International Journal of Advances in Scientific Research and Engineering (ijasre)

E-ISSN : 2454-8006

DOI: 10.31695/IJASRE.2022.8.9.5

Volume 8, Issue 9
September - 2022

Experimental Study of effect of Powder Coating thickness and layers on Hardness and Corrosion properties of Carbon Steel Material

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ABSTRACT

Powder coating is one of the coating techniques that are widely used today as a substitute for coating using liquid painting. In this research, we report on the effect of the various layers of powder coating on the hardness and corrosion rate of the material. Three different layers of variation were observed with 1, 2, and 4 layers to obtain the best results. The cleaning process was applied before coating the samples. The coating process was performed in a special room/box to avoid contact with air and contamination from the outside environment with a spraying distance of about 20-30 cm. The morphology is compact and bigger grains are seen to be emerging in the 1 layer deposition. Many grains are visible, and uniform grains are distributed in the 2 layers deposited. For the 4 layers, due to higher layer deposition incorporation, the grain size is seen to be enlarged due to the merging of smaller grains with each other ultimately increasing the grain size. The uncoated material has a corrosion rate of 0.505 mm/year which means fair for the relative corrosion resistance. The coated samples have a corrosion rate of 0.353, 0.252, and 0.354 mm/year for the 1 layer, 2 layers, and 4 layers, respectively. Based on the calculation, the average number of the Rockwell hardness of un-coated and coated samples for the 1 layer, 2 layers, and 4 layers, respectively were estimated at about 70, 78, 79, and 58 HRB, respectively. The highest average hardness value is in sample B with 2 layers of 79 HRB. The lowest average hardness value is in sample B with 2 layers of 58 HRB. The lowest performance of sample D with 4 layers confirms the result as shown in the corrosion rate result.

Key Words: Coating, Layer, Corrosion, Hardness, Powder Coating.

1. INTRODUCTION

The surface process technique consists of a cleaning process, surface treatment and a coating or thin layer deposition process. Nowadays, industries need innovation and novelty in surface processing techniques. Metal plating is one of the finishing techniques in a production process that is widely used. Based on theory, the coating is a process of deposition of coating material into a parent surface using either electrolytic or non-electronic techniques. There are many advantages obtained from the coating process, especially coating with powder coating, among others: thick adhesive properties, thick surface, able to close pores perfectly, environmentally friendly, and thicker color [1]. Coating technique using powder is one of the coating techniques that are widely used today as a substitute for coating using liquid painting [2, 3]. Conventional painting techniques that cause many detrimental effects have begun to be abandoned in coating techniques. Apart from better quality results, powder coating techniques also have the advantage of being environmentally friendly because conventional techniques generally contain a lot of harmful organic compounds [4-7].

Based on the consideration of those advantages, metal coating with powder coating was carried out in this study. Layer variations will be applied to samples with 1, 2 and 4 layers to obtain the best results. Samples were cleaned by degreasing and rinsing processes and then heated at 200^0 C. The hardness and corrosion resistance tests were applied to test the quality of the coating.

2. EXPERIMENTAL PROCEDURE

The samples were coated by using the Wagner Prima EGP-2008 manual powder coating system. Sterling powder coatings has been used to coat the samples (Fig. 1). The A36 as medium carbon steel was used for the specimen. The samples specimen for the coating with a dimension of 50 mm × 50 mm × 0.8 mm. In the first step, the sample was sanded and cleaned using phosphoric acid liquid. The cleaning process using phosphoric acid aims to remove dirt from the sample and then rinse with water. In this research, three different layers of variation were observed with 1, 2, and 4 layers to obtain the best results. The coating process was performed in a special room/box to avoid contact with air and contamination from the outside environment with a spraying distance of about 20-30 cm. The microstructures of the samples coating are observed by using optical microscope. The macro Rockwell hardness tester was used for macro-hardness measurements with ASTM A36 standard. The averages of hardness tests of the samples were taken and compared from at least 3 different areas. Corrosion resistance was tested using H2SO4 solution. The samples coated were immersed in a corrosive medium for 7 days (168 hours). Corrosion resistance calculation parameters are applied according to equation 1.

$$\textbf{Corrosion rate}\ (\mathbf{mm/year}) = (\mathbf{87,6}\ \times \mathbf{W})/(\mathbf{D} \times \mathbf{A} \times \mathbf{T}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ \mathbf{Eq.1}$$

Where W is weight loss (mg), d is density (g/cm3), A is the specimen area (cm2), and T is the exposure time (hours) [8]. The level of resistance of a material to corrosion generally has a corrosion rate value between 1-200 mpy or 0.02-5 mm/year. Table 1 shows the classification of the level of material resistance based on the corrosion rate.

Fig 1. The powder coating equipment consists of Wagner Prima EGP-2008, furnace, and room/box for spray coating.

Table 1. The classification of the level of material resistance based on the corrosion rate [9].

Relative Corrosion Resistance	Approximate Metric Equivalent				
	mpy	mm/year	μm/yr	nm/yr	pm/sec
Outstanding	< 1	< 0.02	< 25	< 2	< 1
Excellent	1-5	0.02-0.1	25-100	2-10	1-5
Good	5-20	0.1-0.5	100-500	10-50	5-20
Fair	20–50	0.5-1	500-1000	50-100	20-50
Poor	50-200	1-5	1000-5000	150-500	50-200
Unacceptable	200+	5+	5000+	500+	200+

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3. RESULT AND DISCUSSION

Figure 2 shows the microstructure of sample on different layer deposition. The microstructure of all samples consisted of ferrite and pearlite [10]. As seen from microstructure (2a), the morphology is compact and bigger grains are seen to be emerging in the 1 layer deposition. As for sample (2b), many grains are visible, and uniform grains are distributed in the 2 layers deposited. For the sample (2c), due to higher layer deposition incorporation, the grain size is seen to be enlarged due to the merging of smaller grains with each other ultimately increasing the grain size.

Table 2 shows the data calculation for the corrosion rate analysis. The data are taken from all samples after being immersed an H2SO4 solution. Fig. 2 clearly seen the different between the uncoated and coated material. The uncoated material has a corrosion rate of 0.505 mm/year which means fair for the relative corrosion resistance (table 1). The coated samples have a corrosion rate of 0.353, 0.252, and 0.354 mm/year for the 1 layer, 2 layers, and 4 layers, respectively. All the samples coated were in zone "good" in the relative corrosion resistance (table 1). Interesting results were observed, the corrosion rate was decreased after being coated 2 layers. The 4 layers sample has degradation of performance which has increased the corrosion rate.

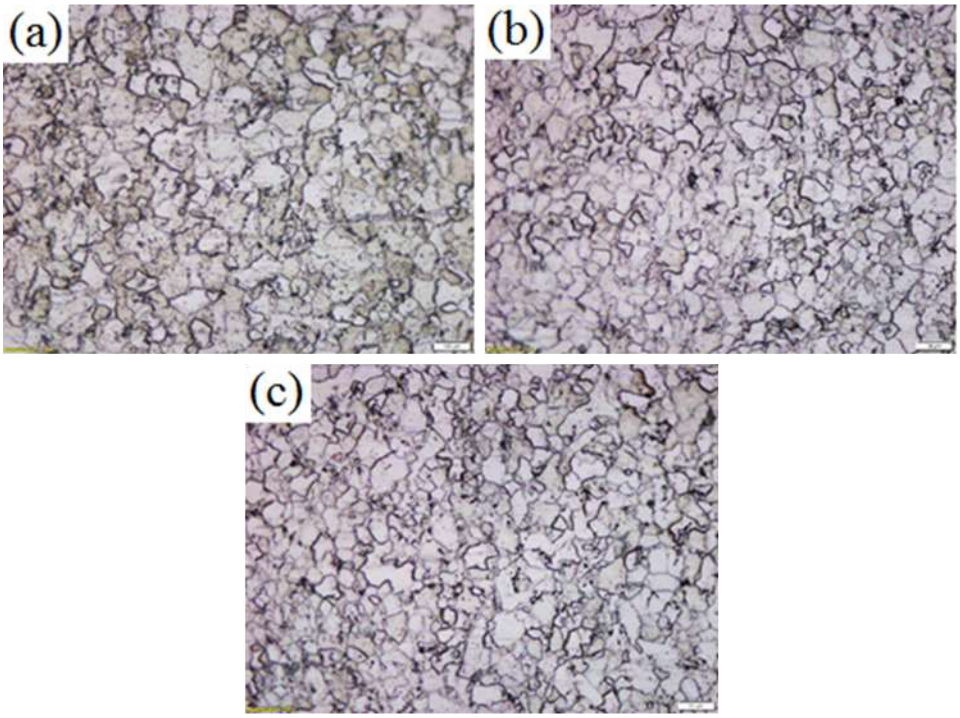

Fig 2. Microstructure images of sample on different layer deposition (a) 1 layer, (b) 2 layers, and (c) 4 layers.

Table 2. The data calculation for the corrosion rate analysis

Sample	Thickness coating (mm)		Weight loss (g)	Surface area (mm^2)	Corrosion rate (mm/year)
	Before	After			
A (uncoated)	0.832	0.832	0.1	1313	0.505
B (1 layer)	0.832	0.924	0.07	1315	0.353
C (2 layers)	0.838	0.933	0.05	1316	0.252
D (4 layers)	0.835	0.943	0.065	1313	0.354

Figure 3 shows the results of the Rockwell hardness test at 3 test points. Hardness is measured by the Rockwell Hardness Test method. Based on the calculation, the average number of the Rockwell hardness of un-coated and coated samples for the 1 layer, 2 layers, and 4 layers, respectively were estimated at about 70, 78, 79, and 58 HRB, respectively. The highest average hardness value is in sample B with 2 layers of 79 HRB. The lowest average hardness value is in sample B with 2 layers of 58 HRB. The lowest performance of sample D with 4 layers confirms the result as shown in the corrosion rate result.

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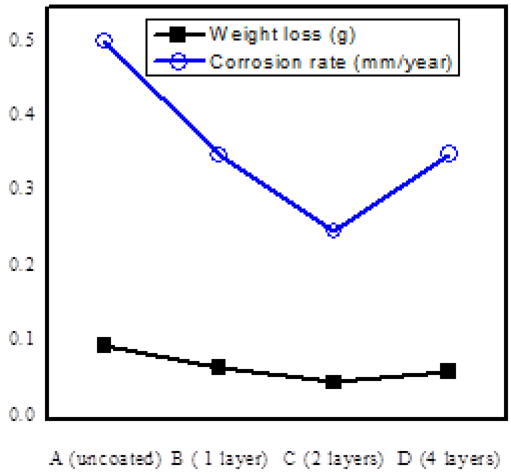

Fig 2. The corrosion rate and the weight loss of the un-coated and coated samples for the 1 layer, 2 layers, and 4 layers.

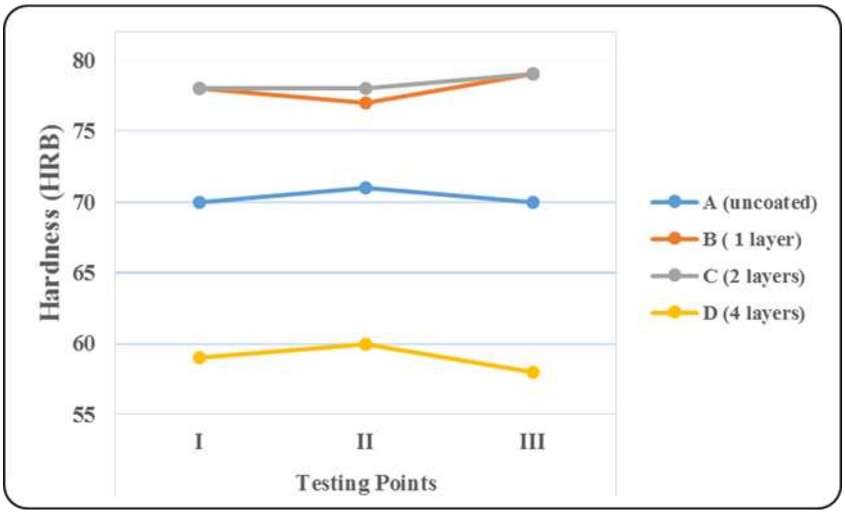

Fig 3. The behavior of the hardness of the samples with the un-coated and coated samples for the 1 layer, 2 layers, and 4 layers on three testing points.

4. CONCLUSION

We have demonstrated the feasibility of various layers of powder coating on the hardness and corrosion rate of the material. The morphology were changed with variation of layers deposition. Different result between the uncoated and coated material. The uncoated material has a corrosion rate of 0.505 mm/year which means fair for the relative corrosion resistance. All the samples coated were in zone “good” in the relative corrosion resistance. Interesting results were observed, the corrosion rate was decreased after being coated 2 layers. The 4 layers sample has degradation of performance which has increased the corrosion rate. . The highest average hardness value is in sample B with 2 layers of 79 HRB. The lowest average hardness value is in sample B with 2 layers of 58 HRB. The lowest performance of sample D with 4 layers confirms the result as shown in the corrosion rate result.

Acknowledgements

We would like to thank P3M of Bandung State Polytechnic, Bandung, Indonesia, for the funding research and permitting us to access the laboratories in the Mechanical Engineering Department.

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DOI: 10.31695/IJASRE.2022.8.9.5