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High electric current and hours can increase layer thickness and decrease white rust corrosion using Zn^{2+} electroplating

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Abstract. Electroplating was the process of coating metal surfaces using the electrochemical method. We used alkaline zinc (Zn^{2+}) plating that was anti-corrosion coating, cheapest, evenly adhesion, as well as better-looking crushing. This study aims to test and measure the thickness of the layer on spark plugs with variations in different electrical currents 300, 400, and 500A and increased hours during the coating process, investigate the corrosion resistance of white rust on the surface and analyze the changes in alkaline zinc concentration and temperature that affect the thickness of the layer, respectively. The results, such as 1st sample 13 pcs, 300A, and thickness of 7.26-micron with white rust 9 pcs. 2nd sample 13 pcs, 400A, and thickness of 9.15-micron white rust 5 pcs. 3rd sample 13 pcs, 500A, and thickness of 12.75-micron white rust 3 pcs. The high electric current (500A) and 45 hours of the experiment would influence the lowest white rust corrosion level. The high alkaline zinc solution with an optimum 36°C solution temperature and 500A electric current would undoubtedly deposit the white rust until 3 pcs.

Keywords: Coating, Electrical Current, Electrochemical, Spark Plugs, White Rust.

INTRODUCTION

Electroplating was depositing a substance or metal ion at the cathode electrode (negative field) with electric current and chemical compounds to transfer the coating metal particles to the material to be coated (Saleh, 2014). During the deposition or deposit process, chemical reactions were experienced on the electrodes and electrolytes; either reduction reactions or oxidation reactions occurred (Basmal et al., 2012). This chemical reaction was expected to last continuously and go in a specific direction (Suarsana et al., 2019). Therefore, a direct current with a constant voltage was required (Setiawan et al., 2019).

In electroplating with an active anode, a metal anode that has high purity was used (Protsenko & Danilov, 2014). An electric current flows from the anode towards the cathode through the electrolyte (Assegaff & Purwanto, 2018). The displacement of metal ions with an electric current through which the electrolyte solution passes so that metal ions are deposited on the coated solid object (Rasyad & Budiarto, 2018). Metal ions are obtained from the electrolyte as well as derived from the dissolution of the metal anode inside the electrolyte (Sabekti et al., 2018). Precipitation has occurred in barrels that contain plate steel as cathodes (Andayani et al., 2017).

The mechanism of metal plating starts from the surrounding of metal ions by polarized solvent molecules (Setiawan et al., 2019). Near the surface of the cathode, an electrical double layer (EDL) area has been formed, that is, the dielectric layer (Grahame, 1947). The presence of EDL provides an additional load for ions to pass through (Schütter et al., 2019). With the thrust force of the difference in electrical potential and assisted by chemical reactions, metal ions would be conducted on the surface of the cathode, and electrons are captured from the cathode by depositing themselves on the surface of the cathode (Rasyad & Budiarto, 2018).

A simple example of the electroplating process of plate steel was when coated with alkaline zinc as an anode and the electrolyte solution containing metal ions to be coated (NA+OH and ZN) (Setiawan et al., 2019). Alkaline zinc (Zn^{2+}) plating was anti-corrosion coating, cheapest, evenly adhesion, and better-looking crushing (Electropoli, 2022). The study for analysis of plated steel was interesting, as well as the thickness levels based on the electroplating using alkaline zinc. This study aims to test and measure the thickness of plated steel on spark plugs with variations in different electrical currents and increased hours during the coating process, investigate the corrosion resistance of white rust on the layer surface, analysis the changes in alkaline zinc concentration and temperature that affect the thickness of the layer, respectively.

METHODOLOGY

The study included coating thickness measurements of thin layers on plated steel with increased electric current (300A, 400A, and 500A). Testing the disposition of white rust on plated steel (like corrosion investigation, as well as white rust as the main factors) with Salt Spray Test (Altmayer, 1985; Ito et al., 2020). Testing against the changes in the alkaline zinc concentration to the coating's thickness. Testing is also carried out on changes in the temperature of the alkaline zinc at the thickness of the layer.

The materials used MP0R Thickness Gauge, FISCHER FISCHERSCOPE X-RAY XDLM 237 Coating Thickness Meter (Programmable, motor-driven XY-stage), spark plugs (Fig. 1), as well as Salt Spray Test was occurred to evaluate the corrosion of white rust (Fig. 2).

Figure 1. Spark plug layer anatomy.

Figure 2. Salt Spray Test process of this study.

In Figure 2, the anatomy of the spark plug layer includes hex steel and thread, which would be the plated steel. So the coating thickness (layer) testing includes hex steel, thread, as well as plated steel layer. Plating procedures occurred, including (1) effects of thickness layer level with electrical current 300A, investigation of the corrosion of white rust based on plated steel thickness tested; (2) effects of thickness layer level with electrical current 400A, investigation of the corrosion of white rust based on plated steel thickness tested; (3) effects of thickness layer level with electrical current 500A, investigation of the corrosion of white rust based on plated steel thickness tested; (4) effects of different alkaline zinc concentration for the coating; and (5) effects of different temperature for the coating. All procedures were completed based on the different hours of experiments (maximum is 45 hours).

RESULTS AND DISCUSSION

300A Experiment Results

Experiments with 300A electric current for thickness layer evaluation within a maximum of 45 hours are presented for hex steel (Fig. 3), thread (Fig. 4), and plated steel (Fig. 5), as well as white rust disposition (Fig. 6).

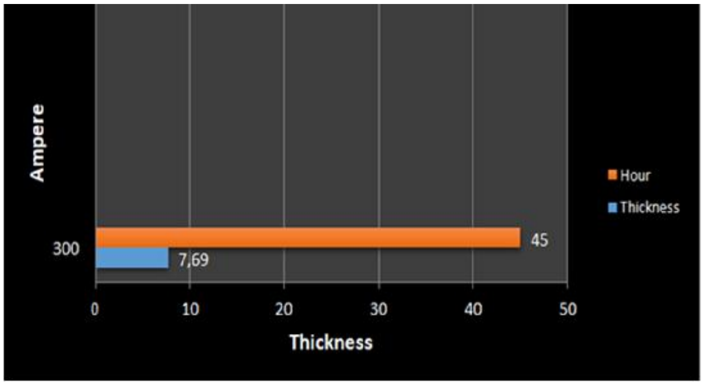

Figure 3. Hex steel thickness level experiment with 300A.

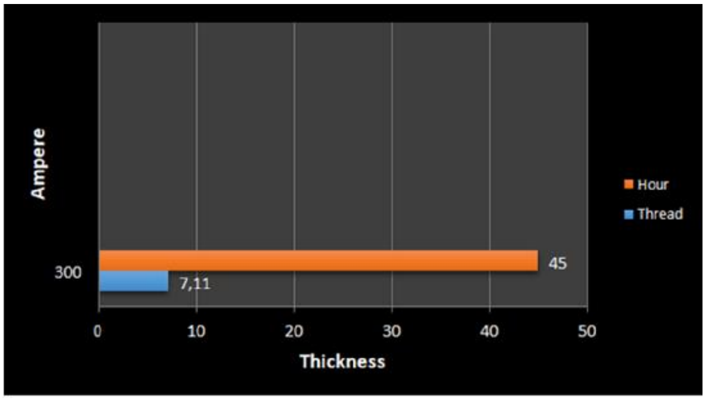

Figure 4. Thread thickness level experiment with 300A.

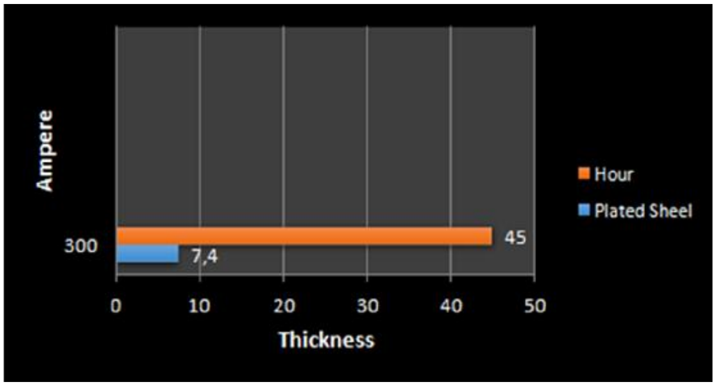

Figure 5. Plated steel thickness level experiment with 300A.

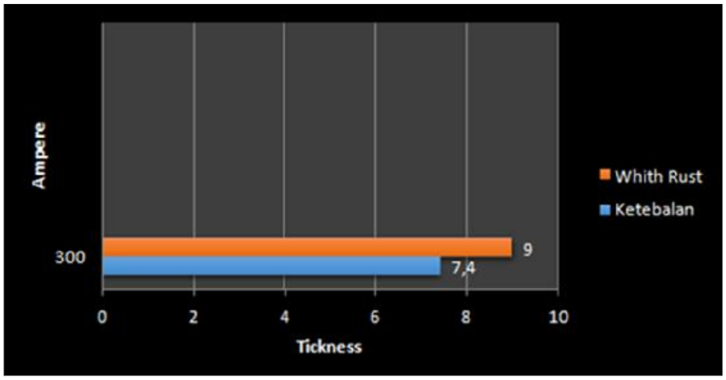

Figure 6. Plated steel thickness level experiment with white rust deposition result.

400A Experiment Results

Experiments with 400A electric current for thickness layer evaluation within a maximum of 45 hours are presented for hex steel (Fig. 7), thread (Fig. 8), and plated steel (Fig. 9), as well as white rust disposition (Fig. 10).

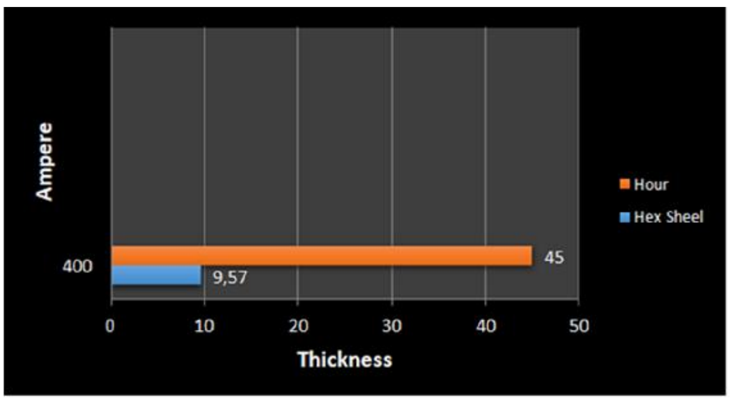

Figure 7. Hex steel thickness level experiment with 400A.

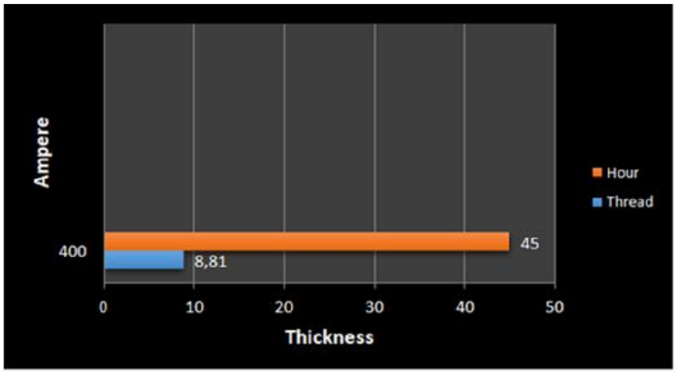

Figure 8. Thread thickness level experiment with 400A.

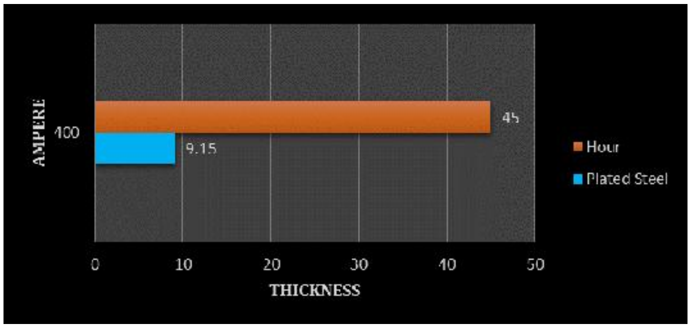

Figure 9. Plated steel thickness level experiment with 400A.

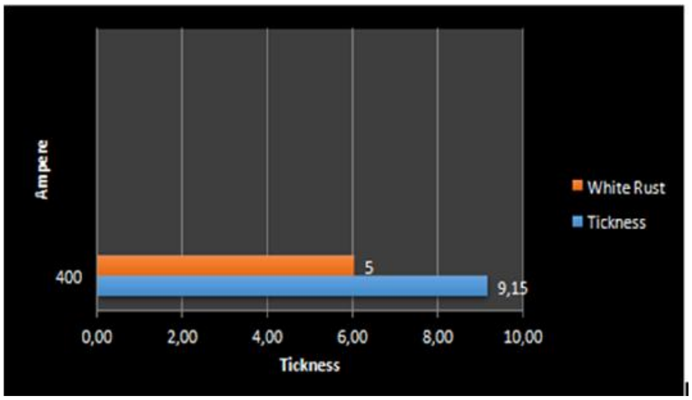

Figure 10. Plated steel thickness level experiment with white rust deposition result.

500A Experiment Results

Fig. 11 shows the experiment result of hex steel thickness level within a maximum of 45 hours. Fig. 12 explains the experiment result of thread thickness level for a maximum of 45 hours. Fig. 13 shows the experiment result of plated steel thickness level for a maximum of 45 hours, as well as Fig. 14 with the white rust disposition result.

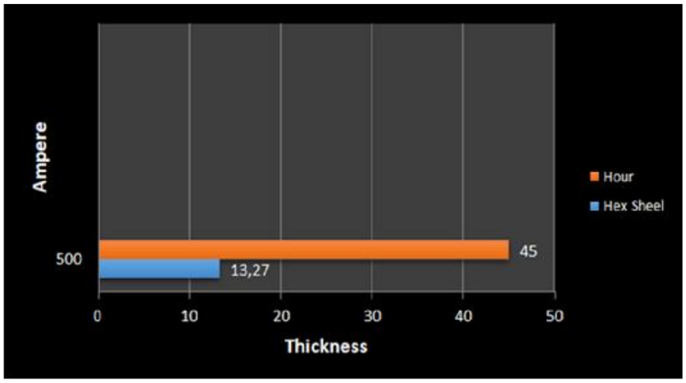

Figure 11. Hex steel thickness level experiment with 500A.

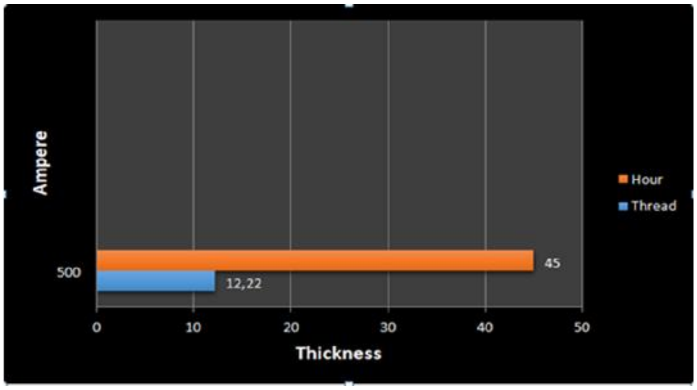

Figure 12. Thread thickness level experiment with 500A.

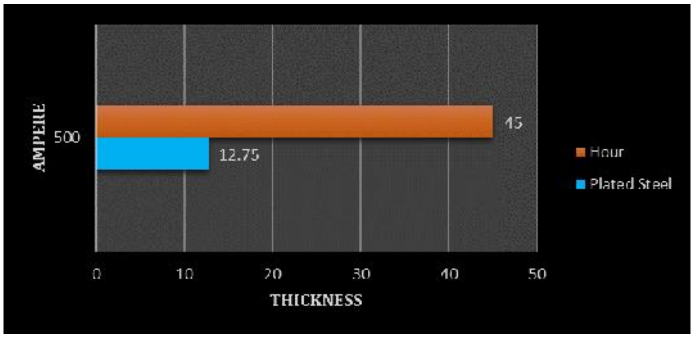

Figure 13. Plated steel thickness level experiment with 500A.

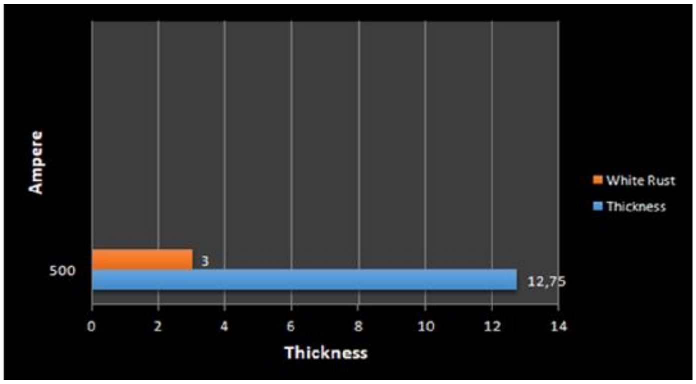

Figure 14. Plated steel thickness level experiment with white rust deposition result.

Alkaline Zinc Concentration and Temperature Experiments

The test results of the change in the concentration of alkaline zinc solution against the thickness of the plated steel layer with an experimental time of 45 hours are presented in Figure 15. The test results of changes in the concentration value of alkaline zinc solution at the temperature variation of the solution to the thickness of the plated steel layer with an experimental time of 45 hours are presented in Figure 16. The results of the alkaline zinc solution concentration test (14-17 g/liter) against changes in temperature and thickness of the plated steel layer are presented in Figure 17. The best concentration of alkaline zinc (15 g/liter) is determined with different electrical currents and temperatures against the evaluation of white rust corrosion, as seen in Figure 18.

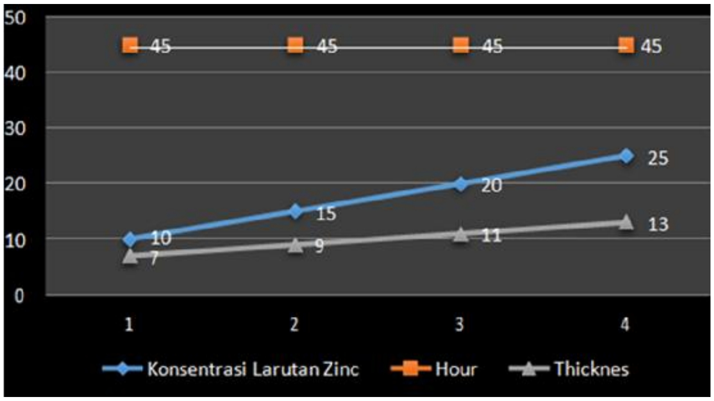

Figure 15. Results of the change in the concentration of alkaline zinc solution (10, 15, 20, 25 g/liter) against the plated steel layer thickness with 45 hours of experimental time.

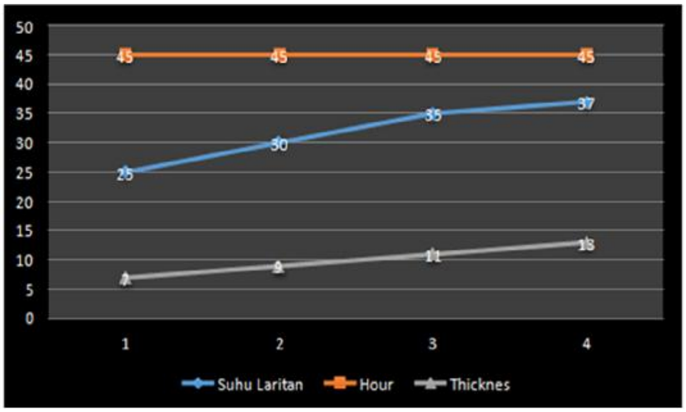

Figure 16. Results of different temperatures of alkaline zinc solution (10, 15, 20, 25 g/liter) against the plated steel layer thickness with 45 hours of experimental time.

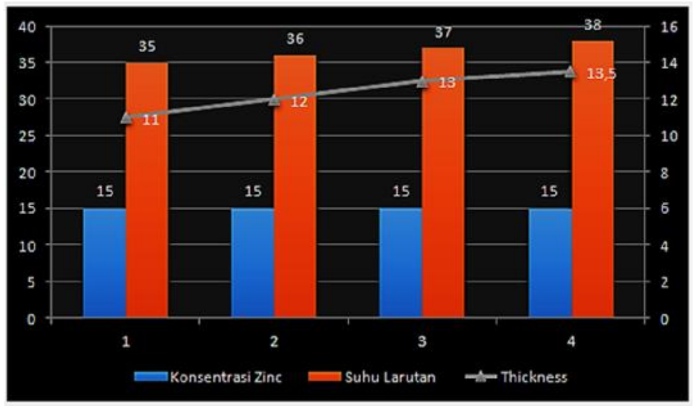

Figure 17. Results of the best concentration of alkaline zinc solution (15 g/liter) with increased electrical current (1 is 400A, 2 is 450A, 3 is 500A, 4 is 600A) and different temperatures against the evaluation of white rust corrosion.

Discussion

The different electric currents can affect the thickness level as well as white rust corrosion. Based on 300A experiments, alkaline zinc can coat the spark plug layers (increased layer thickness, Fig. 3,4,5) and then make plated steel thickness final value (7.40µm) (Fig. 5). This electric current can deposit the white rust until 9 pcs level (Fig. 6). Based on 400A experiments, alkaline zinc can coat the spark plug layers (increased layer more thickness, Fig. 7,8,9) and then make plated steel thickness final value (9.15µm) (Fig. 9). This electric current can deposit lower than previous electric current 300A the white rust until 5 pcs level (Fig. 10). Based on 500A experiments, alkaline zinc can coat the spark plug layers (increased layer very thickness, Fig. 11,12,13) and then make plated steel thickness final value (12.75µm) (Fig. 13). The 500A electric current can deposit lowest white rust corrosion until 3 pcs level (Fig. 14). So, the optimum layer thickness used in this study is within the electric current of 400–500A, and the corrosion rate of white rust decreases.

The best alkaline zinc concentration is about 14–17g/liter (estimated is 15 g/liter) then obtained a plated steel layer thickness of 12.75µm (Fig. 15) with a temperature of 36°C (Fig. 16) and a slowed growth rate of white rust (Fig. 17). With this experiment results, the 15 g/liter concentration of alkaline zinc can affect the optimum thickness of the plated steel layer as well as lowest white rust corrosion, which is the higher electric current experiment (500A in this study).

According to Setiawan et al. (2019), zinc solution can be used for material (metal) plating that is easily contaminated with environmental air, which would be affected to be corrosion (white rust or red rust). This study is related to the condition of the material, a spark plug containing metal materials (Fig. 2), as well as the coating results, which prove that alkaline zinc is a good coating solution for that material.

According to Setiawan et al. (2019), the optimum electric current and time in the zinc coating process are 900A, and in one hour, the SGD400 steel thickness level is about 15µm. For the corrosion investigation, the best moments for no corrosion are about 72 hours (no white rust) and 168 hours (no red rust). In this study, the optimum electric current and time are 500A and 45 hours, as well as the spark plug's plated steel thickness level, is about 12.75µm. The corrosion investigation shows that 45 hours can reduce the white rust corrosion until the level of 3 pcs. So, the Salt Spray Test method would decrease corrosion levels (Setiawan et al., 2019).

Another research conducted by Selly et al. (2020) that used silver (Ag) coating inside zinc (Zn) would affect the copper (Cu) substrate as well as the more extended time of the coating process. Another research also reported that silver (Ag) coating could be used to better coat the aluminum (Al) with high electric current and experiment times (Sungkowo et al., 2021). That research also reported substrate color changes based on that experiments. Instead, zinc (ZN) or silver (Ag), the standard coating solution for experimenting with electric currents, and increase the electric currents would undoubtedly increase the thickness layer (Sabekti et al., 2018).

CONCLUSION AND RECOMMENDATION

The alkaline zinc (ZN) solution is the standard coating material that can affect the thickness of the layer; within the high electric current (500A) and 45 hours of the experiment would influence the lowest white rust corrosion level. The high alkaline zinc solution with an optimum 36°C solution temperature and 500A electric current would undoubtedly deposit the white rust until 3 pcs.

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