Effect Electrolyte Temperature and Electrode Distance to Electroplating Hard-Chrome on Medium-Carbon Steel

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Abstract. ASSAB 618S steel is a type of medium carbon steel that is often used as a machining tool for the petroleum industry. Based on the observation, it does not work optimally due to high acidity. As a result, there is corrosion in the machining tool. In this study, an electroplating process will be carried out as a way to overcome corrosion in machining made of ASSAB 618S steel. The variables involved independent variables, dependent variables, and control variables. The independent variable is the temperature of the electrolyte solution with variations of 55°C to 70°C. The dependent variable is the corrosion rate on the results of electroplating hard chrome coating. The controlled variable is the distance of electrodes with variations of 3 and 9 cm. The data obtained showed that the highest corrosion rate was obtained from the temperature variation of the electrolyte solution of 55°C to 70°C. The dependent variable is the corrosion rate on the results of electroplating hard chrome coating. The controlled variable is the distance of electrodes with variations of 3 and 9 cm. The data obtained showed that the highest corrosion rate was obtained from the temperature variation of the electrolyte solution of 55°C to 70°C. The lowest corrosion rate was obtained at a temperature variation of 70°C electrolyte and 3 cm electrode distance. The data is in accordance with the theory of corrosion rate that is smaller better. It means that the smaller the corrosion rate, the better the corrosion resistance. Based on the results of this study, it can be concluded that the temperature of the electrolyte solution, the distance of the electrode, and between both interactions give an influence on the corrosion rate of the electroplating hard chrome coating.

1. Introduction
The steel industry has experienced demands to create steel that has good mechanical properties and physical properties. On the other hand competition between steel producers is followed by market demand which requires steel producers to produce cheap and easy steel in the manufacturing process. Medium carbon steel has good mechanical properties, only the corrosion resistance is not very good. While Chrome has good corrosion resistance, but the price per gram is more expensive than steel.

1.1. Medium Carbon Steel
Steel is a metal with the main constituents of Ferro (Fe) and Carbon (C), the next element found in carbon steel is manganese, silicon and phosphorus and several other elements with very little content. Based on the carbon element, steel can be classified into low carbon steel, carbon steel, and high carbon steel. Steel with a carbon content of less than 0.30% is called low carbon steel. Medium carbon
steel has a carbon element with a range from 0.30% to 0.60%. If the carbon content is more than 0.60 to 1.5%, then the steel can be categorized as high carbon steel. [1] In carbon content rises, the metal becomes harder and stronger but less ductile. ASSAB 618S steel with a carbon content of 0.36% can be categorized as medium carbon steel, other elements can be seen in table 1. Medium carbon steel is widely used in petroleum industry, including as bolts, turbine casings, gears, wire rods, seamless tubing, and pipe are also objects constructed from medium carbon steel. [1] Generally medium carbon fiber has characteristics; good plastic deformation, machinability, polish ability and conductivity but are weak in corrosion resistance and wear. Because of its easy availability, low cost and uncomplicated fabrication [20]. Although have limitation in corrosion resistance, carbon steel the most widely used engineering material (2). And also medium carbon steel.

| Element     | Content |
|-------------|---------|
| Carbon      | 0.37 %  |
| Silicon     | 0.3 %   |
| Mangan      | 1.4 %   |
| Chromium    | 2.0 %   |
| Molybdenum  | 0.2 %   |
| Nickle      | 1 %     |

1.2. Electroplating

Electroplating is one of the important processes in metal industries. The original purpose of electroplating process is to enhance the value of base metal by improving their physic and mechanical properties [3]. Parameter must be under control during electroplating are; bath temperature, pH of the bath, current. Current density can fix the coefficient of friction. pH of the bath can increasing wear resistance. Bath temperature can increase corrosion resistance. Particle concentration of the bath can increase mechanical properties of base metal. particle size can reduced internal stress [4] Current density, pH and temperature of the bath are the main electroplating parameters. Size and concentration of the particles, also electrolyte types are secondary parameters [5]. Electroplating is flown by farraday law and its equation. Faraday law is:

- Chemical action or decomposing power is exactly proportional to the quantity of electricity which passe.
- Electrochemical equivalents coincide and are the same with ordinary chemical equivalents.

Faraday's equation of electroplating can be expressed as:

\[ Q = \frac{zm}{M} \]

\[ Q = It = zFn \]

Where Q is the charged passed, I is the current passed, t is the time the current is passed, z is the change in oxidation state, m are mass and M are molar mass, F is the Faraday constant (96.485 C mol⁻¹, the charge of one mole of electrons), and n is the amount of substance oxidized or reduced [6]. The results of electroplating chrome thickness are intended to prevent corrosion by coating chrome metal which is resistant to corrosion on the metal to be coated specifically using chrome. The amount of corrosion rate that occurs in metals is influenced by many factors and one of them is physical and metallurgical factors [16]. The physical factors that influence are the thickness of the layer, while the thickness of the layer is closely related to electrolyte conductance. Electrolyte conductance determines
the amount of ions and the fast movement of ions in electrolyte solutions, if the resistance is large, the conductance is smaller [17]. Chromium has good hardness index, excellent melting interval and good liquids temperature change index. Chromium showed excellent adhesion when applied on steel, as well as on the nickel plating [18]. Chromium applied in aluminum alloy have good surface roughness [19].

1.3. Corrosion Penetration Rate

Corrosion is the deterioration of a material by a chemical attack or reaction between material and environment, and can be degradation of material properties. Corrosion is a continuous process which could be difficult to control and terminate. The deterioration of metals is very common in material containing carbon, such as steel and iron materials [7]. The corrosion of metals remains a worldwide scientific problem as it affects the metallurgical, chemical, construction and oil industries [8]. Corrosion can be attacked in mild carbon steel, even in stainless steel (9). For low carbon steel, the inhibitor caused corrosion is a chemical inhibitor, followed by underground (soil), saltwater, freshwater, and atmosphere [10]. The corrosion degradation can be serious damage to bridge construction [11]. The corrosion scientist studies corrosion mechanisms to improve the understanding of the causes of corrosion and the ways to prevent or at least minimize damage caused by corrosion. They’re one of the methods to minimize corrosion are using a metal coating. Metal coatings are applied by dipping, electroplating, spraying, cementation, and diffusion. Electroplating is one of the most efficient way to minimize corrosion [12]. Chemically corrosion reactions can be stated as follows: Fe(s) → Fe$^{2+}$ + 2e (oxidation) and O$\text{2}^{-}$+2H$\text{2}$O → 4 OH$^{-}$ (reduction). Metal passivation is a corrosion barrier due to the formation of corrosion products as a protective layer that inhibits the continuity of the reaction rate. In others, a metal passivation is an event of metal reaction loss due to the presence of certain conditions (14). When a metal is not in equilibrium with a solution containing its ions, the electrode potential is different from the corrosion potential free and the difference between the two is called polarization (15). Passivation and polarization of metal if tested in a potentiostat will be stated in the Analytical Taffel. From the analysis taffel Icorr (Exchange Current per unit area tested) the equation used to calculate the corrosion rate is:

$$CPR = K \left( \frac{ai}{ND} \right)$$

(3)

Where, CPR is the corrosion rate (mmpy), K is the constant constant (0.00327), a is the metal atomic weight, i is the density ($\mu$A/cm$^2$), n is the number of missing electrons and D is the density (gr/cm$^3$). CPR shows the magnitude of the average penetration of corrosion of metals in each unit of time. The high corrosion rate value indicates low metal resistance to corrosion attack. Likewise, the opposite is that the high level of resistance to corrosion is indicated by the low corrosion rate [16].

2. Methods

In these research using independent variable, control variable are and dependent variable. Independent Variable are The temperature of the electrolyte solution using 3 stage 55$^\circ$C, 60$^\circ$C, 65$^\circ$C, and 70$^\circ$C. Distance of electrode is using 2 stage 3cm dan 9cm. Dependent Variable is corrosion penetration rate (CPR) of electroplating metal. Control Variable are current 45A/dm$^2$, pickling solution using H$\text{2}$SO$\text{4}$ 90% with aquades 10% during 1 minute, corrosion applied is forced corrosion using a 2% NaCl solution. The shape of the specimen and the corrosion data retrieval point is shown in Figure 1. The purpose of this use is to prove that the coating results are uniform, it is expected that the corrosion rate between data collection points is not too different.
Data analysis is using in this research shown in table 2. Y112 is the corrosion rate data on the variation of the temperature of the electrolyte 55°C and the electrode distance of 3 cm and the second test.

Table 2. Formatting sections, subsections and sub subsections.

| Temperature (°C) | Replication | Electrode distance (3 cm) | Electrode distance (9 cm) |
|-----------------|-------------|---------------------------|---------------------------|
| A1(55)          | 1st         | Y111                      | Y121                      |
|                 | 2nd         | Y112                      | Y122                      |
| A2(60)          | 1st         | Y211                      | Y221                      |
|                 | 2nd         | Y212                      | Y222                      |
| A3(65)          | 1st         | Y311                      | Y321                      |
|                 | 2nd         | Y312                      | Y322                      |
| A4(70)          | 1st         | Y411                      | Y421                      |
|                 | 2nd         | Y412                      | Y422                      |

3. Result

The decrease of corrosion rate is caused by chrome ions coating thoroughly on the coated metal surface, it can prevent the occurrence of corrosion reactions. In addition, the temperature variation of the 70oC electrolyte provides better activation energy. The chromium ions are bonded to each other more, and the small electrode distance causes the ion to move closer and faster. So, the chrome ions that settle on the specimen are increasing. The further the distance of the electrode causes the slower movement of ions and the reduced number of moving chrome ions for hard chrome coating on the metal. The fewer chrome layers that line the metal surface, the corrosion rate will increase. The longer the electrode distance will increase the corrosion rate. In the previous discussion it was found that the higher the temperature of the electrolyte solution causes the higher the rate of the reaction which causes the higher movement of ions and the greater the number of chrome ions that move to coat the metal to be coated. From table 3 we see thicker the chrome layer is coated, the lower the corrosion rate. In the graphical comparison analysis of electroplating hard chrome coating process with a 9 cm electrode distance the corrosion rate is greater than the 3 cm electrode distance due to the longer distance of the electrode, the lower the number of chrome ions and the higher the corrosion rate. From the results, it can be concluded that there is a significant effect of the change in temperature of the electrolyte solution and the distance of the electrode to CPR. CPR shows the magnitude of the average penetration of corrosion of metals in units of time [16] This also happens in the same way [3].
Table 3. Data of corrosion penetration rate.

| Temperature (°C) | Electrode distance 3 cm | Electrode distance 9 cm |
|------------------|-------------------------|-------------------------|
|                  | Icorr | CPR (mmpy)   | Icorr | CPR (mmpy)   |
| 55               | 281,111 | 3,2665.10^-4 | 1025,30 | 1,1914.10^-2 |
|                  | 326,470 | 3,7936.10^-4 | 2255,60 | 2,6672.10^-2 |
| 60               | 184,100 | 2,1392.10^-4 | 792,540 | 9.2093.10^-3 |
|                  | 185,980 | 2,1611.10^-4 | 695,880 | 8.0861.10^-3 |
| 65               | 17,0340 | 1,9793.10^-5 | 28,825 | 3,3495.10^-3 |
|                  | 29,1690 | 2,1611.10^-5 | 57,792 | 6,7154.10^-3 |
| 70               | 6,26180 | 7,2761.10^-6 | 31,845 | 3.37004.10^-4 |
|                  | 2,34110 | 2,7203.10^-6 | 20,8190 | 2,04260.10^-4 |

In contrast, the solution temperature does not have a significant effect [4], because it uses Nickel-based electrolyte solution i.e BaCr$_2$O$_4$-Ni and Al$_2$O$_3$-Ni. Nickel has better thermal resistance than chrome. Low CPR shows low metal resistance to corrosion. The amount of corrosion rate that occurs in metals is influenced by many factors and one of them is physical and metallurgical factors. Physical factors affect the effective age of a layer. Corrosion rates can also determine the effective age of a layer. The effective age of a layer other than depends on the operational environment also depends on the thickness of the layer [17]. Tafel Analysis from potensiostat show in figure 2, 3 and 4. From those image we have Icorr data, after obtaining Icorr data, the CPR value is counting by using equivalent 3.

Figure 2. Result from potensiostat of Y111 specimen

Figure 3. Result from potensiostat of Y222 specimen

Figure 4. Result from potensiostat of Y422 specimen
4. Conclusion

The fewer chrome layers line in metal surface, will make the corrosion penetration less than from other specimen in this racerh. That shown from data corrosion penetration rate, in this situation corrosion rate will increase. The longer the electrode distance will increase the corrosion rate. In the previous discussion it was found that the higher the temperature of the electrolyte solution causes the higher the rate of the reaction which causes the higher movement of ions and the greater the number of chrome ions that move to coat the metal to be coated.

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