Metal Coat Spray Distance Analysis of AISI Steel 1045 to Corrosion Resistance with Stainless Steel as Lamination

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Abstract – The process of surface coating by using electric arc spray is an effort to improve the quality of the metal surface. To protect base metals from damaging environmental conditions, it is required that layer results should have feasible harshness, corrosion resistance, and layer strength. This research was aimed to find out the effect of spray distance toward harshness, corrosion resistance, and layer strength. Electric arc wire spraying used twin wires which were fed into the heat flow. An arc would arise between the ends of two wire feeds (316 stainless steel*)* and the heat formed would melt the ends of both wires. High-pressure gas (6 bars) was streamed to take the liquid metal to the substrate surface. The substrate surface was cleaned and roughened first by using grit blasting before being coated with the first layer of 95%Ni5%Al and the second layer of 316 stainless steel by varying the spray distance (10 cm, 20 cm, 30 cm). This technique is commonly used to coat the surface of steel roller, roller, and plastic roller and reclaim hydraulic rams, piston, axis, and pad. The test result showed higher harshness after being coated with the maximum amount of 332 VHN, acquired at 20 cm spray distance. Lower corrosion rate with the best amount of 1.1526 mpy was acquired at 30 cm spray distance. Maximum coating strength is obtained at 30 cm spray spacing at 4071.94 psi.

1. INTRODUCTION

Thermal spraying is a process in which metal and non-metal materials are heated and converted from the atom form into its basic form. The materials are originally in the form of wire, rod, or powder. The materials are heated until they reach plastic or liquid state by oxyfuel gas flame, electric arm or plasma, the detonation of the gas mixture. In thermal spraying process*,* the temperature of the coating material to be fed to the spray gun will gradually rise and reach the substrate surface in the form of a particle. Next, the layer on the surface of the substrate will be shaped. The density of this layer depends on the materials, temperature when it reaches the substrate, and energy with its impact. The adhesion between the layer and the substrate depends on several factors; including the condition of the substrate surface (it must be clean and rough). The rough surface of the substrate can be obtained by shot blasting or rough machining process.

Takeshi Kobayashi and Toru Maruyama (2003) conducted research on the characteristics of pure aluminum and zinc layer by the flame spraying method. The test results showed that the tensile strength of the aluminum coating materials tends to decrease with the increase of spray distance since the particle of the coating materials is not sufficiently diffused on the base material. The tensile strength of the zinc coating material decreases as the spray distance is reduced due to the number of oxides formed on the layer surface. The closer spray distance leads to the increase of harshness due to the rapid cooling rate.

2. METHODS

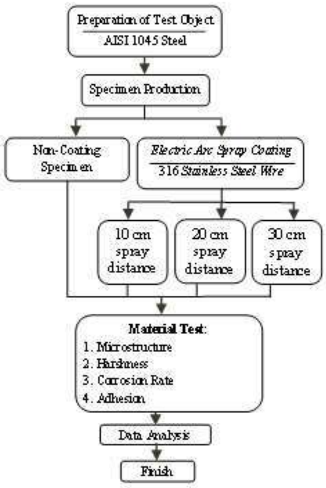

Figure 1. Flowchart of Research

3. RESULTS AND DISCUSSION

3.1 Result of Metallography Test

3.1.1 Metallography of Surface Layer

Figure 2, shows the microstructure of the coating with a variation range of 10, 20, and 30 cm with the stainless steel coating of 316L PMET 730.

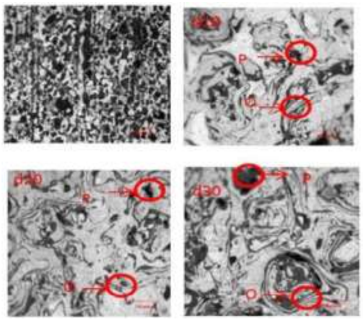

Figure 2. Microstructure. P) Porosity, O) Oxides

As seen in Figure 2, there were some black dots indicating the porosity occurring during the coating. However, the porosity was still below the standard. By using the planimetric method, it was revealed that the magnitude of porosity diameter was of 19 µm with a porosity area of 31,2% at 10 cm spray distance, 15% and 22 µm at 20 cm spray distance, and 17% and 16 µm at 30 cm spray distance. Farther spray distance allowed wider diffusion, causing the porosity to increase. The emersion of oxides was the reaction between oxygen with chromium or nickel during the spraying process. As seen in d10 and d20 specimen, the oxides formed were almost as many, while the oxides in d30 specimen were less than the two and dominated by the porosity, causing the lower harshness in d30 compared to d10 and d20 specimen. The oxides were more grayish and lengthy, appearing in the layer which was parallel to the substrate. The oxides formed were due to the insufficient evaporation on the layer. The humid condition resulted in the liquid particle during the spraying process to react with the oxygen, which formed the oxides. The more oxides formed, the higher the harshness.

3.1.2 Metallography of Layer Limit and Raw Materials

The metallography on the inside of the materials was aimed to analyze the coating results in the layer limit and the raw materials to estimate the strength of the adhesion of the coating results.

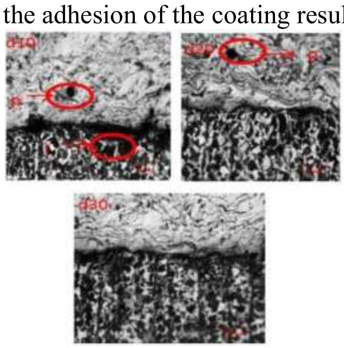

Figure 3. Metallography in the layer limit. P) Porosity, I) Internal Defect

The internal defect is a defect which occurs between layer limit and raw materials. The internal defect may be one of the indications which cause the growing extent of crack, resulting in a lack of adhesion of the coating. Based on the observation, it was revealed that the internal defect occurred in the coating at 10 cm spray distance and almost did not take place at 20 cm and 30 cm spray distance. The internal defect can reduction of the coating adhesion at 10 cm spray distance due to the crack indication which could widely spread.

3.2 Result of Harshness Test

The test on harshness was carried out by using Vickers method with a load of 10 HV. In the test of each specimen, there were 5 points of stamping on the surface. Figure 3, shows that with 10 cm spray distance, the harshness acquired was of 324 VHN. While for 20 cm and 30 cm spray distance, the harshness acquired was respectively of 332 VHN and 303 VHN. The harshness as the result of the coating was above the harshness of raw materials. The result of harshness test is shown in Table 1 and Figure 3.

Table 1 Result of Harshness Test (VHN)

Sample				
Rm	Ss316	d10	d20	d30
183	254	324	332	303

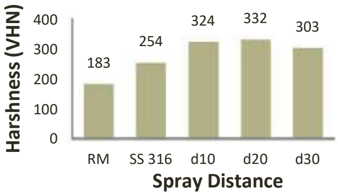

Figure 3. Graphic of Relation between Harshness and Spray Distance

Overall, the harshness after being coated increased compared to the raw materials (183 VHN). However, the harshness differed at each variation of the spray distance. The highest harshness was at 20 cm spray distance with the amount of 332 VHN, while the lowest was at 30 cm spray distance with the amount of 303 VHN. The harshness may occur due to the different spray distances, resulting in the focal point of powder diffusion on different nozzles. The harshness would affect the density of the spray powder attached to the layer, as seen in the porosity percentage and porosity diameter.

At 10 cm spray distance by using the ASTM E-562 method, it was revealed that the porosity diameter on d10 layer surface in ASTM E-112 table was of 19 µm. This amount was still below the average of the maximum amount of porosity determined by CFM56 (2002), which is of 30 µm. The percentage of porosity at 10 cm distance was of 31,2%. This amount did not exceed 50% of the layer surface. Thus, the coating was considered to meet the standard.

At 20 cm spray distance with the same method, it was revealed that the porosity diameter decreased to 16 µm, while the porosity area fell back to 17%. The two of the amount affected the harshness of d20 which was higher compared to d10. The lower porosity extent and diameter allowed the avoidance of porosity to be affected by the indenter in the process of harshness test.

At 30 cm spray distance, the porosity area fell back to 15%. However, the porosity diameter increased to 25 µm. At 30 cm spray distance where the harshness decreased, the indenter might affect the porosity, causing the indenter to have an effect on the softer raw materials.

The porosity in the coating might affect the nature of the harshness. The higher the percentage of the layer porosity, the lower the harshness, and vice versa. The porosity was due to the effect of the melting state, and as mentioned earlier, the oxides affected at the materials level. The harshness would be higher if there were more oxides formed.

3.3 Result of Corrosion Rate Test

The method used was a three-electrode cell by using NaCl liquid at the level of 3%.

Table 2 Result of Corrosion Rate

No.	SAMPEL	E COOR (Mv)	I COOR (uA/cm2)	COOR RATE (mpy)
1	RM	-498,05	3,88	1,7915
2	d 10	-495,56	3,77	1,7404
3	d 20	-499,03	3,13	1,4475
4	d 30	-498,05	2,5	1,1526

To make the reading easier, the result of corrosion rate is shown in the following graphic:

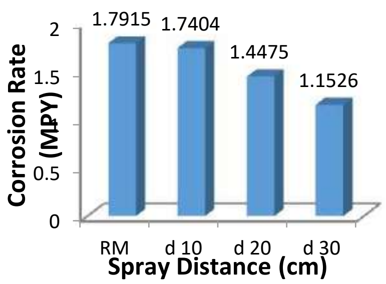

Figure 4. Graphic of Relation between Spray Distance and Corrosion Rate (mpy)

It was indicated that the raw materials had the highest corrosion rate. The high corrosion rate showed a lack of material resistance toward the corrosion. After being coated, the corrosion rate decreased more, indicating the resistance toward the corrosion which experienced an increase. It turned out that the variation of spray distances had an effect on the corrosion rate. The farther the spray distance, the better the corrosion rate.

The porosity had an effect on the corrosion rate. The extent of porosity area was directly proportional to the corrosion rate. The following is the amount of corrosion rate compared to the extent of the porosity area, depicted in Figure 5.

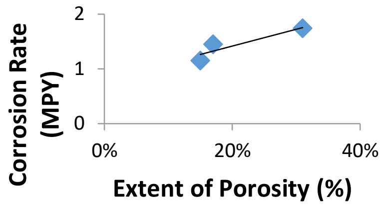

Figure 5. Graphic of Relation between Extent of Porosity Area and Corrosion Rate

3.4 Relation between Harshness and Corrosion

The harshness of metal is the measure of material resistance toward deformation. The material can be easily or hardly corroded by the environment. The following is the relation between the harshness and the corrosion rate.

Table 3. Relation between Harshness and Corrosion

No.	Sample	Harshness (HVN)	Corrosion Rate (mpy)
1	RM	183	1,7915
2	d 10	324	1,7404
3	d 20	332	1,4475
4	d 30	303	1,1526

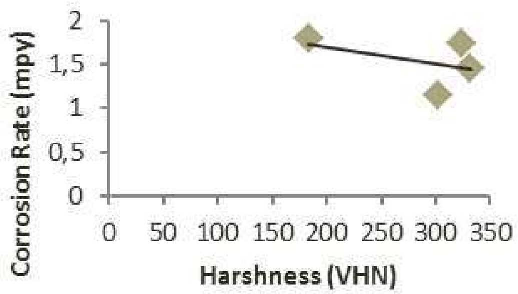

Figure 6. Graphic of Relation between Harshness and Corrosion Rate

The graphic above shows the relation between harshness and corrosion rate. Based on the graphic, it can be seen that the higher the harshness of material, the lower the corrosion rate. That means the higher the harshness of material, the better the resistance toward the corrosion. The harshness is related to the density of the surface (porosity). The low porosity causes favorable corrosion rate and increasing harshness.

4. CONCLUSIONS

1. The harshness after being coated with 316 SS experienced an increase, compared to the raw materials. However, it was no higher than the harshness of 316 SS. This was due to the porosity occurring on the layer surface. The maximum amount of harshness was acquired at 20 cm spray distance, which was of 332 VHN.
2. The corrosion rate experienced a decrease in the materials of layer result, compared to the raw materials. The farther the spray distances, the lower the corrosion rate. The minimum amount of corrosion rate was acquired at 30 cm spray distance, which was of 1.1526 mpy.

5. REFERENCES

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