# Analysis of the corrosion rate of SS 316l metal in a tsunami detection tool in seawater media

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**Abstract.** Indonesia frequently faces tsunami disasters, making the need for early detection tools essential. As a technological innovation, the inabuoy was created. This device uses underwater sensors to provide early warnings for tsunamis. Inabuoy is installed in areas prone to tsunamis and uses a 316L stainless steel frame submerged in seawater. Due to its underwater position, it is subject to corrosion from seawater with a pH of 7 to 8.5. This study aims to determine the corrosion rate of stainless steel 316L, a wmical method with seawater media with variations of 0, 24, 48, 72, and 96 hours of immersion. Analysis of the corrosion rate of 316L stainless steel specimens in seawater media with immersion of 0, 24, 48, 72, and 96 hours by potentiodynamic electrochemical method. It was found that the lowest corrosion rate data occurred on specimens of 0 hours of immersion with an average value of 4.5681 x 10-3 mmpy while the highest corrosion rate occurred in specimens that were immersed for 96 hours, showing an average value of 8.6811x10-3 mmpy, this shows the value of the corrosion rate that occurs increases with the length of immersion time. This research contributes to achieving SDGs 9, 11, 13, and 14.

## 1. INTRODUCTION

Indonesia is a country that often experiences potential tsunamis and earthquakes caused by the movement of tectonic plates. This happens because the territory of Indonesia is located at the confluence of two of the longest active mountain paths in the world. A tool called in buoy was created to help know the early detection of a tsunami. A buoy (Indonesiabuoy) is a tsunami early detection tool that works on the sea surface.

Buoys are floating devices used to detect tsunami waves caused by underwater earthquakes. Buoys will monitor and record changes in sea level in the ocean. Inabuoy will be placed at several points where tsunamis frequently occur. Inabuoy tsunami early detection devices have been installed in the sea in the southern part of the island of Java starting from

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Bali, South Malang, South Cilacap, and the Sunda Strait. This tool uses a battery-powered tsunami detection sensor and has been left in the sea for years.

A buoy frame uses 316L stainless steel; due to the importance of this frame component, it is necessary to study the corrosion resistance of the metal frame in its work function in the marine environment. The frame for reinforcing the mooring line hook is very important because it protects the frame structure of the inabuoy. After all, at this inabuoy, no one has conducted corrosion studies on the frame for reinforcing the hook mooring line [1-12].

## 1.1. Corrosion

Corrosion is the breakdown or degradation of a metal by reaction with a corrosive environment. Corrosion, commonly known as rusting, is a chemical phenomenon in metal materials under various environmental conditions. The study of electrochemical systems has dramatically helped explain this corrosion, namely the chemical reaction between the metal and the substances around it or other particles in the metal matrix.

So, from a chemical point of view, corrosion is the reaction of a metal into ions on a metal surface that is in direct contact with an aqueous and oxygen environment. When viewed from the interactions that occur, corrosion is the process of transferring electrons from the metal to its environment. The metal acts as a cell that gives electrons (anode) and the environment acts as an electron acceptor (cathode) [13-25].

## 1.2. Stainless steel 316l

Typical uses for 316L stainless steel are in dual heat dissipation processes, furnace components, heat exchanger components, jet engine components, pharmaceutical and photographic equipment, valves, valves, valves, valves, tubing, pump components, chemical processing equipment, tanks, evaporators, including fabric, paper, and pulp processing equipment as well as various components exposed to water in the marine environment. [2-4] Stainless steel 316L is an austenitic stainless steel derived from SS metals Cr, Ni, and Mo. This material has a low carbon composition, so it can increase corrosion resistance and molybdenum content.

Stainless steel 316L is a variant of molybdenum alloy austenitic stainless steel with a low-carbon composition used in various industries with the need for metal specifications that are resistant to corrosion [4] Stainless steel 316L is a low-carbon version of type 316 (Table 1]. Low carbon is contained in type 316L material to minimize the deposition of carbide, which can damage the welding results. Type 316L stainless steel can be used in welding processes that require maximum corrosion resistance.

Although similar to type 304, types 316 and 316L have better corrosion resistance, are more potent, and can withstand higher temperatures (Table 2). Both also do not require a hardening process by heating, so they are easy to shape directly [26-33].

**Table 1.** Mechanical properties of 316L stainless steel

| Grade | Tensile Strength (MPa) min | Yield Strength (MPa) min | Elongation(% in 50 mm) min | Hardness | |
|---|---|---|---|---|---|
| | | | | Rockwell B (HRB) | Brinell (HB) max |
| 316L | 485 | 170 | 40 | 95 | 217 |

**Table 2.** Composition of 316L

| Element | Percentage (%) |
|---|---|
| C | 0.03 |
| Si | 1 |
| Mn | 2 |
| P | 0,045 |
| S | 0,030 |
| Ni | 12-15 |
| Cr | 16-18 |
| Mo | 2-3 |

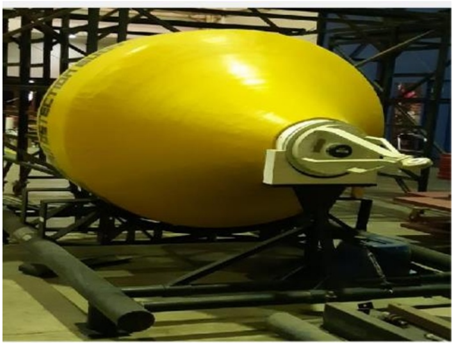


**Fig. 1.** Hook Mooring Line [6].

### 1.3. Indonesia Tsunami Early Warning System

Ina-TEWS (Indonesia Tsunami Early Warning System) is a comprehensive tsunami early warning system in which a new technology, the Decision Support System (DSS), has been implemented. DSS is a system that collects all information from the results of earthquake monitoring systems, tsunami simulations, tsunami monitoring, and deformation of the earth's crust after an earthquake occurs.

This information collection is the supporting factor for broadcasting tsunami early warning news and becomes material for evaluating tsunami early warnings. The DSS will issue several types of news or early warnings from the monitoring system that the operator must take at a predetermined time through the GUI (Graphic User Interface). Through Ina-TEWS, a product called Inabuoy was created. [6] The hook mooring line is a reinforcing frame used in tsunami or inabuoy detection devices. This frame uses sus 316L/316L stainless steel as its primary material.

## 2. Methods

### 2.1 Material immersion stage

After the material is cut, picked, and processed, the material is then immersed in seawater for 24, 48, 72, and 96 hours. The process is:

1. Prepare 12 materials for the soaking process

2. Prepare a medium of seawater, and 4 pots of ointment as a place for soaking
3. Put three specimens in each ointment pot, add seawater, and let it rest for 24, 48, 72, and 96 hours

### 2.2 Testing using electrochemical methods

In testing this electrochemical method using potentiodynamic polarization testing, 316L stainless steel metal specimens without coating will be tested electrochemically to determine the passivation ability and the corrosion rate in stainless steel metal. In the electrochemical process, potentiodynamic polarization utilizes an electric current flowing from a positively charged material, namely platinum, to a charged metal.

## 3. Results and Discussions

### 3.1 Testing the corrosion rate with the electrochemical method

For corrosion rate analysis, the authors used the electrochemical method with the potentiodynamic polarization technique for 316L Stainless Steel specimens without the coating process with variations in seawater immersion for 0, 24, 48, 72, and 96 hours. The potentiodynamic polarization test with the potential range is -1 V to 1 V with a scan rate value of 5 mV/s. This potential range was obtained from research conducted by [1]. Based on the polarization results in Fig. 2, the potential value (E) will be known to the current density log (I). The result of the method is the curve between the potential (E) and the current density log (I).

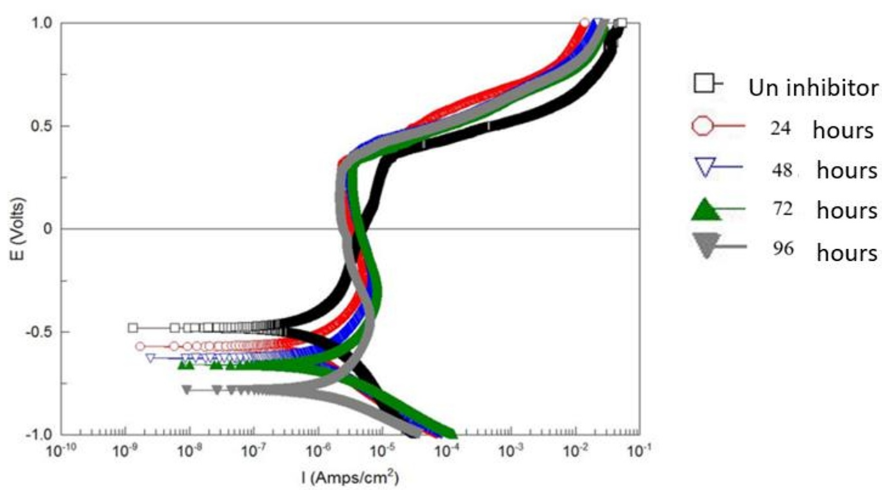



**Fig. 2.** Graph of Potentiodynamic Polarization potential (E) against current (I) 316L stainless steel without coating with variations of immersion in seawater media

Table 1 presents the result of immersion testing using the electrochemical method using Potentiodynamic Polarization testing on 316L stainless steel specimens, showing the corrosion rate of the results for specimens without coating, which were immersed with variations in immersion time of 0, 24, 48, 72, and 96 hours in seawater media.

**Table 1.** Analysis Results of 316L stainless steel Potentiodynamic Tafel with variations of immersion in seawater media

| Sample | Immersion time (hour) | Specimen | Icorr (A/cm$^2$) | Ecorr (V) | Corrosion rate (mmpy) | Average (mmpy) |
|---|---|---|---|---|---|---|
| *Stainless Steel 316L* | 0 | Specimen 1 | 4.5539 x $10^{-6}$ | -0.28409 | 4.8727 x $10^{-3}$ | 4.5681 x $10^{-3}$ |
| | | Specimen 2 | 3.8705 x $10^{-6}$ | -0.43688 | 4.1415 x $10^{-3}$ | |
| | | Specimen 3 | 4.3831 x$10^{-6}$ | -0.53566 | 4.69 x $10^{-3}$ | |
| *Stainless Steel 316L* | 24 | Specimen 1 | 5.3782x$10^{-6}$ | -0.21832 | 5.7547 x $10^{-3}$ | 5.9491 x $10^{-3}$ |
| | | Specimen 2 | 5.5113x$10^{-6}$ | -0.37424 | 5.8972 x $10^{-3}$ | |
| | | Specimen 3 | 5.7901x$10^{-6}$ | -0.38979 | 6.1954 x $10^{-3}$ | |
| *Stainless Steel 316L* | 48 | Specimen 1 | 6.1935x$10^{-6}$ | -0.1318 | 6.627 x $10^{-3}$ | 6.6039 x $10^{-3}$ |
| | | Specimen 2 | 6.1025x$10^{-6}$ | -0.43145 | 6.5298 x $10^{-3}$ | |
| | | Specimen 3 | 6.2196x$10^{-6}$ | -0.38688 | 6.655 x $10^{-3}$ | |
| *Stainless Steel 316L* | 72 | Specimen 1 | 6.9708x$10^{-6}$ | -0.46205 | 7.4588 x $10^{-3}$ | 7.7 x $10^{-3}$ |
| | | Specimen 2 | 7.18x$10^{-6}$ | -0.43415 | 7.6826 x $10^{-3}$ | |
| | | Specimen 3 | 7.4379x$10^{-6}$ | -0.15556 | 7.9586 x $10^{-3}$ | |
| *Stainless Steel 316L* | 96 | Specimen 1 | 8.0784x$10^{-6}$ | -0.18904 | 8.6439 x $10^{-3}$ | 8.6811 x $10^{-3}$ |
| | | Specimen 2 | 8.1143x$10^{-6}$ | -0.1823 | 8.6824 x $10^{-3}$ | |
| | | Specimen 3 | 8.1469x$10^{-6}$ | -0.58559 | 8.7172 x $10^{-3}$ | |

From Table 1, the corrosion value can be determined based on the Icorr value. The higher the Icorr value, the corrosion rate value also increases. At 0 hours to 96 hours of immersion, the current seems to have increased from 4.5539 x $10^{-6}$ A/cm2 to 8.0784x10-6 A/cm2. From the data obtained the value of the corrosion rate, the value of the corrosion rate at 0-hour immersion obtained an average of 4.5681 x $10^{-3}$ mmpy, and at 24 hour immersion obtained an average of 5.9491 x $10^{-3}$ mmpy. At 48 hours of immersion, an average of 6.6039 x 10-3 mmpy was obtained. At 72 hours of immersion, an average of 7.7 x $10^{-3}$ mmpy was obtained, while at 96 hours of immersion, an average of 8.6811 x $10^{-3}$ mmpy was obtained. This shows that the value of the corrosion rate that occurs is in the "Outstanding" category with a range of values of the corrosion rate <0.02 mm/yr or <2 x $10^{-2}$ mmpy.

From these data it shows that the lowest corrosion rate occurs in the specimen 0 hours of immersion with an average value of 4. mpy while the highest corrosion rate occurs in specimens soaked for 96 hours, with an average value of 8.6811 x $10^{-3}$ mmpy, this shows that the value of the corrosion rate that occurs increases with the length of immersion time. VAF used 3.5% NaCl media with a potentiodynamic polarization technique and research conducted by researchers obtained higher results because in the study [16] a coating or treatment process was carried out first, but in research conducted by researchers the specimens were not pre-coated or treated.

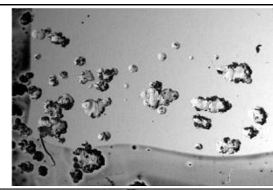
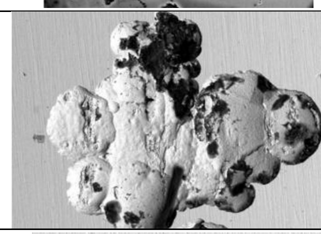
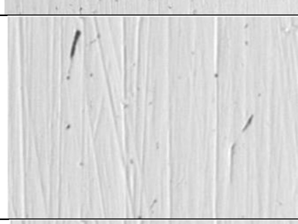
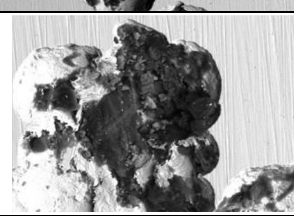
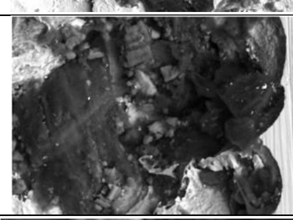
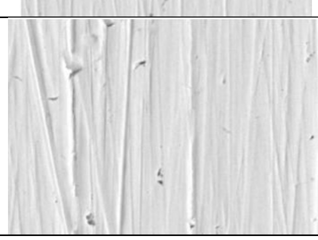
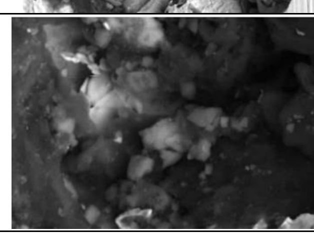
SEM testing was carried out in a study conducted [27] on printed stainless steel Alloy 316L and AISI 316L in 3.5% NaCl solution using potentiodynamics. The results showed that the corrosion rate was higher than that carried out by the researchers. These data were obtained from testing 316L stainless steel in seawater media by carrying out tests at potentiodynamic polarization and then conducting SEM tests.

### 3.2. SEM results

This SEM test was carried out in the BRIN laboratory with the Quanta 650 type. The SEM test aims to see a more precise description of the layer structure with a larger magnification scale to obtain a clear picture of the occurring corrosion.

The test results (Table 2) show that the lowest corrosion rate was at 0-hour immersion and the highest at 96-hour immersion. Then, SEM testing will be carried out with magnifications of 30x, 200x, 500x, 1000x, and 2500x so that morphological images of the surface of 316L stainless steel can be seen at 0 hours and 96 hours immersion in seawater media.

**Table 2.** SEM test results

| Magnification | immersed for 0 hours in seawater media | immersed 96 Hours In Seawater Media |
|---|---|---|
| 30x |  |  |
| 200x |  |  |
| 500x |  |  |
| 1000x |  |  |
| 2500x |  |  |

The results of the SEM test showed that at 30x magnification at 0 hour immersion, black dots, and small holes were visible on the surface. When magnified at 200x, 500x 1000x, you can see the scratches and black dots getting more apparent, and zooming in at 2500x, you can see small holes on the surface. At 96 hours of immersion at 30x magnification, deep holes can be seen and spread on the surface. When magnified 200x, 500x, 1000x, and 2500x, the more clearly visible the more profound the holes. If this corrosion occurs continuously, it will result in material loss and cause the hook mooring line frame to become unable to hold the inabuoy frame.

## 4. Conclusions

Analysis of the corrosion rate of 316L stainless steel specimens in seawater media with immersion of 0, 24, 48, 72, and 96 hours by potentiodynamic electrochemical method. It was found that the lowest corrosion rate data occurred on specimens of 0 hours of immersion with an average value of 4.5681 x $10^{-3}$ mmpy while the highest corrosion rate occurred in specimens that were immersed for 96 hours, showing an average value of 8.6811x10-3 mmpy, this shows the value of the corrosion rate that occurs increases with the length of immersion time.SEM test results for surface morphology on 316L stainless steel metal can show that there were holes that occurred at 0-hour immersion, namely the formation of black dots and small holes. Then, at 96 hours of immersion, deep holes were seen and spread on the surface.

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