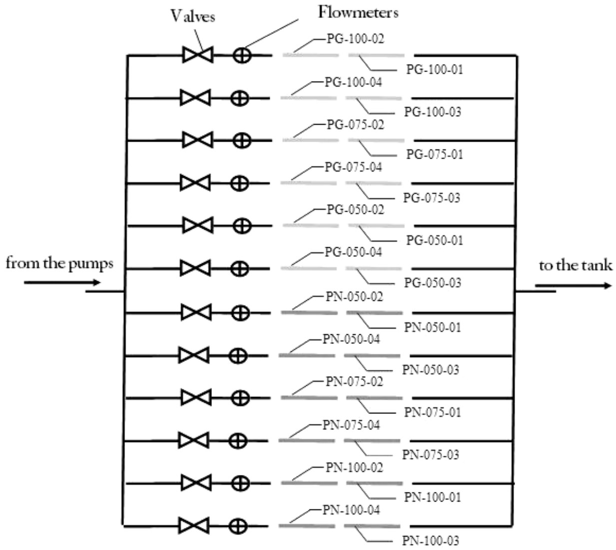


Figure 2. The top view of the scheme of corrosion test equipment

d. Corrosion Rate Calculation

The corrosion rate in this study is defined as the increase in the amount (weight) of corrosion that occurs as a function of time. Measurement of the weight of corrosion that occurs is carried out by cleaning the corroded specimen until it is clean, then weighing it. The weighing results are used to reduce the initial weight of the specimen before the experiment.

Corrosion weight = initial weight – final weight

$$\% \text{ corrosion } = \frac{\text{corrosion weight}}{\text{intitial weight}} \times 100\% \quad [1]$$

e. Metallography

Metallographic observations are carried out to determine the microstructure of the test specimen; in this case, micrographic observations are carried out.

f. Micrographic Photo Observation Process

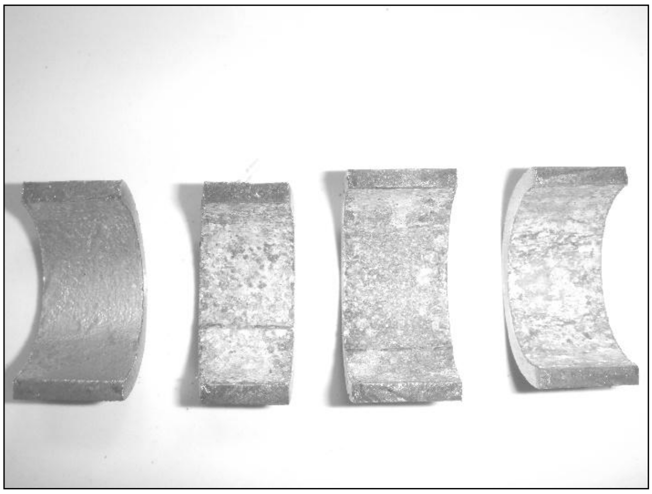


Figure 3. Specimen section for micro photos

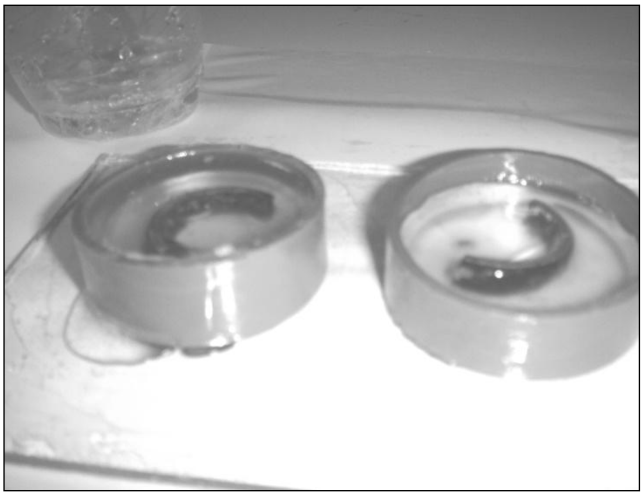


Figure 4. Fiber printing process

Figure 5. Material polishing

Figure 6. Polishing results

Figure 7. Micrography process

Result and Discussion

a. Corrosion Rate

Using the method described previously, the necessary data and calculations are carried out to obtain the corrosion rate, both on galvanized and non-galvanized pipes, with variations in seawater fluid flow rates, which are regulated by valve openings. The research results are presented and explained in the following tables, figures, and descriptions

Table 1. Data on dissolved content in the seawater fluid used Data on dissolved content in the seawater fluid used

No.	Type of analysis	Content
1.	Salinity	29,45 ‰
2.	Chlorinity	16,3 ‰
3.	pH	7,6
4.	Dissolved O_2	1,76 mlO_2/lt

Table 2. Data from the testing results of pipe material composition

No.	Type of Pipes	Content (%)				
		Fe	Mn	Ni	Si	Zn
1.	Galvanized	93.85	0.19	0.01	0.03	4.96
2.	Non-Galvanized	99.80	0.16	-	0.01	-

Table 3. Data on the percentage of galvanized pipe corrosion

		Flow rate (valve opening)		
		50%	75%	100%
Corrosion Rate after:	1 month	0.02%	0.03%	0.05%
	2 months	0.07%	0.09%	0.15%
	3 months	0.14%	0.22%	0.24%
	4 months	0.23%	0.57%	0.85%

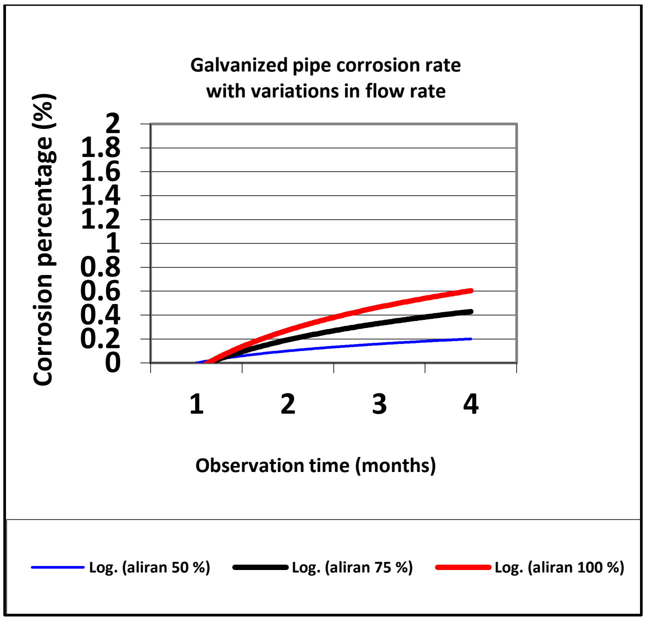


Figure 8. Comparison of corrosion rate with variations in fluid flow rate in the galvanized pipes

Figure 8 shows a comparison between the corrosion rates that occur between each flow rate, where the corrosion rate of galvanized pipe at a flow rate of 100% occupies the highest position, followed by a flow rate of 75% and a flow rate of 50%, or in other words the more The higher the flow rate through the galvanized pipe, the greater the rate of corrosion that occurs in the pipe.

Table 3. Data on the percentage of non-galvanized pipe corrosion

		Flow rate (valve opening)		
		50%	75%	100%
Corrosion Rate after:	1 month	0.47%	0.49%	0.52%
	2 months	1.39%	1.36%	1.50%
	3 months	2.63%	2.84%	3.18%
	4 months	4.52%	5.02%	5.11%

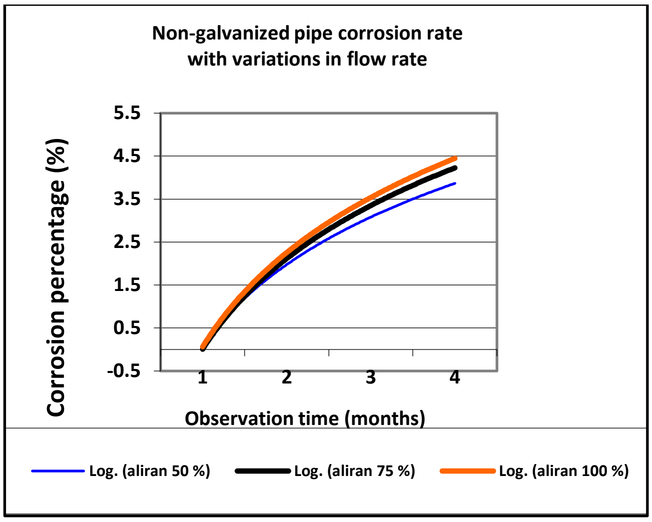


Figure 9. Comparison of corrosion rate with variations in fluid flow rate in the non-galvanized pipes

Figure 9 shows a comparison between the corrosion rates that occur between each flow rate, where the corrosion rate of non-galvanized pipe at a flow rate of 100% occupies the highest position, followed by a flow rate of 75% and a flow rate of 50%, or in other words the more The higher the flow rate through the galvanized pipe, the greater the rate of corrosion that occurs in the pipe.

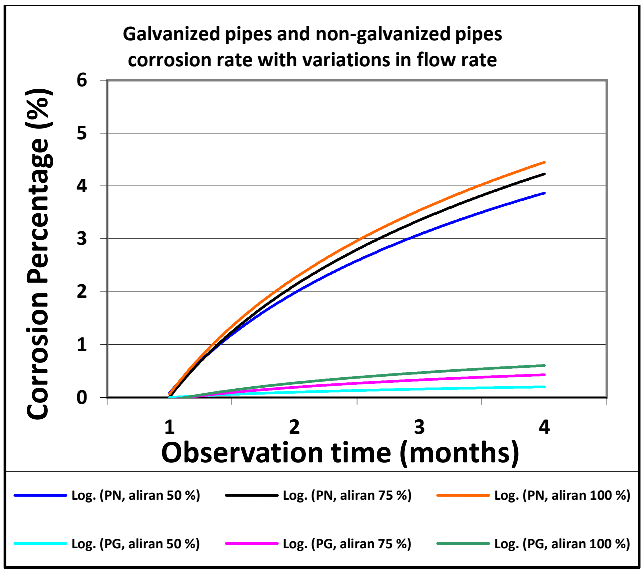


Figure 10. Comparison of corrosion rate with variations in fluid flow rate for galvanized and non-galvanized pipes

From 10, it can be seen that, for both galvanized and non-galvanized pipes, the fluid flow rate influences the pipe corrosion rate. The higher the fluid flow rate in the pipe, the higher the rate of corrosion in the pipe. The corrosion rate due to fluid flow in non-galvanized pipes is higher than the corrosion rate in galvanized pipes for the same fluid flow rate.

b. Microstructure Observations

Observation of the microstructure of pipes, both galvanized pipes and non-galvanized pipes, is carried out by carrying out micrographic observations, which is one of the metallographic observation methods.

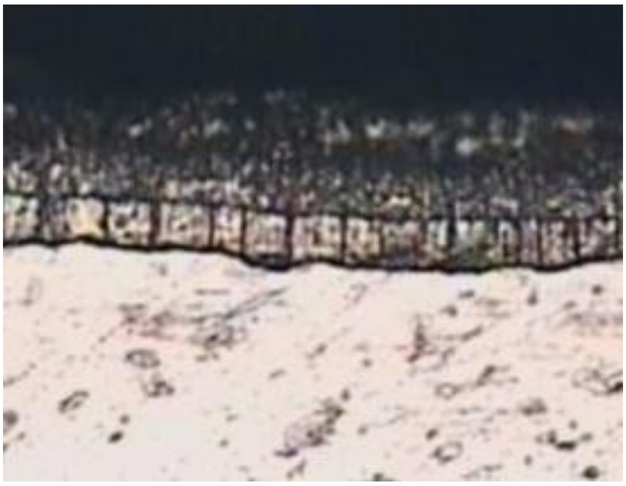
Observations were made on each variation of the specimen after being subjected to corrosion testing. The aim is to find out whether corrosion also occurs on the inside of the pipe or only in the part exposed to the fluid flow of seawater. This will help in determining the type of corrosion that occurred on the specimen. The final goal is to determine the protection or protection against corrosion that will occur in pipes in systems that use seawater.

(a)

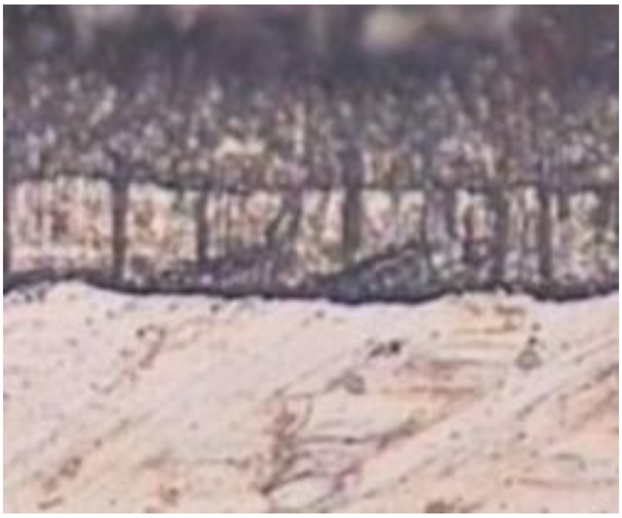
(b)

Figure 11. Photo of the microstructure of the galvanized pipe specimen before the corrosion

test, (a) 100x magnification, (b) 500x magnification



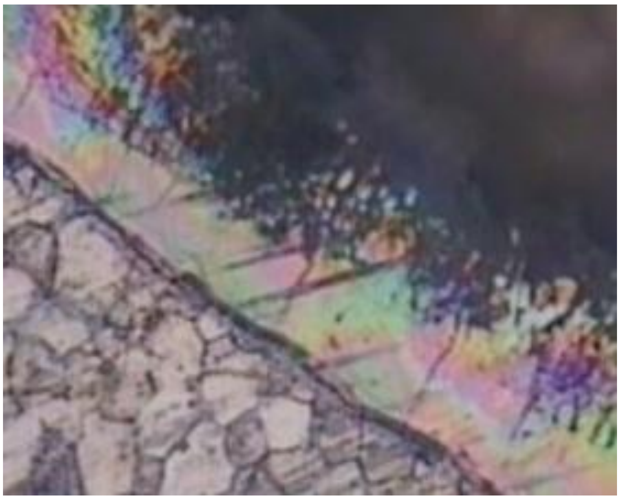
(a)



(b)

Figure 12. Photo of the microstructure of the galvanized pipe specimen, with a fluid flow rate of 0%, (a) 50x magnification, (b) 200x magnification

(a)



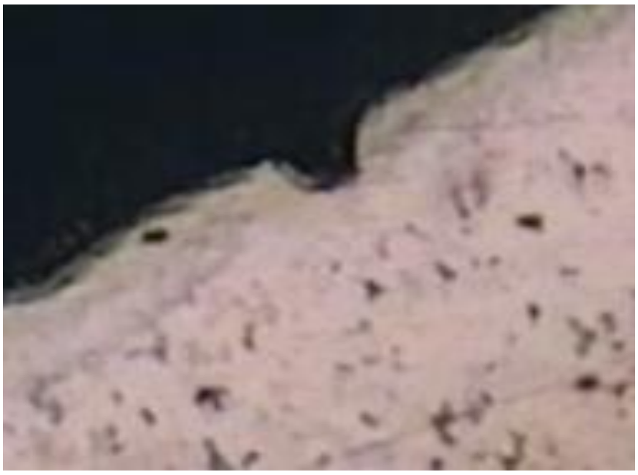
(b)

Figure 13. Photo of the microstructure of the galvanized pipe specimen, with a fluid flow rate of 50%, (a) 50x magnification, (b) 200x magnification

(a)

(b)

Figure 14. Photo of the microstructure of the galvanized pipe specimen, with a fluid flow rate of 75%, (a) 50x magnification, (b) 200x magnification



(a)

(b)

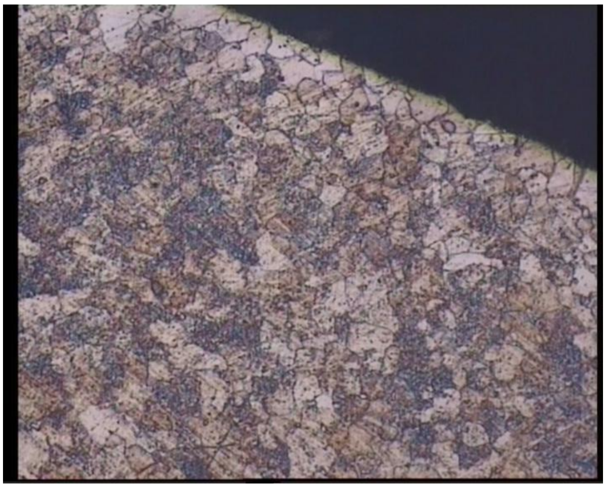
Figure 15. Photo of the microstructure of the galvanized pipe specimen, with a fluid flow rate of 100%, (a) 50x magnification, (b) 200x magnification

(a)

(b)

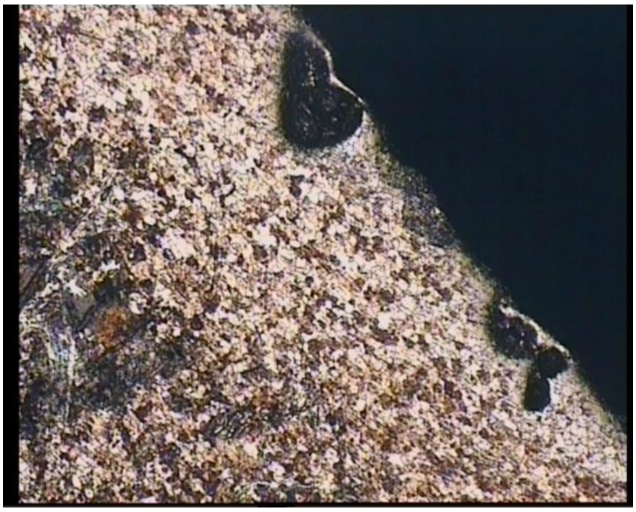
Figure 16. Photo of the microstructure of the non-galvanized pipe specimen before the corrosion test, (a) 100x magnification, (b) 500x magnification

(a)

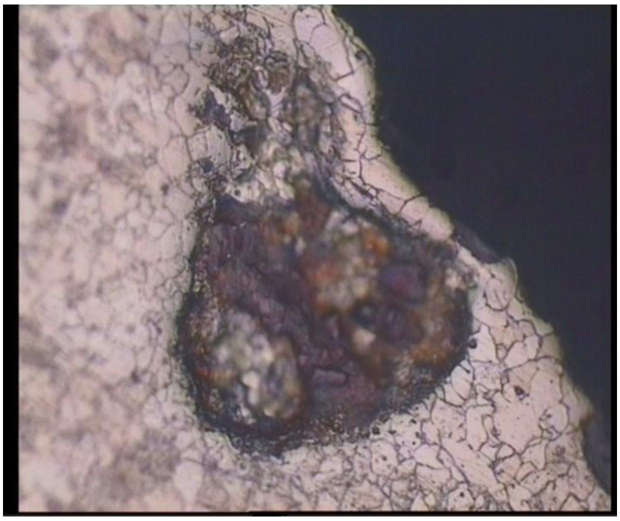


(b)

Figure 17. Photo of the microstructure of the non-galvanized pipe specimen, with a fluid flow rate of 0%, (a) 50x magnification, (b) 200x magnification

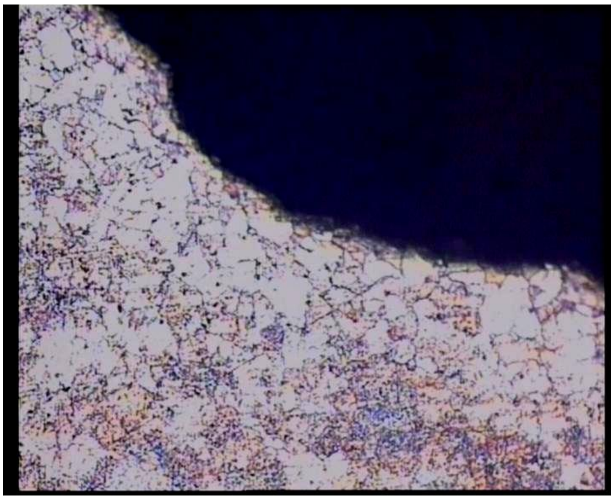


(a)



(b)

Figure 18. Photo of the microstructure of the non-galvanized pipe specimen, with a fluid flow rate of 50%, (a) 50x magnification, (b) 200x magnification

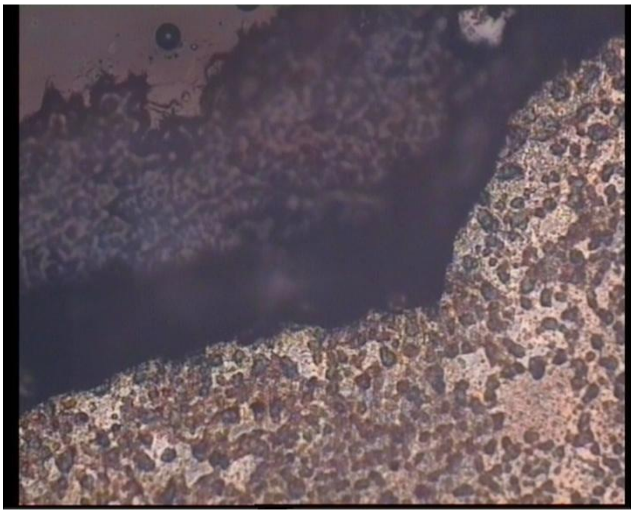


(a)

(b)

Figure 19. Photo of the microstructure of the non-galvanized pipe specimen, with a fluid flow rate of 75%, (a) 50x magnification, (b) 200x magnification

(a)



(b)

Figure 20. Photo of the microstructure of the non-galvanized pipe specimen, with a fluid flow rate of

100%, (a) 50x magnification, (b) 200x magnification

From metallographic observations, there is no visible intergranular corrosion or corrosion at the grain boundaries of the microstructure. Meanwhile, on visual observation, some specimens showed pitting and abrasion marks on the pipe surface, both galvanized and non-galvanized pipes. From this observation, we can conclude that the corrosion that occurs is abrasion and pitting corrosion.

Conclusion

From the tests and observations that have been carried out, it can be concluded that:

1. The relationship between seawater fluid flow rate and corrosion rate in this experiment is that the higher the flow rate, the higher the corrosion rate that occurs.
2. The corrosion that occurs is abrasion corrosion and pitting corrosion.

References

[1] Dwisetiono, D. Laju Korosi Pelat Baja Lunak "Grade A" Di Perairan Laut Surabaya Dengan berbagai Tingkat Sandblasting. Jurnal Sains dan Teknologi vol. 5 no.2. [2007].

[2] Fachroini T.A., Dwisetiono D. Penerapan MGPS (Marine Growth Prevention System) Pada Lambung Kapal. Hexagon Vol. 3 No. 1. 2022 Jan 28. Pp.53-5. DOI: https://doi.org/10.36761/hexagon.v3i1.1523

[3] Suhartanti, D. Laju Korosi Baja di Kawasan Udara PLTP Kamojang Jawa Barat. Seminar Fakultas Matematika dan Ilmu Pengetahuan Alam, Universitas Indonesia, Depok [2005].

[4] Agustini D, Fitriah L, Fahrurrozi F. Pemodelan Matematika pada Sistem Korosi Logam. Lombok Journal Of Science Vol. 5 No. 1 [2023] Apr 29. pp.33-41.

[5] Moelyo M. Tingkat Korosifitas Air Terhadap Infrastruktur Sumber Daya Air Menurut DIN 4030 dan Langelier Saturation Index. Jurnal Sumber Daya Air Vol. 8 No. 2 [2012] pp.187-200.

[6] Suharlinah, L., Sonjaya, H.G. Kerusakan Akibat Korosi Pada Komponen Baja Jembatan. Batam: Dinas Pekerjaan Umum [2008].

[7] Dwisetiono, D., Sambodho K., Winarno, A., Prayogi, U., Felayati, F.M., Karyatanti, I.D.P., Kristiono. T.A., Korosi Di Lingkungan Laut. Hang Tuah University Press. Surabaya, Indonesia (2024).

[8] Dwisetiono, D., Asmara, R.G. Analisa Kegagalan Sistem Bahan Bakar Kapal Dengan Menggunakan Metode Preliminary Hazard Analysis (PHA) dan Fault Tree Analysis (FTA). Hexagon Vol. 3 No. 1 [2022] Jan 28. pp. 34-9. DOI: https://doi.org/10.36761/hexagon.v3i1.1348