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Effect of Current and Coating Time on the Layer Thickness and Corrosion Rate of Electroplated AISI 1045

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Abstract

Corrosion mostly occurs on carbon steel which is applied for automotive components and household needs. This natural phenomenon is impossible to be avoided. However, it can be set by escalating its corrosion initiation time. Electroplating is a method that can be used to give protection to slower the corrosion initiation time by forming a layer on the specimen surface, additionally, this method is simple and low cost. One of the most commonly used metals for electroplating is nickel, nickel electroplating is suitable for automotive component coating. For these reasons, this study is focused on analyzing the effect of current and coating time on the layer thickness and corrosion rate of AISI 1045 carbon steel with nickel electroplating. The current variations used were 0.5; 1.0; and 1.5 A and the coating time variations were 5, 10, and 15 minutes. AISI 1045 was used as the cathode, nickel was as the anode, and nickel chloride was the electrolyte solution. The specimen with a current of 1.5 A and a coating time of 15 minutes shows the thickest coating and the lowest corrosion rate, with values of 0.0205 mm and 0.94 mpy, respectively. This study indicates that the increase of the current and coating time enhances the layer thickness and declines the corrosion rate.

Keywords: nickel electroplating, current, coating time, layer thickness, corrosion rate, AISI 1045.

Abstrak

Korosi paling sering terjadi pada baja karbon yang diaplikasikan pada komponen otomotif dan kebutuhan rumah tangga. Kejadian ini bersifat alami dan tidak mungkin dihindari, namun dapat diatur dengan meningkatkan waktu inisiasi korosinya. Elektroplating merupakan salah satu metode yang dapat digunakan untuk memberikan perlindungan dengan memperlambat waktu inisiasi korosinya dengan cara membentuk lapisan pada permukaan spesimen, selain itu metode ini juga sederhana dan berbiaya rendah. Salah satu logam yang paling umum digunakan untuk pelapisan listrik adalah nikel, pelapisan nikel cocok untuk pelapisan komponen otomotif. Oleh karena itu, penelitian ini difokuskan untuk menganalisis pengaruh variasi arus dan waktu pelapisan terhadap ketebalan lapisan dan laju korosi baja karbon AISI 1045 dengan pelapisan nikel. Variasi arus yang digunakan adalah 0,5; 1,0; dan 1,5 A serta variasi waktu pelapisan 5, 10, dan 15 menit. AISI 1045 digunakan sebagai katoda, nikel sebagai anoda, dan nikel klorida sebagai larutan elektrolit. Benda uji dengan arus 1,5 A dan waktu pelapisan 15 menit menghasilkan lapisan paling tebal dan laju korosi paling rendah, masing-masing dengan nilai 0,0205 mm dan 0,94 mpy. Studi ini menunjukkan bahwa peningkatan arus dan waktu pelapisan meningkatkan ketebalan lapisan dan menurunkan laju korosi.

Kata Kunci: pelapisan nikel, arus listrik, waktu pelapisan, ketebalan lapisan, laju korosi, AISI 1045.

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1. Introduction

Carbon steel is a widely used in industrial application. This steel is applied for making agricultural equipment, automotive components, and household needs. However, it has low corrosion resistance (Saefuloh and Winisuda, 2017). Corrosion leads the decaying of a metal from its surface to the inside part, as a result of chemical reactions with its surrounding environment (Afandi, Arief and Amiadji, 2015). This natural process cannot be avoided, but it can be modified by increasing the initiation time of the corrosion. One of the methods is by giving a protection coating on the metal surface using a metal that has a higher corrosion resistance. This method can be done by using a direct current, then called electroplating technique (Saefuloh and Winisuda, 2017). Some previous studies commonly used chrome and nickel as the plating metal (Oloruntoba, Eghwubare and Oluwole, 2011; Sukrawan, 2016; Widodo, 2016; Rozak, 2017), using chrome as the plating material on a metal provides hard surface, corrosion resistance, and aesthetic value with golden yellow color. Meanwhile, using nickel can give an excellent electrical and thermal conductivity, as well as the corrosion resistance and impressive decorative with silvery white color. Moreover, the electroplating technique can also be influenced by many factors which affect the coating quality. The electrical current factor gives a significant effect on the coating thickness. The increase of electrical current results in higher layer thickness (Tarwijayanto, Raharjo and Triyono, 2013). On the other side, the improvement of coating time presents an increase of the coating thickness result (Suarsana, 2008). In correlation with the corrosion rate, the previous study states that the longer coating time is able to slow down the corrosion rate (Widodo, 2016).

The electroplating technique is easy, simple, and low cost, but highly potential (Saefuloh and Winisuda, 2017). Additionally, the mostly used metal for coating on automotive components is nickel. Moreover, the carbon steel is also generally used for automotive components making, especially AISI 1045 steel which needs further improvement for its corrosion resistance using surface modification (Vishnuja and Bhaskar, 2018). For these reasons, this research is concerned to study the influence of the electrical current and coating time on the layer thickness and corrosion rate of the nickel electroplating results on AISI 1045 steel.

2. Methods

2.1. Tools and Materials

The tools used in this work were the grinding machine, digital scales, 1 L beaker glass, lab spatula, rectifier or DC power supply with the voltage range 0 – 50 V, ampere meter with the ampere range 0 – 2 A, 5 L bucket, stopwatch, and micrometer screw.

The materials used were AISI 1045, nickel bar, nickel chloride ($NiCl_2 \cdot 6H_2O$) >97% by SAP chemical, and distilled water. In this work, AISI 1045 was used as cathode and machined to the dimension of 50 × 30 × 5 mm, additionally, nickel was used as anode for the coating material.

2.2. Electroplating Process

The material to be coated was abraded and polished after the cutting process, in order to remove the impurity and rust on its surface before the electroplating process. The last step before electroplating was washing to clean the grease on the surface of the material. Then, this work was carried out by installing the cathode, anode, 50% nickel chloride solution, power supply, and ampere meter as illustrated in Figure 1. The experiment was conducted with the electrical current variations of 0,5; 1; and 1,5 A, then each current variation was carried out with the different time coating of 5, 10, and 15 minutes.

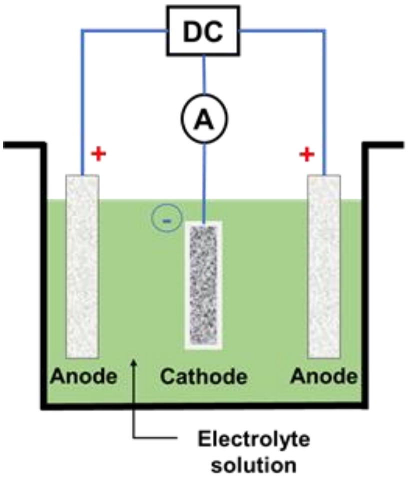

Figure 1: Electroplating Illustration

2.3. Layer Thickness and Corrosion Rate Measurements

The thickness was measured using micrometer screw with three points on different location for each specimen, then the three points ware averaged. The thickness measurement method was sketched in Figure 2. The layer thickness was achieved by measuring the specimen thickness before and after the electroplating process, then calculated the thickness difference and divided by two.

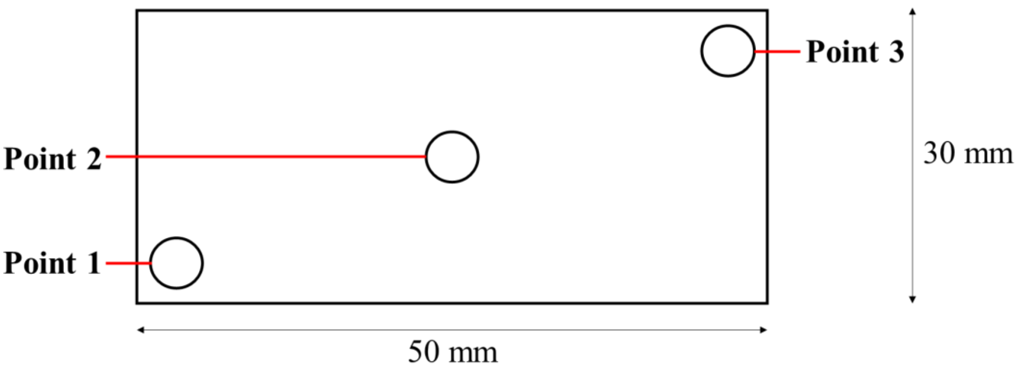

Figure 2: Layer Thickness Measurement Scheme

The corrosion rate test was done using 5% of NaCl which composed from 50 grams of NaCl with 1 L of distilled water. The examination was carried out for 48 hours. The corrosion rate was calculated using weight loss method, so the first step before the examination was to measure the initial weight (w_0) of the specimen using the digital scales. Then, after the immersion step was done in the ambient temperature with the determined time and 5% of NaCl solution, the immersed specimen was taken out and measured the last weight after the immersion (w_i) (ASTM G31 – 72, 2004). The following formula was used to calculate the corrosion rate.

$$Mpy = \frac{534 \times W}{\rho \times A \times T} \quad (1)$$

Which is:

Mpy : mils per year
534 : the constant if the corrosion rate is notated with mpy
W : weight loss (mg) = $w_0 - w_i$
ρ : specimen density (g/cm^3)
A : surface area (in^2)
T : exposure time (hour)

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3. Result and Discussion

3.1. Layer Thickness of Coating Results

The nickel deposition successfully occurred and layered on the specimen surface. When the nickel chloride was dissolved in water, the nickel became ion with positive charges (Ni^{2+}) in solution. Furthermore, when the current was applied, the nickel ions reacted with two electrons and turned into metallic nickel (Ni) at the cathode. The reaction is shown as follow (DiBari, 2002):

$$Ni^{2+} + 2e^{-} \rightarrow Ni$$

Figure 3 shows the layer thickness results in the correlation with the current and coating time variations. The thickest layer is 0.0205 mm with 1.5 A of the electrical current and 15 minutes of the coating time. Meanwhile, the thinnest layer value is 0.0025 mm with the electrical current variation of 0.5 A and the coating time of 5 minutes. It can be clearly seen that higher current leads to thicker layers. This is due to the increased number of ions when escalating the electrical current, so the released nickel ion rises and deposits in the cathode. Furthermore, the increase of the coating time also gives the layer thickness enhancement. The reason is because higher coating time can provide more time for nickel ions to deposit on the cathode substrate. These results are in line with the previous studies (Suarsana, 2008; Tarwijayanto, Raharjo and Triyono, 2013; Niam, Purwanto and Respati, 2017; Saefuloh and Winisuda, 2017).

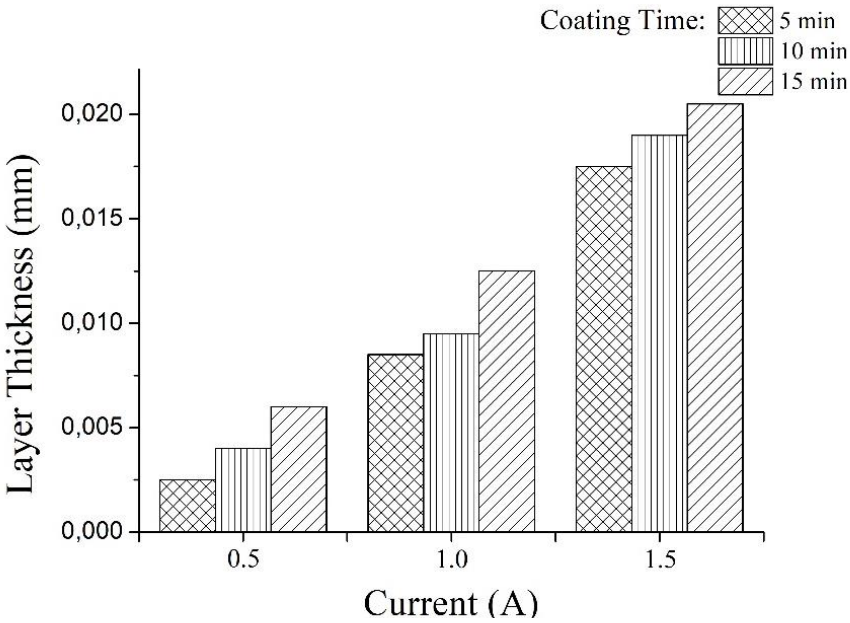

Figure 3: Layer Thickness Results with The Electrical Current and Time Variations

3.2. Corrosion Rate

The corrosion rate was calculated from the electroplated specimens and pristine specimen using weight loss method. The corrosion rate values can be seen in Figure 4. The pristine specimen shows the highest corrosion rate with the value of 42.52 mpy. In the meantime, the electroplated specimen with the variations of 0.5 A current and 5 minutes coating time has the highest corrosion rate value of 27.4 mpy, after the pristine specimen. The lowest corrosion rate is 0.94 mpy with the 1.5 A current variation and 15 minutes coating time. The higher electrical current and coating time gives lower corrosion rate. This is also correlated with the layer thickness, the thicker layer on the specimen surface shows low corrosion rate which means high corrosion resistance due to the electroplated specimen with the thicker layer result gives thicker protection that can endure the specimen longer from the corrosion. These results are similar to the previous discussions (Widodo, 2016; Saefuloh and Winisuda, 2017).

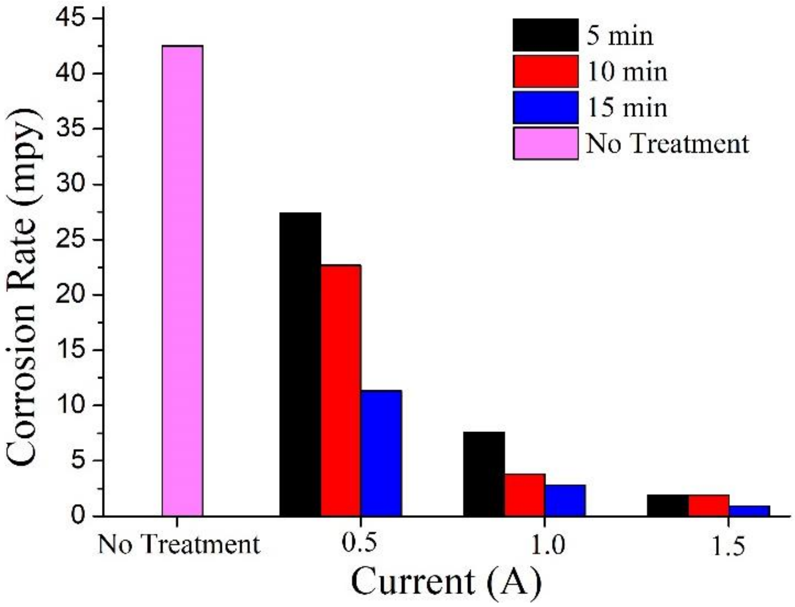

Figure 4: Corrosion Rate Results with The Electrical Current and Time Variations

4. Conclusion

The effect of current and coating time variations to the layer thickness and corrosion rate of the nickel electroplated AISI 1045 steel was successfully studied and concluded that the increase of the current and coating time results in the thicker layer on the specimen surface with the thickest layer value of 0.0205 mm for 1.5 A current and 15 minutes coating time variation. The corrosion rate values decrease with the increase in current and coating time due to the thicker layer. Additionally, the lowest corrosion rate is 0.94 mpy with the current variation of 1.5 A and the coating time variation of 15 minutes. The future work can be focused on the modified electroplating examination and equipped with optical microscope or SEM observation and EDX or XRD to prove what kind of compound is formed on the specimen surface after the electroplating process.

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