Study of Protected Current for Stainless Steel and Carbon Steel Cathode from Rust Attack to Determining Optimum Flow of Electricity

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Abstract. Rust protection in a construction can be done by several methods such as the use of organic or inorganic layers of protection, anodic protection, and cathodic protection method. Cathodic protection consists of protection by using sacrificial anode as a producer of a protected current and using a protection current generated by an external power supply continuously. In a water-immersed construction commonly used sacrificial anode as a protection against rust in the construction, such as water tank. A sacrificial anode (rod, usually Magnesium or Zinc) is inserted in the construction. When submerged, the anode will be submerged. Water serves as an electrolyte solution. By connecting the sacrificial anode with the construction, a cathode anode system is formed. The anode releases the electrons and undergoes an oxidation reaction, while the cathode undergoes a reduction reaction. By achieving an equilibrium between the oxidation and reduction reactions, the construction is protected from rust. Considering the above, then made the system of protection against rust that is more practical by using the current protection method. The difference with the sacrificial anode method is the use of an external power supply to produce a current (direct current) that is passed through an inert anode such as aluminum, stainless steel or graphite, so no anode replacement is required as long as the tank is used. Using a simple circuit, the amount of electric current flowed can be adjusted according to the dimensions of the tank. Electric current used is also relatively small so it is safe for users. To study the above system made a model use stainless steel and carbon steel material to be able to determine the optimal protection current.

1. Introduction
Determination of electric current and electrical voltage is an important passage in the application of impressed current cathodic protection so that the development of the instrumentation that is needed can be done. The instrumentation involves the direct current (dc) of current source used is the rectifier and monitor it.
The impressed current cathodic protection has not been commonly used in relatively small constructions such as the water storage tank, water heater tank and others, to prevent rust. The system commonly used is sacrificial anode cathodic protection. Anode is inserted in the construction or tank and connected to the construction. Water acts as an electrolyte medium so that the construction or tank functions as a cathode or object protected from the appearance of rust.

In the impressed current cathodic protection, the anode is still needed as a distributor of the protected current that flows from a set of dc power supply (rectifier). The protection will occur as long as the rectifier does not take interference and there is not interruption of the supply of electricity from the local network. However, the provision of excessive amounts of protection current and voltage can reverse condition to accelerate rust, can also be harmful to the environment and human. Therefore, the amount of electric current and voltage provided as a protection current must be optimal so that protection is also optimal. Furthermore, the proper rectifier design also determines the success of the protection.

To study the above system, a model is made on various materials to determine optimal protection current. A set of rectifiers with varying voltages are used to find the magnitude of dc electric current needed to be able to protect the construction material from rust optimally. It is hoped this model can be adopted as a new feature in the next construction, so that maintenance is simpler, reduces production costs, simplify fabrication, simplify the production and design process, and do not need to use materials such as platinum, chromium, graphite, as an anode for the impressed current cathodic protection, because using stainless steel can be used as an alternative anode.

2. Experimental Section

2.1. Material and Instrumentation
The materials that were used on this research, there are SUS 304 and SPHC as cathode sample, SUS 304 as anode as a distributor of the protected current, pH indicator, and Ag/AgCl as a reference electrode. While the instruments that used were dc power supply (rectifier), backup power supply, AVO meter, and thermometer & humidity.

2.2. Procedures
Establishment Anode and Cathode Samples
Making test samples with specifications SUS 304 (20x100x2) mm; SPHC (20x100x2) mm, and SUS 304 (20x100x2) mm as an anode, by using a shear cut machine. Then, the finishing process on these samples so that the surface of the samples pieces is not sharp. Providing sample mark that will be used as anode and cathode and preparing a standard sample (which does not occur rust) as a comparison for the sample tested.

Testing Preparation
The experiment was carried out in a box that will be used for testing cell by filling water up to a volume of three-quarters of a box, then preparing and assembling the test equipment (power supply, connecting cable, reference electrode, AVO meter, supporting tools: 3-Watt LED, thermometer & humidity, and pH indicator).

Testing Process
The testing process was carried out for each pair of anode and cathode by the first pair is the anode and the cathode: stainless steel and stainless steel, the second pair is the anode and cathode: stainless steel and SPHC carbon steel. Then, set the dc voltage with an initial voltage of 1 Volt in each pair. The visual observations on the surface of the anode and cathode every 12 hours to 48 hours increase, which
start for the first 12 hours and recording the observations in the form of photos and data. Then, the testing repeatedly until it reaches a dc voltage of 5 Volts.

3. Result and Discussion

The testing the galvanic series describes stainless steel is more stable than carbon steel so it is more cathodic [2]. In the impressed current cathodic protection, the required anode properties are relatively more stable material. Mostly the impressed current cathodic protection uses graphite, platinum [4] or other material that is more stable but more expensive, and requires higher cost fabrication. However, replacement of expensive material anode with stainless steel anode is already to cost reduction.

In a cell cathodic protection, between stainless steel (SUS 304) and SPHC carbon steel show the resistance of carbon steel cathode to rust formation increase parallel to voltage, that shown in Table 1 and Figure 1.

| Potential Between Electrode Reff Vs Cathode Voltage (Volt) | Load Voltage (Volt) | Current Cell (mA) | Rust formation (Hour) |
|-----------------------------------------------------------|---------------------|-------------------|-----------------------|
| 0.402                                                      | 1.0                 |                   | 24                    |
| 0.439                                                      | 1.5                 |                   | 36                    |
| 0.548                                                      | 2.0                 |                   | 48                    |
| 0.788                                                      | 2.5                 | 0.14              | No Rust               |
| 1.196                                                      | 3.0                 |                   | No锈**                   |
| 1.553                                                      | 3.5                 |                   | Formation             |
| 1.818                                                      | 4.0                 |                   |                       |
| 2.114                                                      | 4.5                 |                   |                       |
| 2.077                                                      | 5.0                 |                   |                       |

Figure 1. The Influence of Voltage on the Rust Formation of Carbon Steel Cathodes.

The rust formation does not occur at the cathode when given a voltage of 2.5 Volt with a maximum observation of 48 hours. This voltage has provided protection against rust in the sample, which is indicated no rust formation in the cathode during observation. The flowing current in the cell ranges from 0.14 mA, it is still safe according to the electric shock for human body standard. In Figure 2, the condition of carbon steel cathode after undergoing testing at various voltages and times.
Figure 2. The Specimen Condition of Carbon Steel Cathodes. (a) After 24 hours exposed on 1.0 Volts (found rust on specimen surface); (b) After 36 hours exposed on 1.5 Volts (found rust on specimen surface); (c) After 48 hours exposed on 2.0 Volts (found rust on specimen surface); (d) After 48 hours exposed on 2.5 Volts (not found rust on specimen surface).

As for the pair of anode - cathode: stainless steel and SPHC carbon steel obtained an anode behavior similar to the pair of anode - cathode: stainless steel and stainless steel. In the same observation condition, no rust was found on the surface of the stainless-steel anode used so that it was concluded that the stainless-steel anode was stable in the conditions of the study.

Figure 3. The Specimen Condition of Stainless Steel Anode, After 48 Hours With Voltage Increase 0.5 Volt.

Whereas the cell system between stainless steel and stainless steel (SUS 304) shows that stainless steel is nobler than carbon steel. In this case it means that the stainless-steel cathode requires very small impressed current. The use of stainless steel anodes also optimizes the protection system (Table 2). In the application sample on a structure (for example, a tank of stainless steel material) will be optimal if it is protected using impressed current by using the same anode material (the anode can be made from its waste material), so as to save the production costs of the structure. The specimen condition of stainless steel cathode in various testing are as follows:
Table 2. Testing Results on Anode - Cathode: Stainless Steel - Stainless Steel

| Potential Between Electrode Reff Vs Cathode Voltage (Volt) | Load Voltage (Volt) | Current Cell (mA) | Rust formation (Hour) |
|-----------------------------------------------------------|---------------------|-------------------|-----------------------|
| 0.167                                                     | 1.0                 |                   |                       |
| 0.409                                                     | 1.5                 |                   |                       |
| 0.681                                                     | 2.0                 |                   |                       |
| 0.832                                                     | 2.5                 |                   |                       |
| 1.307                                                     | 3.0                 |                   |                       |
| 1.725                                                     | 3.5                 |                   | 0.14                  |
| 1.933                                                     | 4.0                 |                   |                       |
| 2.264                                                     | 4.5                 |                   |                       |
| 2.618                                                     | 5.0                 |                   |                       |

Figure 4. The Specimen Condition of Stainless Steel Cathode after 48 Hours of Observation, There is not Rust Formation on (a) 1.0 volt (b) 1.5 volt (c) 2.0 volt (d) 2.5 volt.

The behavior of stainless steel as an anode in this protection both pairs the anode - cathode: stainless steel and stainless steel as well as the pair of anode – cathodes: stainless steel - SPHC carbon steel does not rust formation. This is indicated by no rust formation on the surface of stainless steel (surface corrosion) anode, both from variation in voltage and variation in 48 hours observation, shown in Figure 5, for number 1 through 9 shows the voltage increase of every 0.5 Volts starting at a voltage of 1 Volt to 5 Volt.
Figure 5. The Surface of The Stainless Steel Anode After 48 Hour Observations for The Anode-Cathode Pair: Stainless Steel and Stainless Steel.

4. Conclusion
Stainless steel in the impressed current cathodic protection can be used as an alternative anode based on not forming a rust layer on the cathode as a material that must be protected. Stainless steel functions as a stable anode under this research conditions indicated by not forming a rust layer on its surface either on the pair of anode - cathode: stainless steel and stainless steel or on pairs of anode - cathode: stainless steel - SPHC carbon steel. The amount of voltage applied to protect the SPHC carbon steel cathode is 2.5 volts with a current of 0.14 mA. This fulfills the safety aspects of the use of electricity for humans. Whereas to protect the stainless steel cathode with a voltage of 1 volt with a current of 0.14 mA is sufficient to protect the stainless steel cathode. The application of stainless steel anode as an alternative anode give cost reduction in the impressed current cathodic protection sustains for protection of structures made of stainless steel or SPHC carbon steel.

5. References
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