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To cite this article: Z Mansjur *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **602** 012092

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Effect of coating time and protective current on thickness of paint layer of Steel ST-37 by continuous painting

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Abstract. Corrosion is a major cause of the failure of the materials; especially in the cutting tools that mostly use carbon steel ST-37. Painting is performed on ST-37 to reduce or protect metal surface from the destructive effects of weather or the occurrence of corrosion. Besides, it is also applied to improve the esthetical and artistic value of metals. This study was conducted to determine how the influence of the current as well as the time of protection on the thickness of paint by continuous painting method. In this method, the specimens are hanged and hooked at the driving belt that put on the coating tub, and then the specimens are moved along tub during the painting process using the motor. The variables used for protection current are 1A, 2A, and 3A, while the variable times of paintings are 30, 45, and 60 minutes. The thickness of painting is investigated by Optical Microscope. As results, the thickness of the paint layer at a current of 1A, 2A, and 3A and time of 30 minutes are 154.15, 166.6 and 172.8 μm . For the coating time of 45 minutes, the thicknesses of the paint layer are 162.4, 181.2, and 191.6 μm . Meanwhile, for a coating time of 60 minutes with same above current, the thicknesses of paint are 235.3, 252.05, and 279.1 μm . The effective protection layer is found at a protective current of 1A, on 30 minutes of coating time with a thickness of paint layer is 154,15 μm .

1. Background

Corrosion is a major cause of the failure of the material. It is not only caused by high content of moisture in the air but also by a high temperature of material during operation. This phenomenon commonly occurs at any tools or some machines that provide heat during their application due to friction, such as cutting tools or vehicle machines. Corrosion can be controlled in many ways, such as good design, material selection, cathodic protection, inhibitor, environment conditioning, and coating. The coating is one of the methods to make material become resist to corrosion. Coating itself has any aims such as decorative and protected purposes [1]. Moreover, the coating can be effective protection to corrosion because it is an effective electrical insulator that can be applied without failed, easy to repair, and become a good initial film in protecting material for a longer time [2]. The coating is a covering process of the metal surface with solution or powder which it will be attached continuously on the protected metal surface after solidification. The protective layer is required to prevent the corrosion because it can hold any atom of oxygen enter into the metal surface. This process can decrease metal intensity to contact with its environment. The widely used of the coating process is a painting. The coating can be classified regarding covered material, such as a polymer (organic and inorganic, ceramic, and metal that employed by electroplating, cladding, hot dip coating, liquid



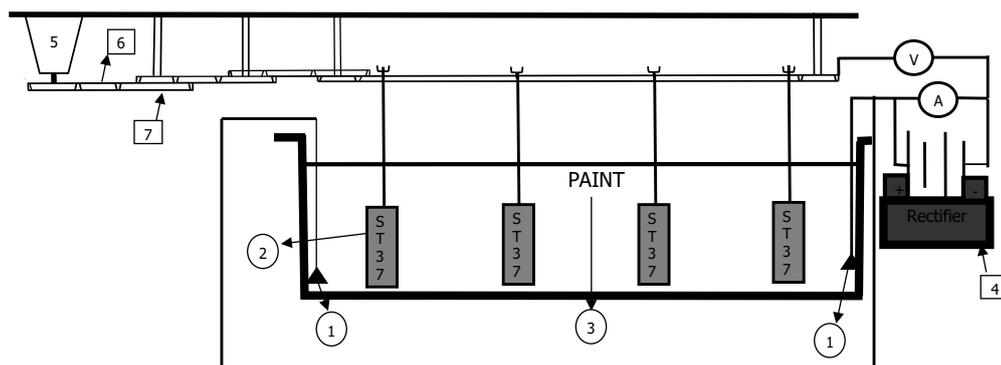
coating or protective coating [3]. Paint is composed of binder, expender, solvent, and additive. They have any important functions in the coating process. Recently, a single painting process with the static mechanism is usually used to protect the material from corrosion in a small quantity. However, there are still few recorded researches on continuous painting. Therefore, this study applies the continuous painting method for the material in a large quantity. The coating current is varied in 1Ampere (A), 2A, 3A with different coating time are 30, 45, and 60 minutes. The thickness of the paint layer then detected by Optical Microscope.

2. Materials and Methods

2.1. Sample preparation

The cylinder sample shape is made from low carbon steel ST-37 with diameter \varnothing of 14mm and length of 65 mm. The substances of the coating are paint and thinner. The rectifier is the main equipment of the coating process that has a function as a source of direct current (DC) with varying voltages. A coating tub is used as a place to immerse the specimens with dimension is the thickness of 5mm, the height of 100 mm, the width of 120 mm, and length of 800 mm.

2.2. Coating process



1. Anode (+) cation
2. Specimen (cathode) (-) Anion
3. Paint
4. Rectifier current (DC)
5. Motor
6. Belt
7. Pulley

Figure 1. The series of coating process by Direct Current (DC)

The Continuous Painting method is used in this as in the following steps:

1. Before coating process, samples after cutting are polished by emery paper. The coating process is carried out at a current of 1A, 2A, and 3A with a time of 30, 45, and 60 minutes.
2. In this process, specimens are hanged and hooked at the driving belt that is put on the coating tub so that the specimens will be moved along tub during the painting process.
3. Finally, the painted specimens are dried at air temperature.

2.3. Paint layer characterization

The thickness of the paint layer is observed by an Optical Microscope by the magnification of 10x; then it is measured by Microsoft Visio.

3. Results and Discussions

3.1. Results

3.1.1. The microstructure of paint layer

Sample photograph after continuous painting at the variation of protective current at 1A, 2A, and 3A and coating time at 30, 45, and 60 minutes are displayed in Figure 2. From this visual observation, it can be seen that the change of thickness of paint layer through colors cannot be distinguished clearly. However, this difference can be detected when it is investigated by an optical microscope as displayed in Figure 3 — the thickness of the paint layer change regarding the variation of coating time and protective current.

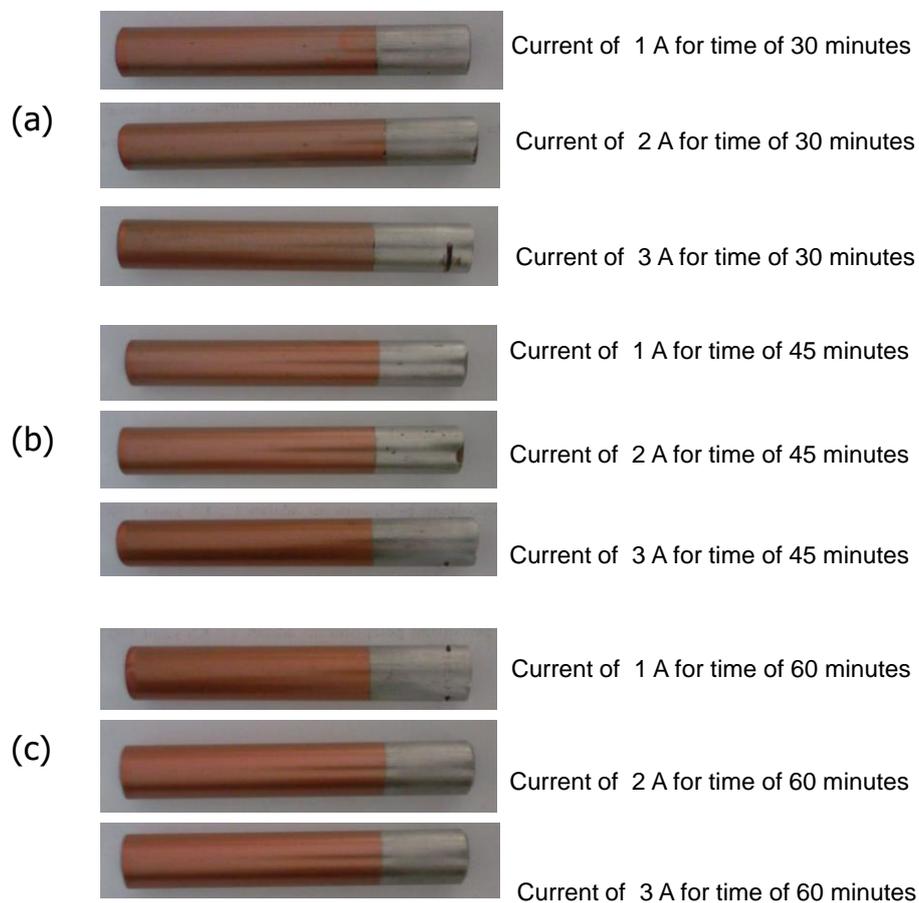


Figure 2. The sample photograph after continuous painting at varies current of 1A, 2A, and 3A at time of 30, 45, and 60 minutes.

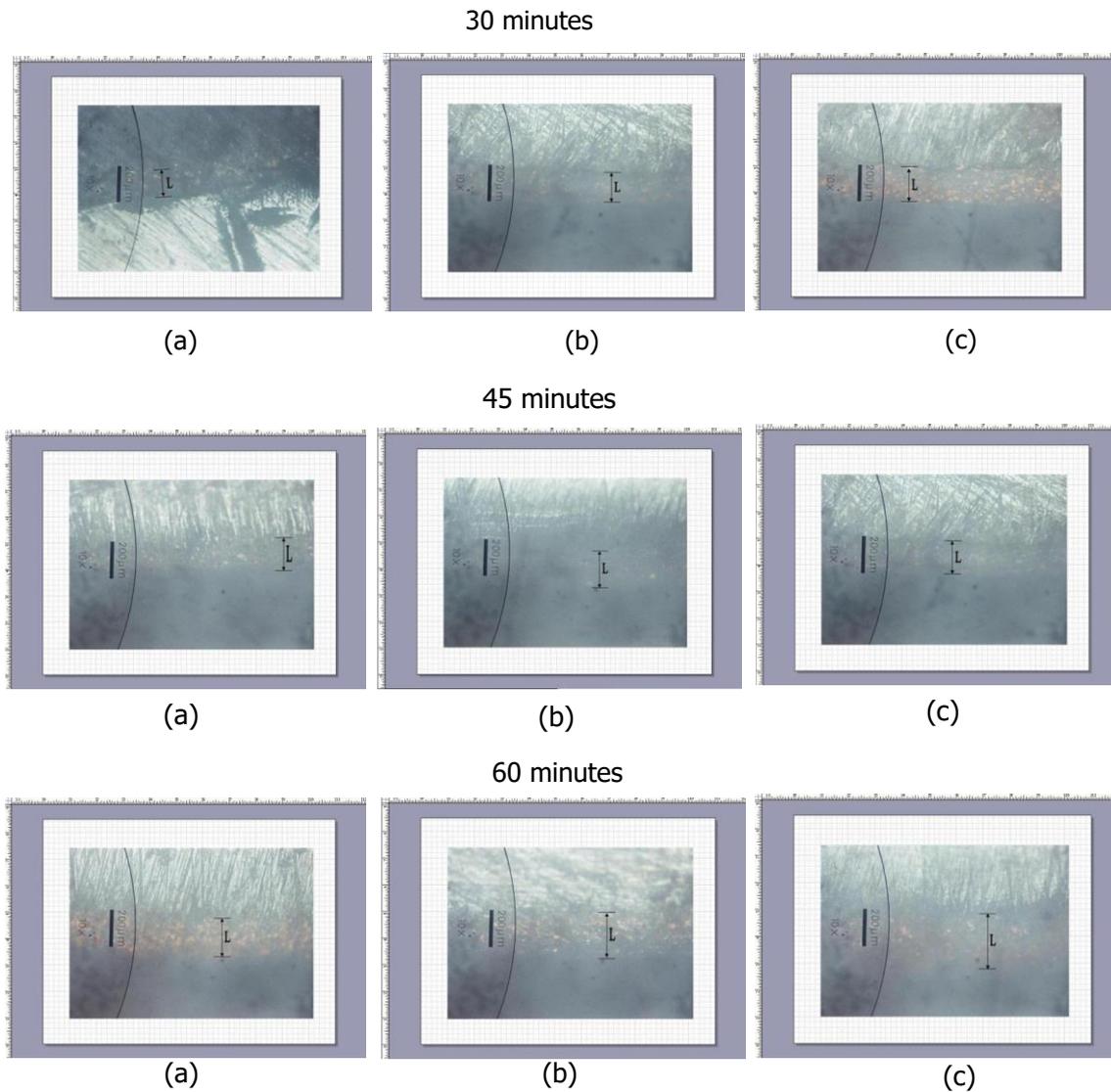


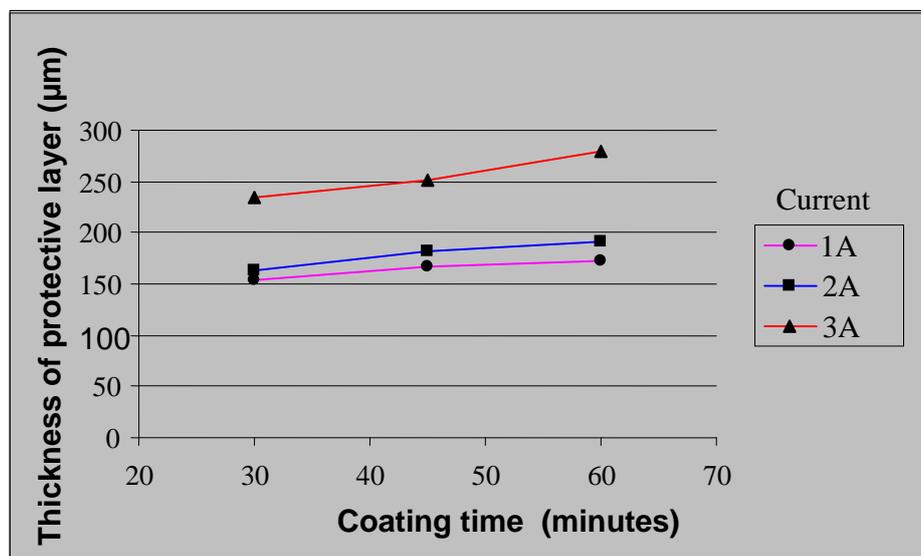
Figure 3. Microstructures of paint layer at 30, 45, and 60 minutes of coating time and difference protective current (a) 1 Ampere, (b) 2 Ampere, and (c) 3 Ampere.

3.1.2. Thickness of Protective Layer. The thickness values of the protective layer with different time and current are displayed in Table 1. When the protective time of 30 minutes and varying current of 1A, 2A, and 3A, the detected thickness layers are 154.15, 166.6, and 172.8 μm . At the same various current and the different time of 45 minutes and 60 minutes, the thickness layers are 162.4, 181.2, 191.6 μm and 235.3, 252.05, and 279.1 μm , respectively.

Table 1. The distribution of thickness of paint layer at different protective time and currents

| No | Time (minutes) | Current (Ampere) | Thickness layer (μm) |
|----|----------------|------------------|-----------------------------------|
| 1 | 30 | 1 | 154.15 |
| 2 | 30 | 2 | 166.6 |
| 3 | 30 | 3 | 172.8 |
| 4 | 45 | 1 | 162.4 |
| 5 | 45 | 2 | 181.2 |
| 6 | 45 | 3 | 191.6 |
| 7 | 60 | 1 | 235.3 |
| 8 | 60 | 2 | 252.05 |
| 9 | 60 | 3 | 279.1 |

The table above is represented in a graph as shown in Figure 4. In this figure, it can be noticed that the thickness of the paint layer gets larger by the rise of the protective time as well as the currents.

**Figure 4.** The relationship among the thickness of the paint layer, coating time and coating current.

3.2. Discussions

3.2.1. Effect of coating time on the thickness of the paint layer

The mechanism of the coating process is a change of metal surface chemically. This means that the metal ions are solved on the metal surface and combined with a crystal which has good adhesion during this process. Through an electrolyte solution, the chemical processes can occur with electricity support [4]. The adhesion characteristic can cause one substance to be attached to another properly. Coating or painting time affects significantly to the thickness of coating layer within which by the longer of coating or protecting time, many electrons can flow and many moles of substances can be

formed on the metal surface. As a result, the paint layer attached to the surface becomes thicker. This condition occurs probably because of the increment of adhesion capability of the layer and the existence of precipitation which is changed to atoms of paint on the metal surface [5]. In the electropainting process, anode and cathode are immersed in paint solution flowed by direct current (DC). From this process, ions of the paint solution will be decomposed and brought onto the metal surface then finally transformed to atoms on the metal.

3.2.2. Effect of protective current on the thickness of the protective layer

Conceptually, in the coating process using direct current, a positive current is moved from high potential to low potential. Consequently, the electrons flow from the high negative potential to the low one. The oxidation process or releasing electron occurs at the anode. Meanwhile a reduction process or taking electrons is taken place at cathode [6]. If the current is applied to this process, it will produce an electron and cause oxidation. Hence, the steel becomes protected. In the direct current system, electrons circulate from negative to positive charges. Oxygen molecules from the electrolyte solution are absorbed into metal surface, and then spread out becomes atoms and ions. Metal ions and oxide combine to form an initial layer. The metal ions appear continuously on the electron surface and diffuse through the oxide layer so that it ionizes the oxygen on the surface. Finally, it will create a potential difference on the metal surface meaning that there is a current flow on the surface. Hence, by increasing the current rate, the number of flowed ions increases. As a result, many moles of substances are produced, and the thickness of the paint layer raises.

3.2.3. Mechanism of film forming on the metal surface. The forming of a thin layer on the metal surface is generated by the oxidation and reduction process as shown in Figure 5. The electrons are moved from a negative pole to those of positive in an electric series. The electrons affect the coating process and the paint layer formation crucially. The mechanism of painting layer formation in this study is called as a convertible mechanism because the convertible layer formed the content of resin or the components form a resin that changes chemically during the forming film process [7].

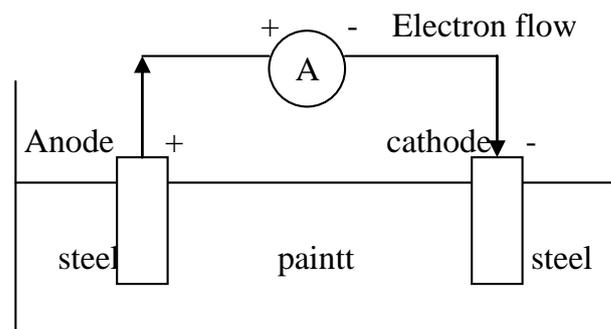


Figure 5. The mechanism of film forming

4. Conclusions

From the results above, it can be concluded;

1. The coating time and current influence the thickness of the paint layer significantly which by increasing the coating time and current, the thickness layer also increases.
2. The greatest thickness of the protective layer (154.15 μm) can be detected at the coating time of 30 minutes and current of 1A.

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