The study of corrosion behaviour api 5l steel in sea water using immersion test method

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Abstract. API 5L steel, a low carbon steel with a high alloy content, is often used as an underwater construction material or oil and gas pipeline. Banten has a wide sea area and has a long coastline where part of the coastline is used for petrochemical industries. There are three coast areas of Banten, namely Bayah Rangkasbitung, Anyer and Merak, that are used for petrochemical industries. Most of those industries use API 5L steel for underwater construction materials and pipes to channel seawater, chemical compounds, gas and oil. Whereas, seawater will greatly affect the lifetime of API 5L construction steel because it can cause corrosion. The purpose of this study is to analyze the corrosion characteristics of API 5L steel affected by the environment of seawater media and the temperature of seawater in accordance with its natural conditions. The samples of API 5L steel were immersed in seawater media with variation of immersion time of 5, 10, 15 Days and variation of immersion temperature of 20°C, 40°C, and 60°C. In this study, a series of tests were carried out, namely immersion test, weight loss test, and SEM test (Scanning Electron Microscopy). The highest corrosion rate on API 5L steel is 0.39 mmpy which belongs to Merak’s seawater media in the immersion time of 15 Days and the temperature of 60°C, while the lowest corrosion rate on the API 5L steel is 0.013 mmpy which belongs to Bayah’s seawater media with a time of immersion of 10 Days and a temperature of 20°C.

1. Introduction
Corrosion is a form of metal damage caused by metal contact with the surrounding environment [1]. Corrosion, in other definition, is a damage or degradation of metal due to redox reactions between a metal and various substances in its environment that produce compounds that are not desired [2]. Almost all industrial sectors have problems with corrosion, for example; the metal industry sector, the transportation industry, the mining and energy industry, public works, and the agricultural industry [3]. Problems that arise can be in the form of damage, the life of goods that do not meet expectations to the inadequate safety factor, and a damage to equipment or a failure in operations that cause no small losses [1-3].

Banten has a large sea area with a long coastline where part of the coastline is used for petrochemical industries. There are 3 areas of Banten that are used for petrochemical industries, namely; Bayah (Indian Ocean), Anyer (Indian Ocean), and Merak (Sunda Strait). Most of these industries use API 5L steel as underwater construction material and pipes to channel seawater, chemical compounds, gas and oil. Sea water will greatly affect the service life of API 5L steel because it can cause corrosion [4-5].
Many factors can cause material corrosion, one of them is the influence of the concentration of corrosion media [1,3]. The concentration of solute in a solution, which causes more and more free ions in the solution. In seawater media, chloride ions become a source of problems to corroded materials [4-6]. The more concentration of chloride ions the faster corrosion occurs to the materials. In addition, the existence of bacterial chloride ions in seawater can also degrade heavy metals due to bacterial corrosion or bio-corrosion. Besides, the different temperatures between the surface of the middle and in the sea are catalysts that can accelerate the corrosion of AISI API 5L steel material [7-9].

Nowadays, many studies have been conducted in relation with the corrosion rate of API 5L steel affected by chemical compounds, the media of gas corrosion, oil and sea water, for example; the corrosion which is affected by chemical compounds such as; sulfuric acid and sodium chloride [10-12], both of these compounds are strong electrolytes. The study conducted by showed that the constant interaction between the material and its environment can cause a decrease in the value of the material both slowly and significantly [4-5].

According to the reason above, it is interested to examine the corrosion rate of API 5L steel which is widely used in construction and oil and gas pipelines using seawater media taken from various industrial areas in Banten. In this research, temperature and immersion time in the sea water will be added to calculate the corrosion rate in API 5L steel, bearing in mind that the implementation of this research is in offshore building construction. It is hoped that this research can provide information about the effect of seawater in various areas on the corrosion rate of the material most widely used for the petrochemical industry.

2. Method
This research was conducted in 2 stages. The first stage involved the process of preparation of API 5L Steel samples. The process included:
1. Sample Cutting
   In this study, API 5L steel was cut with dimensions of 30 mm x 20 mm x 2 mm
2. Sanding Samples
   In this process, the samples were sanded to lose the metal oxides on the surface of the sample. The sanding process was carried out by using sandpaper with grid roughness values of 180, 300 and 800.
3. Sample Cleanup
   The samples were dipped in liquid acetone to clean the impurities that stuck on the steel, then the samples were washed using liquid distilled water.

The second stage involved the weight loss test method which aimed to determine the corrosion rate (mmpy) of the samples by weighing the initial weight and final weight after the test [13]. The steps of weight loss testing were as follows:
1. Measuring the dimensions of the samples.
2. Weighing the samples to find out the initial weight of the samples.
3. Immersing the samples into corrosion media in the form of sea water with the provisions of immersion time 5, 10, and 15 days at a temperature of 20ºC, 40ºC and 60ºC.
4. The samples, that had been immersed, were then removed from the liquid. Afterwards, the samples were dried out and weighed to get their final weight which aimed to determine the corrosion rate.

3. Results and Discussion
3.1. The Characteristic of Corrosion (chemical and biological content) of each water area media.
The results of this corrosion rate test can be analyzed in the seawater as the corrosion media which is divided into 3 different types of seawater, namely Bayah Rangkasbitung seawater (Indian Ocean), Anyer seawater (Indian Ocean) and Merak seawater (Sunda Strait), by using the variations of the temperature of each seawater. Based on the results of the calculation of the corrosion rate, the results of the corrosion rate for time variations of 5, 10, 15 days and temperature variations of 20ºC, 40ºC, 60ºC can be seen in the following graphic image:
Figure 1. Relationship Among Corrosion rate and immersion time and temperature variation to API 5L steel corrosion rate (a) Anyer seawater (Indian Ocean), (b) Merak seawater (Sunda Strait), and (c) Bayah seawater (Indian Ocean).

The picture above shows the value of the corrosion rate (mmpy) of each test sample material as well as for each variation of the test. The corrosion rate values in the seawater immersion media has obtained the data that the value of the corrosion rate has a tendency to rise in line with the increase of each temperature and each additional time of immersion.

According to the seawater temperature variation, The highest rate of corrosion, that has a value of 0.392 mmpy, occurs to Merak seawater (Sunda Strait) at the temperature of 60 °C and the lowest rate of corrosion, which is 0.136 mmpy, occurs to Merak seawater (Sunda Strait) at the temperature of 20 °C. This is because the temperature is an important factor in the chemical reaction process and in the corrosion rate of the material. Moreover, the increase in temperature will also increase the rate of corrosion due to the higher temperature will accelerate the diffusion of oxygen through the cathodic layer of oxide formed. If the temperature rise higher, it will cause the particles to move more actively so that collisions between particles also occur frequently and cause the rate chemical reactions are getting faster, the percentage increase in the rate of corrosion that is affected by the temperature reaches 60%. For this reason, it can be concluded that the higher the temperature, the higher the corrosion rate.

Based on the immersion time variation, the highest corrosion rate, which has a value of 0.392 mmpy, occurs to Merak seawater (Sunda Strait) with the immersion time of 15 days and the lowest corrosion rate occurs to Anyer seawater (Indian Ocean) with the immersion time of 5 days (0.136 mmpy). This is due to the increased surface activation level of API 5L steel where activation is the process of forming metal oxide compounds on the metal surface. The rate of corrosion increases because metal oxides react
more actively with the metal surface. In addition, the rate of chemical reaction between the metal surface and seawater will increase slowly so that the corrosion rate on the material also rises, the percentage increase in the corrosion rate which is affected by the immersion time also reaches 60%. For the influence of the immersion time, it can be concluded that the longer the immersion time, the more corrosion rate will increase.

3.2. The Comparison of the Corrosion Rate of Three Areas (Bayah, Anyer, and Merak Seawater)

![Comparison graph of the corrosion rates of the three areas](image)

Figure 2. Comparison graph of the corrosion rates of the three areas (a) temperature (b) immersion time

Based on the figure above, it can be analyzed that Merak Seawater is more corrosive compared to the two regions (Anyer and Bayah). This is because Merak sweater has higher concentration of sea chloride ion than two others. The chloride ion content can accelerate corrosion reactions on metal surfaces. Moreover, Merak seawater contains a lot of bacteria or microbiology which can cause API 5L steel surface to degrade due to microbiological corrosion or bacterial corrosion.

3.3. The Observation of API 5L Steel Surface using SEM (Scanning Electron Microscopy)

Based on observations of microstructure using scanning electron microscopy (SEM) shown in Figure 3, the corrosion forms that occur on the surface of API 5L steel from the three areas are the same, namely uniform corrosion.

![Observation of API 5L Steel Surface using SEM](image)
Figure 3. Scanning Electron Microscopy (SEM) Testing (a). 1000x magnification before immersion, 100x magnification at temperature of 60°C (b) Anyer Seawater, (d) Merak Seawater and (f) Bayah Seawater and 1000x magnification at temperature of 60°C (c) Anyer Seawater (e) Merak Seawater (f) Bayah Seawater.

Figure 3 (c) shows the form or pattern of corrosion that occurs for types of seawater originating from Merak. The figure resembles the shape of sea corals due to the corrosion reaction that occurs between the surface of API 5L steel is dominantly in the form of bacterial corrosion or microbiology corrosion, but for the two other areas (Anyer and bayah) which are indicated by figures 3 (c) and (g), the corrosion occurs because of the interactions between the acidic chloride ion compounds contained in seawater and the metal surface.

4. Conclusion

Based on the results of testing and analysis it can be concluded that the temperature and immersion time affect the rate of corrosion. The higher the temperature, the higher the corrosion rate will occur, and the longer the immersion time, the higher the corrosion rate will have. Based on the comparison of
corrosion rates in each area, seawater originating from Merak (Sunda Strait) is more corrosive compared to seawater originating from Anyer and Bayah (Indian Ocean). The types of corrosion that occur in both processes and the three regions are the same, namely uniform corrosion.

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Reference
[1] Roberge, P. R. 2000 Handbook of Corrosion Engineering (McGraw-Hill, New York) 333-351, 1093.
[2] ASM International, 2003. ASM Metals Handbook Corrosion: Fundamentals Testing and Protection United State of America 13A.
[3] Jones, D. A. 1996 Principles and Prevention of Corrosion Second Edition (Pretice Hall Inc. Unites States of America) 34 – 390.
[4] Shaojun Yuan, et al. 2013 Surface chemistry and corrosion behaviour of 304 stainless steel in simulated seawater containing inorganic sulphide and sulphate-reducing bacteria Corrosion Science 74 353-366
[5] Abd Alrahim Al Shikshak, et al. 2015 Effect of flow velocity of sea water on corrosion rate of low carbon steel Applied Mechanics and Materials 799-800 232-236.
[6] MS Paula, et al. 2015 Carbon steel corrosion induced by sulphate-reducing bacteria in artificial seawater: electrochemical and morphological characterizations Revista Matéria 21 (4) 987-995
[7] S Paul, A Pattanayak, SK Guchhait 2014 Corrosion behavior of carbon steel in synthetically produced oil field seawater International Journal of Metals 1-11.
[8] A Abdullah, N Yahaya, et al. 2014 Microbial corrosion of API 5L X-70 carbon steel by ATCC 7757 and consortium of sulfate-reducing bacteria Journal of Chemistry 1-7.
[9] L.M. Quej-Aké, A. Contreras and J. Aburto 2018 Electrochemical Study on Corrosion Inhibition of X52 Steel by Non-ionic Surfactant in Substitute Ocean Water, Int. J. Electrochem. Sci. 13 7416–7431
[10] Yunan Prawoto, WB wan nik et al. 2009 Effect of pH and Chloride Concentration on The Corrosion of Duplex Stainless Steel The Arabian Journal for Science and Engineering 34 (2C) 116-127.
[11] Iman Saefuloh, Nufus Kanani, et al. 2020 The Corrosion Inhibition of API 5L Steel Using Natrium Acetate and Natrium Nitrite in Natrium Chloride Acid Solution Materials Science Forum 988 3-10.
[12] Iman Saefuloh, Nufus Kanani, et al. 2020 The Study of Corrosion Behavior and Hardness of AISI Stainless Steel 304 in Concentration of Chloride Acid Solution and Temperature Variations Journal of Physics: Conference Series 1477, 052058.
[13] ASTM Internasional. 2004 ASTM G31 – 72: Standard Practice for Laboratory Immersion Corrosion Testing of Metals, Philadelphia 5 .