EMPD 1 (2) Nopember 2022, 46-52 ISSN 2964-6987
Energy, Materials and Product Design
https://journal.unram.ac.id/index.php/empd

THE EFFECT OF NICKEL ELECTROPLATING ON THE SURFACE HARDNESS OF LOW CARBON STEEL

Salman*, Ardi Wiranata, Sinarep, Paryanto Dwi Setyawan

Dept. of Mechanical Engineering, Faculty of Engineering, University of Mataram, Jl. Majapahit no. 62 Mataram, NTB, 83125, Indonesia

**Corresponding author*
*E-mail addresses:*salman@unram.ac.id

ABSTRACT

Electroplating on steel is basically established with the aim of protecting the surface of the materials. It is necessary to identify the quality surface of steel that has undergone electroplating. This research is determining the electroplating time and the best anode and cathode distance to the surface hardness in the nickel electroplating process on low carbon steel. The method was carried out by placing the specimens into an electrolyte solution. Then the hardness of the specimens was measured. The result shown that the highest hardness number of coating nickel of ST-37 steel was 246.7kg/mm^2 that was obtained with plating time was 12 minutes and the distance between the anode and cathode was 150mm. By statistical analysis the coating time significantly affected the surface hardness.

Keywords: *Electroplating, Surface hardness, Nickel electroplating, ST-37 steel, Statistical analysis*

1. Introduction

Manufactured products from metal require finishing to make them more attractive and durable. Currently, the electroplating industry has developed a lot that works on vehicle engine parts such as swing arms, drums, shafts and other engine components. Electroplating is the process of coating an object with another metal that utilizes electricity in an electrolyte liquid [1] and [2]. The electroplating process has several factors that influence the mechanical characters of the materials such as potential difference, current density, layer thickness, temperature, concentration, and coating time. The basic principle of electroplating is the placement of metal ions plus electrons originating in the electrolytic solution of the coated metal. The ions are obtained from the anode and electrons from the electrolyte solution [3] and [4].

Many materials can be used in the electroplating process they are tin, zinc, nickel, chrome, copper, silver, and aluminum plating. All of these materials can be used as coating materials because they have many advantages including preventing corrosion, beautifying the appearance of the materials and improving the expected mechanical properties. In case of electroplating on steel it is basically conducted with the aim of protecting the steel surface from corrosion attack because the coating metal prevents the interaction the metal surface with the environment that avoids the oxidation process [5].

Electroplating has been studied by many researchers for instance a study on the effect of temperature and time of electroplating copper-nickel plating on low carbon steel on thickness and hardness values [6]. From the results it was obtained that the thickness of the copper layer is 42.8 m at temperature of 40^{o}C with a time of 10 minutes, while for the nickel layer is 65.4 mm at temperature of 65^{o}C with a time of 20 minutes. As the operating temperature increases, the surface hardness and coating thickness increase as well.

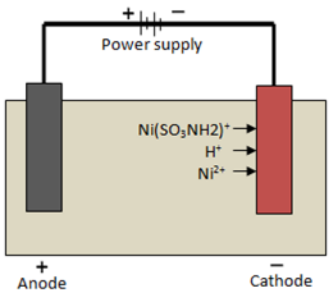

Figure 1 The cell is filled with electrolyte that contains nickel that deposited on the surface of the targeted material [8]

Beforehand a study was conducted to observe the effect of nickel on copper [7]. The results of the research showed that the thickness of the coating increased, namely at 5 minutes of nickel plating the thickness was 14.1 mm to 55.77 mm with the time of 25 minutes of plating.

Meanwhile relating to the combination of the immersion pH treatment, it was obtained that there was a difference in the mass of nickel on low carbon steel due to variations of pH in electrolyte solution with a significance level of 95 %. The nickel plating process using the electroplating method for low carbon steel materials should be carried out at a pH that has an acidity level of pH 3.00 in the nickel plating process [9]. Meanwhile with different approach focused on the coating time and the electric current relating to the weight of the sample. From several voltage variations and electroplating time, it was found that the highest weight gain was achieved at 6 A current and at 2400 s of 1.52 g, and the lowest weight gain occurred at 2.5 A current and at 600 s of 0.37 g [10]. Therefor the relationship between electroplating current and time is very influential on the encroachment of weight. The longer the time and the higher the electric current, the more weight was gained.

To determine the quality of a material, hardness testing is closely related to how strong the material supports a certain load, therefore a test is carried out to determine how strong the material withstands blows and friction forces. Several parameters that affect the results of coating using electroplating include the plating time. This research discusses the effect of nickel electroplating time and the distance between anode and cathode on low carbon steel and its surface hardness. Therefore, the purpose of this study was to determine the electroplating time and the best anode and cathode distance to surface hardness in the nickel electroplating process on low carbon steel. The illustration of electroplating process by using nickel plating is shown in Figure 1.

2. Materials and Method

The tools those be used in this research were rectifier to convert AC into DC current, cutting grinding machine was used to cut the specimen according to the specified size, drilling machine was used to make holes in the specimen, polishing machine was used to smooth the surface of the specimen before the electroplating process was carried out, stopwatch was used to calculate electroplating time, micro hardness test equipment was used to test the hardness of the specimen and to determine the value of the hardness of the specimens. The materials were used in this research were ST 37 plate (as the cathode) with size 100 mm long, 30 mm wide, and 3 mm thick (Figure 2), coating anode nickel (Ni) plate (as the anode) (Figure 3) and electrolyte solution.

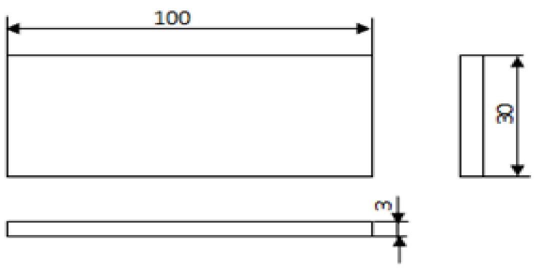

Figure 2 Steel plate (as the cathode) with size 100 mm long, 30 mm wide, and 3 mm thick

Figure 3 Nickel plate as anode

Figure 4 The process of coating plating

Materials were weighed according to the specified composition. The distilled water was heated to a temperature of 60ºC. The nickel sulfate, nickel chloride and boric acid were stirred until evenly mixed or the solution became homogeneous. The brightener I-06 and M-07 were added into the solution and mixed thoroughly with the solution. After the solution was all well mixed, the solution was ready to use. The specimens were flattened and smoothed with sand paper until they were completely shiny.

2.1 Coating Process

Coating was done in the following way:

a. Bonding the nickel plating (anode) with a copper wire connected to the rectifiers (power supplies) (Figure 4).
b. Connect the copper wire connected to the rectifier (power supply) to the specimen as the anode.
c. Wrap the nickel plating with a filter cloth so that the plating results are smooth.
d. Turn on the power button on the rectifier (power supply) and insert the nickel plating (anode) into the solution.
e. Put the specimen into the plating bath containing the electrolyte solution with a certain distance between the anode and cathode and make sure the specimen is completely submerged with the electrolyte solution.
f. After the time has elapsed, remove the specimen from the bath filled with the electrolyte solution.
g. Clean the specimen using clean water, and then dry it using a clean cloth.
h. Measure the thickness of the specimen using a micrometer screw and a microscope then record the measurement results.

2.2. Micro Hardness Tester

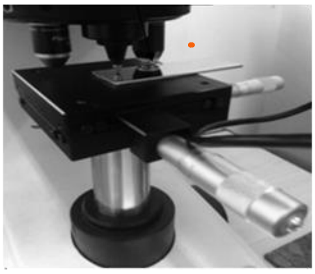

Figure 5 The Vickers hardness test

The hardness testing was carried out to determine the change in the surface hardness of the specimen due to the nickel plating process. The test was completed at the Laboratory in the Department of Materials and Metallurgical Engineering, Faculty of Industrial Technology, Sepuluh November Institute of Technology, Surabaya.

Previously the ST 37 steel has been already treated by nickel plating with variations in plating time and the distance variations between the anode and cathode. The test was attained by using a micro hardness tester machine (Vickers Hardness Test TH 710) [11] (Figure 5) with a diamond indenter in the form of a pyramid with an angle of 136, a large compressive load *P* (kg) of 50 kg and the pressing time of 10 s. The specimen was placed under the microscope and the lever was turned in order to the specimen focused only under the indenter. The indenter then was pressed into the test object or material. The pressing was held for about 10 s. The diagonals of the indentation of the square (rhombus) were studied by using that microscope to ensure the proper position. Carefully the area of indention *A* (mm^2) the average of the diameter of indenter *D* (mm) were measured. After that the button was pressed on the lever to find out the hardness value that appeared on the screen. The hardness number *HV* (kg/mm^2) was calculated as:

$$HV = \frac{P}{A} \quad (1)$$

$$A = \frac{D}{2cos22^2} \quad (2)$$

3. Results and Discussion

The results are agreeing with the previous research [6] and [7]. Where it is known that the thickness of the coating increased as the plating time is longer [9]. It means the coating time and the distance between the anode and cathode affect the hardness of the surface of the specimens. From Table 1, it is shown that when the coating time increases while the distance between the anode and cathode was reduced, the hardness values increase. This is because the coating time has an impact on the deposition of ions on the cathode surface and further contributes in increasing the surface hardness.

If the standard deviation value is much greater than the average value or vice versa the standard deviation is very small, then the average value can be used as a representation of the entire data. Therefor the standard deviation of the surface hardness test is 0. The data for calculating the standard deviation for each specimen is shown in Table 2.

Table 1 Surface hardness test result data

Variations	Code of specimen	Diameter of indenter (D) (μm)	The average of diameter of indenter (μm)	Vickers hardness (HV) (kg/mm²)	Average of Vickers hardness (HV)(kg/mm²)	Standard Deviation (S)
	TP	25.23	25.23	145.6	145.6	0
		25.23		145.6		
		25.23		145.6		
6 min, 150 mm	A1	23.01	23.50	175.1	167.9	6.235
		23.75		164.3		
		23.75		164.3		
6 min, 200 mm	A2	24.05	23.93	160.3	161.9	2.771
		23.69		165.1		
		24.05		160.3		
6 min, 250 mm	A3	24.35	24.35	156.3	156.7	1.401
		24.20		158.3		
		24.49		155.6		
9 min, 150 mm	B1	22.37	22.31	185.3	186.4	5.981
		21.92		192.9		
		22.63		181.1		
9 min, 200 mm	B2	23.11	23.11	173.5	173.5	0
		23.11		173.5		
		23.11		173.5		
9 min, 250 mm	B3	23.53	23.51	167.5	167.7	0.173
		23.50		167.8		
		23.50		167.8		
12 min, 150 mm	C1	19.59	19.45	242.1	246.7	27.931
		18.30		276.6		
		20.47		221.3		
12 min, 200 mm	C2	22.18	21.82	188.5	195.3	13.00
		21.01		210.3		
		22.26		187.1		
12 min, 250 mm	C3	22.48	22.48	183.5	183.5	0
		22.48		183.5		
		22.48		183.5		

Table 2 Data to find the standard deviation of each specimen

No.	Code	Xi	Xi^2
1	TP	145,6	21199,36
		145,6	21199,36
		145,6	21199,36
	∑	436,8	63598,08

From Figure 6 the result shows the variations in plating time and the distance between the anode and cathode. The best hardness value 246.7 kg/mm^2 was obtained at the plating time of 12 min with the distance between the anode and cathode was 150 mm. In this condition, the hardness value increase. While the lowest hardness value 156.7 kg/mm^2, was obtained at the coating time 6 minutes and the distance between anode and cathode was 250 mm. Material hardness testing aims to determine the resistance of a material to plastic deformation when the material is given an external load.

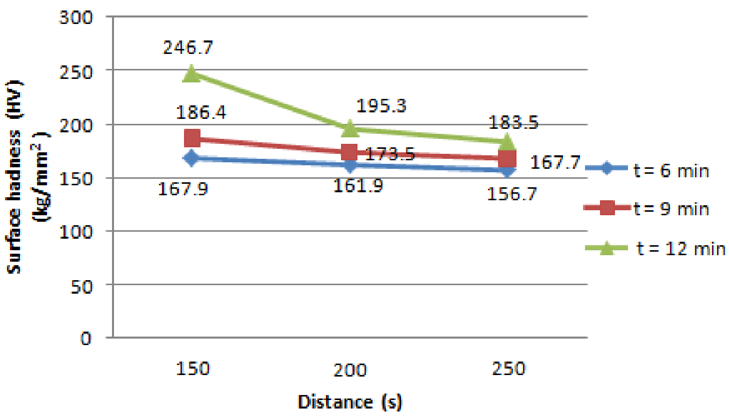

Figure 6 The surface hardness of the steel ST 37 by nickel coating relating to the distance of the plates

It means because the nickel coating has the role to increase the hardness of the surface layer. It can be seen clearly the surface hardness value increases compared to before being coated. The results were validated by two-way ANOVA statistic for the total surface hardness with the nickel layer (see Table 3).

Table 3 ANOVA test of surface hardness number

Source of variation	SS	df	MS	F_{count}	P_{value}	F_{table}
Distance	7660.879	8	957.6098	2.575832	0.051035	2.591096
Time	6144.405	2	3072.203	8.263781	0.003427	3.633723
Error	5948.275	16	371.7672			
Total	19753.56	26				

4. Conclusions

Electroplating on steel is basically established with the aim of protecting and beautifying the steel surface. This research is determining the electroplating time and the best anode and cathode distance relating to the surface hardness on low carbon steel that is treated with nickel electroplating process. The results show that the hardness value of ST-37 steel after coated by nickel is affected by plating time and the distance between the anode and cathode. There is the linear correspondence among the time indention, coating thickness and the hardness of the surface of specimens. By statistical analysis with ANOVA the result validates the experiment and the previous hypothesis where the coating time greatly affects the surface hardness value.

Notation

HV Vickers hardness value (kg/mm^2)
A area of indention (mm^2)
P indenter load (kg)
D diameter of the indenter (μm)
S2 variance
S standard deviation
x_i i-th
x value
n sample size

References

[1] N. Kanani, Electroplating: Basic Principles, Processes and Practice, Atotech Deutschland GmbH, Berlin, Germany, ISBN 978-1-85617-451-0, 2004.

[2] W. Sha, X. Wu and K.G. Keong, Electroless Copper and Nickel–Phosphorus Plating Processing, Woodhead Publishing, ISBN 978-1-84569-808-9, 2011.

[3] R. Selly, S. Rahmah, H.I. Nasution, R. A. Syahputra, M. Zubir, Electroplating method on copper (cu) substrate with silver (ag) coating applied, Indonesian journal of chemical science and technology (IJCST), 3 (2) (2020) 38-41.

[4] O.S.I. Fayomi, I. G. Akande, A. A. Sode, A review on the efficacy of electroplating in deteriorating environments international conference on engineering for sustainable world, IOP Publishing (2019) 1378.

[5] W. Giurlani, G. Zangari, Electroplating for decorative applications: recent trends in research and development, Coatings, 8 (8) (2018) 260-269.

[6] A. Stephani, S. Oediyani, Y. Lestari, E. Mabruri, Effect of nickel pulsed electrode position parameters on deposit microstructure and corrosion rate AISI 410, Widyariset, 4 (2) (2018) 56-62.

[7] S. Basavanna and J. Shankarrao Kavirajwar, Investigation of nucleation mechanism and surface morphology of the crystallites in zinc-cobalt alloy coating, JEPT – Journal of Electrochemistry and Plating Technology, 23 (16) (2021) 34-45.

[8] T. Oloruntoba, A. Oghenedoro, Effect of Some Process Variables on Nickel Electroplating of Low Carbon Steel, Leonardo Electronic Journal of Practices and Technologies, 10 (18) (2011) 79-94.

[9] C. Sherwin, S. Bhat and S.P. Hebbart, A brief review on nickel and chromium coatings developed by electrochemical route, AIP Conference Proceedings, 2236 (2020) 04000.

[10] H. A. Wahab, M. Y. Noordin, S. Izman, and D. Kurniawan, Quantitative Analysis of Electroplated Nickel Coating on Hard Metal, 13 (45) (2013) 25-32.

[11] ASTM Hand Book, Properties & selection, iron steels and high performance alloy, 10th Edition, ASTM International Handbook Committee, USA, 1990.