

A Corrosivity Study of Sea Water in Three Locations by The Rust in Impressed Current Cathodic Protection to The Protection Current of Steel Pipe

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ABSTRACT

Corrosion is a serious problem and disadvantage in the material world. Losses caused by corrosion should be prevented so that the material can be resistant to the environment. One material that is susceptible to corrosion is made of steel pipes. Coating is intended for the first protection on the pipe and the impressed current cathodic protection (ICCP) is as protection when the coating layer is damaged, so it takes a combination of protection on the pipe. The damaged coating can be protected by the ICCP by giving the current flow through the structure to avoid the corrosion. However, in a seawater environment that is extremely corrosive, it may be that the pipe is not protected because of the different characteristics of the sea water. This must be anticipated by adjusting the current capacity given so that it reaches up to -850 mV potential conditions. Therefore, the current is required based on the sea water condition. This study was conducted using a sample of steel pipes of ASTM A106 Grade A giving the coating with primer coat epoxy and a top coat of epoxy. The pipe is then given an artificial defect with size of R3, R4 and R5 (ISO 4682-3) or equal to 1%; 8% and 40% of the surface area of the pipe and also the defect of 20% and 60%. Furthermore, it was conducted the impressed current cathodic protection with the steel anodes, reference electrodes of Ag / AgCl. The electrolyte media used is sea water in Tanjung Priok, Merak and Bojonegara. Before measuring the protection current needs from each sea

water, the potential must show -850 mV at the end of the pipe. In the study, it can be seen that the wider disability, the greater the protection current flow. The more corrosive sea water, the greater the need for protection current.

KEY WORDS: *Ccorrosion; Coating; ICCP, Cl ion, Salinity*

NOMENCLATURE

<i>ICCP</i>	Impressed Current Cathodic Protection
<i>Cl⁻</i>	Chloride Ion
<i>Fe/ Fe²⁺</i>	Iron / Iron Ion
<i>e⁻</i>	Electron
<i>FeCl₂</i>	Iron (II) Chloride
<i>Fe(OH)₂</i>	Iron (II) Hidroxide
<i>NaCl</i>	Natrium Chloride
<i>ASTM</i>	American Standart Testing and Material
<i>mA</i>	mili Ampere
<i>mV</i>	mili Volt

1.0 INTRODUCTION

Indonesia is abundant of natural resources, ones of them are oil and gas including in the type of non renewable resources. The use of pipe is the appropriate method as the fluid transportation as the water, oil and gas because it is more economical, safety and efficient. But, actually pipes often get serious damage giving interfere to the production activity, the pipe damage problem is corrosion. Corrosion can attack the pipe structure causing the pipe leak or even explode a pipe resulting in the environment pollution.

In general, it is known three methods of corrosion prevention in steel, namely coating application, inhibitor and cathodic protection. The three methods have each advantages. Coating is most used method in industry, coating gradually will damage. This damaged coating can no longer give the physical obstruction between the structure and electrolyte. Thus, it is required other corrosion protection method that is by the cathodic protection method, one of which is by *impressed current cathodic protection* (ICCP) method.

Sea water as the electrolyte media also has different corrosivity and aggressivity characteristics namely where there are different element contents and conductivity affecting the corrosion speed in the three sea water. Therefore, it is required big current to protect the pipe by the condition having defect added by the corrosive of sea water. So, it is required to conduct a research concerning the corrosivity study of sea water in three locations by the *rust* in *impressed current cathodic protection* to the protection current of steel pipe.

2.0 BASIC THEORY

2.1 Corrosion

The definition of corrosion in general is the material degradation caused by environment, both chemically and electrochemically. There will be corrosion in metal material if there is conductor solutions (electrolyte solutions), in this case is the humid soil also as the electrolyte.^[1]

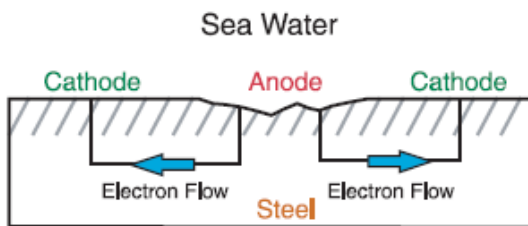


Figure 1; Corrosion Schematic^[2]

1. Anode, as the place of the oxidation reaction.
2. Cathode, as the place of reduction reaction.
3. *Metallic Pathway*, the place of flowing the current from cathode to anode.
4. electrolyte media, as electrical current conductor.

The corrosion mechanism in electrochemistry can be reviewed from the standard potential (reduction). The metal having lower reduction potential is compared to the reduction potential system having spontaneous tendency to oxide.^[1]

2.2 Coating

Coating is generally intended to form film layer with aim to protect the metal layer and isolate from the electric. The layer function is to isolate the metal from direct contact with surrounding electrolyte (prevent contact electrolyte with metal). For instance for the pipe application, coating method is effective enough to be combined with cathodic protection method in the affectivity improvement.^[1]

2.3 Impressed Current Cathodic Protection (ICCP)

Different to *sacrificial anode*, the *impressed current* is corrosion protection method using DC tension. It is by flowing the DC tension from the rectifier, then the metal will get less corrosion because the potential from the metal is made to be negative, so that there is no electron releasing to the environment.

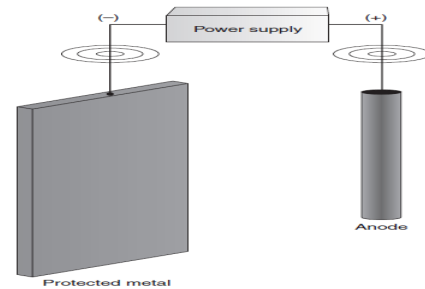


Figure 2. Impressed Current Cathodic Protection Schematic^[4]

Figure 2. describes the negative axis related to the structure protected and the positive axis related to the anode. The current flows from the anode by the electrolyte to the structure layer, then flows along the structure and goes back to the rectifier by the electric conductor. Because the structure receives the current from the electrolyte, so the structure is protected.

The counter current system is used to protect the large structure or for the one requiring greater protection current and is considered less economical if using the sacrificial anode. This system can be used to protect the non-coating structures, unfavorable coating conditions or good condition coating.

2.4 Coating Defect

Coating damage or called as coating defect results in the incomplete protection against the pipe. In the structure of subsea pipelines, the coating protective layer is the first barrier to resist corrosion. The greater number of coating defects will affect the coating adhesion strength, thereby causing the power of attraction between polymer molecules to be decreased. Due to the attractive force is decreased between the polymer molecules, so the mechanical characteristic from its coating layer also decreases.

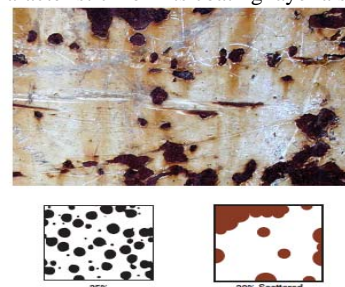


Figure 4: Coating defect at Flat Area^[2]

The *coating* defect is at the pipe result coated like in the figure 4. At the IMO standard, the coating defect result can be counted for the coating defect percentage in the analyzed material, the percentage of corrosion spread in the material.

2.4 Corrosion in Sea Water

The effects of salinity on corrosion in sea water depends on the amount of chloride ions able to solve the passivity layer on the

active-passive metals such as stainless steel and aluminum alloys. High levels of salinity in water will cause chloride ions able to enter into the passive layer and form *initiating pitting* and *crevice corrosion* localized on the metal surface which can be seen in Figure 5. [3]

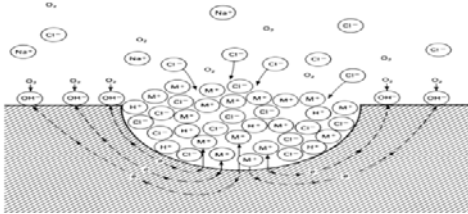
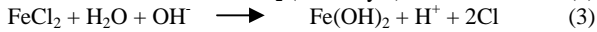
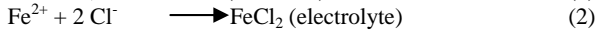
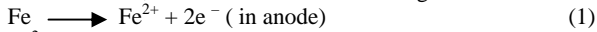


Figure 5. Corrosion Process in Metal Caused by NaCl [3]

The oxygen solubility affects the metal corrosion process, by the existent of other soluble ions in the water, the oxygen solubility will get to decrease. As an example, the higher of Cl⁻ ion, the lower the oxygen solubility in the fluid. If in the steel, there is Cl⁻ ion, so there will be the following reaction :



This will cause the increasing corrosion flow because it can be seen at the reaction equation that the chloride ions will need the iron ions resulted in from the anode to from the stable chloride iron.

3.0 EXPERIMENT PROCEDURE

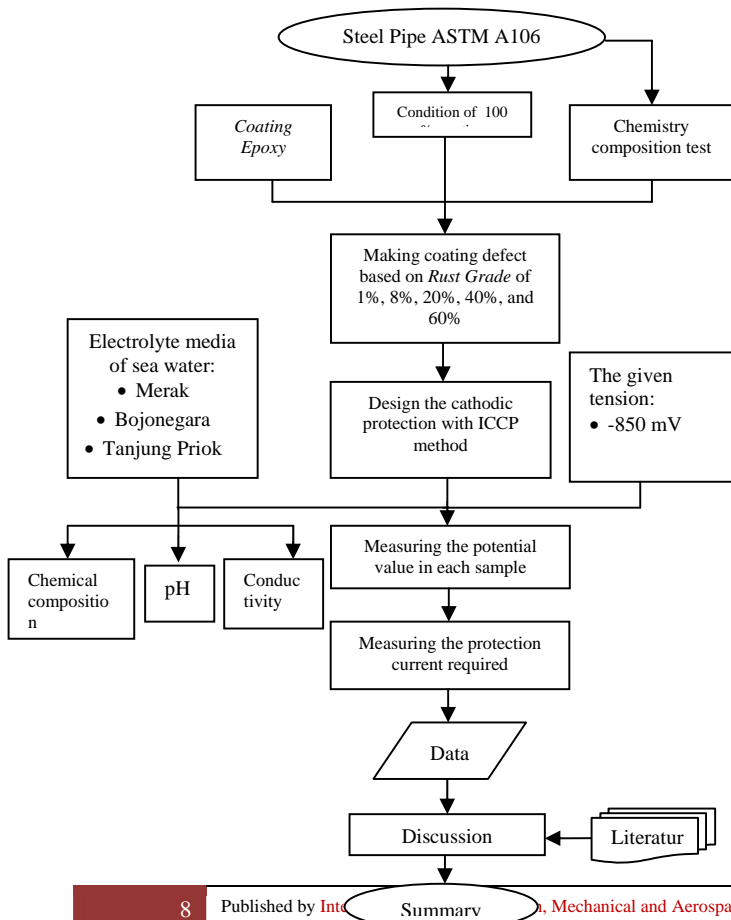


Figure 6: Experiment Flow Chard

3.1 Sample Preparation

1. The samples as 5 pieces of pipe ASTM A106 sanded until clean.
2. The samples of steel pipes are conducted the spectroscopy tool test aiming to obtain the chemical composition based on the ASTM standard pipe.
3. Conducting test point at each particular point in order to get the potential value of the steel pipe samples, it is by welding the steel pipe samples with steel wire.
4. Coating the pipe with epoxy coating.
5. Creating artificial defects based on Rust Grade (level of rust) A 1%, 8%, 20%, 40% and 60%.

1.2 Electrolite Solution Preparation

Preparing an electrolyte solution as corrosive media, the solution used is sea water from three different places, namely Merak, Bojonegara and Tanjung Priok.

1.3 Designing Cathodic Protection Design by Impressed Current Cathodic Protection Methods

1. Submerging the pipe on the tank containing sea water.
2. Pipe is arranged with a rectifier as a source and current rectifier and also connecting to the anode material, then set the voltage in the rectifier according to voltage variation used.
3. Installing *high impedance voltmeter* toll and a *reference electrode* (Ag / AgCl), connected between the positive pole in the anode and the negative pole in the *reference electrode* (Ag / AgCl).
4. Measuring the potential of each sample.
5. Measuring the protection flow needed so that the pipe reaches the protection potential value of -850 mV.

4.0 RESULT AND DISCUSSION

The data results obtained in Figure 7. that by increasing the rust value (rust) on the coating, it will increase the protection flow in sea water which is located in Tanjung Priok. In the sea water at Tanjung Priok, the flow protection with impressed current cathodic protection method continues to increase with rust coating on steel pipes respectively 0.64 mA, 1.30 mA, 3.31 mA, 5.27 mA, 8.85 mA. These are shown by the significant increase in flow protection with increasing defects area in coating.

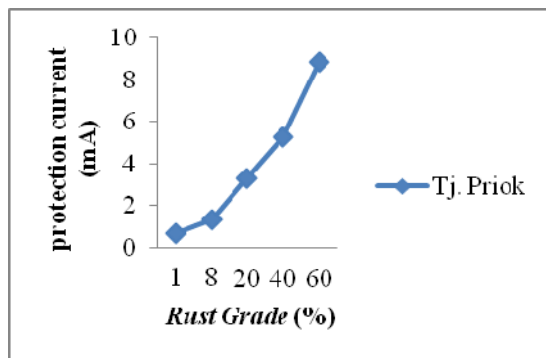


Figure 7. Relationship between Rust Grade Coating and Protection Current required by Sea Water in Tanjung Priok

In Figure 7, it can be seen that the location at the sea water in Tanjung Priok, the pipes with extensive rust on R3 that is 1%, it is obtained the protection current value of 0.64 mA. While the highest protection current on rust area of 60%, it creates protection currents of 8.85 mA. This is in line with the previous studies.^[12] This is because the larger the surface area of the pipe exposed to the environment, the area becomes larger so anodic oxidation reaction will be more prevalent. And when the corrosion requirements have been met, namely the anode, cathode, and electrolyte contact between metallic, then corrosion will occur.

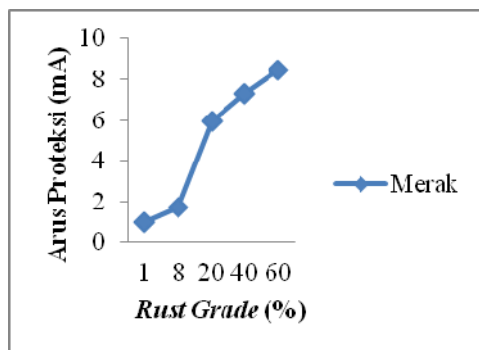


Figure 8. Relationship between Rust Grade Coating and Protection Current required by Sea water in Merak

From the data results obtained in Figure 8. that by increasing the rust value (rust) on the coating, it will increase the protection flow in sea water which is located in Merak. In the sea water at Merak, the flow protection with impressed current cathodic protection method continues to increase with rust coating on steel pipes respectively 0.97 mA, 1.70 mA, 5.92 mA, 7.30 mA, 8.46 mA.

In Figure 8, it can be seen that the location at the sea water in Merak, the pipes with extensive rust on R4 that is 8%, it is obtained the protection current value of 1,74 mA. While the highest protection current on rust area of 20%, it creates protection currents of 5,92 mA.

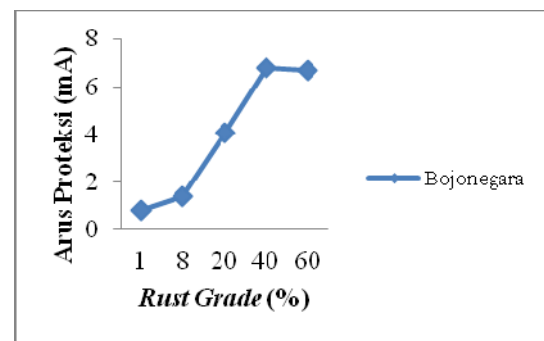


Figure 9. Relationship between Rust Grade Coating and Protection Current required by sea water in Bojonegara

From the data results obtained in Figure 9. that by increasing the rust value (rust) on the coating, it will increase the protection flow in sea water which is located in Bojonegara. In the sea water at Bojonegara, the flow protection with impressed current cathodic protection method continues to increase with rust coating on steel pipes respectively 0,80 mA, 1,41 mA, 4,07 mA, 6,80 mA, 6,67 mA.

In Figure 9, it can be seen that the greater value of rust area in the pipe so the higher protection current increase in pipe structure. In the pipes with rust are of 40%, it is obtained the protection current value of 6,80 mA. While the highest protection current on rust area of 60%, it creates protection currents of 6,67 mA.

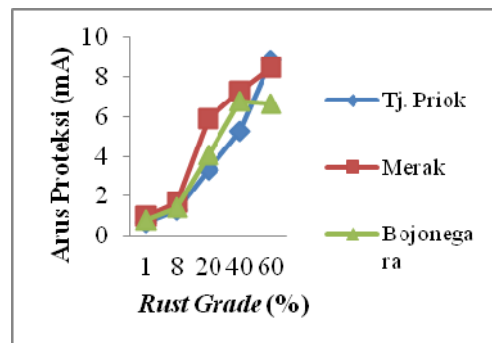
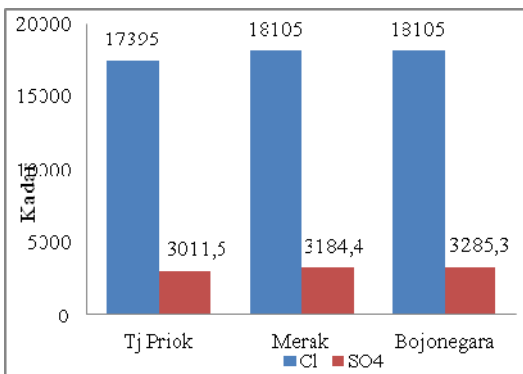


Figure 10. Relationship between Rust Grade Coating and Protection Current required by sea water in Bojonegara

From the result data in Figure 10 that at the same defect percentage, the flow protection demand at ICCP system has increased with the order of Tanjung Priok sea water, Bojonegara sea water, and Merak sea water.

This is due to the nature and characteristics of the sea water itself. By the strong acid elements such as Chloride and Sulfate, then the effect of pH and conductivity of seawater is increasingly destructive to the lifetime (age) of steel pipes



From the data results in Figure 11. The Chlorine ions or Cl is one element which is most associated to corrosion because this element will interact with a steel (Fe) in sea water and get the reduction reaction to form Cl_2 . The Merak sea water is obtained 18 105 ppm Chloride content, this value is higher than the Tanjung Priok sea water and equal to the Bojonegara sea water. This shows that Merak sea water is highly corrosive sea water with a very high Cl content, high chloride content shows the aggressive seawater environment to corrosion. The high chloride content will also lead to increasing salinity and electrical conductivity.

This will cause the increasing corrosion rate as can be seen in the reaction equation that the chloride ions will require iron ions generated from the anode to form a stable ferric chloride. [3] In addition, the sulphate content in the Tanjung Priok seawater is 3011.5 ppm and is 3184.4 ppm at Merak which smaller than the Bojonegara sea water of 3285.3 ppm.

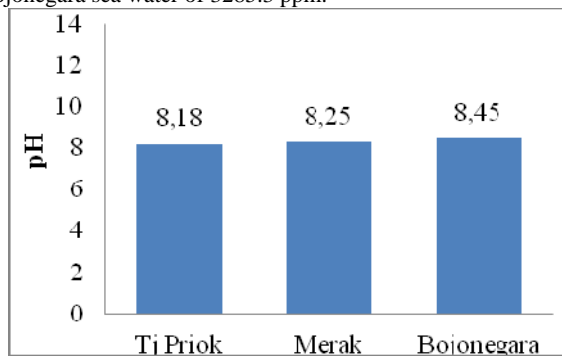


Figure 12. Relationship between sea water location and pH

Figure 12. that the pH value of the three sea water locations increases with the order of Tanjung Priok, Merak, and Bojonegara. The PH changes is caused by environmental factors such as pollution, acid rain and industrial waste. The pH value increases, the activity of hydrogen ions (H^+) declines and changes the form of OH^- ions. While the decrease in the pH, the H^+ ions will increase which means that the corrosion rate of the steel is increased in the low pH so that the H^+ and dissolved oxide are formed. The Merak sea water has the highest conductivity value of 40000 micromohs / cm. Which means that

the ability of sea water Merak to conduct electricity is greater than sea water, located in Tanjung Priok, which only 37400 micromohs / cm and Bojonegara of 38000 micromohs / cm.

5.0 CONCLUSION

1. At the same sea water location, the highest protection current demand is in the specimen with defect of 60% that is 8.85 mA at Tanjung Priok sea water; 8.46 mA at Merak sea water and 6.67 mA at Bojonegara seawater. While the lowest current requirement occurs in specimens with defect of 1% that is 0.64 mA at Tanjung Priok sea water; 0.97 mA at Merak sea water and 0.80 mA in seawater Bojonegara.
2. At the same defect percentage, the protection current demand at ICCP system has increased with the order of Tanjung Priok sea water, Bojonegara sea water, and Merak sea water.
3. The highest content of Cl is obtained at the seawater locations in Merak and Bojonegara which is equal to 18 105 ppm, but the Merak sea water is more corrosive due to the conductivity value of Merak sea water is higher at 40000 mikromohs / cm whereas the Bojonegara sea water is 38000 mikromohs / cm

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