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Analysis of Influence of Abrasive Material Variation and Spray Pressure Variation in Coating Epoxy of ASTM A36 Steel Toward Impact Resistance and Corrosion Rate

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ABSTRAK

Corrosion is a decrease in material quality caused by environmental influences. One of the methods commonly used to control corrosion is coating. In the coating process, the use of spray is the better method compared to roll and brush. Before coating is applied, the choice of abrasive material during the sand blasting process can determine the success of the coating. This research was conducted to analyze the effect of variations in abrasive material and spray pressure on the coating process of ASTM A36 steel material on its impact resistance, corrosion rate, and adhesion forces. Variation of abrasive material used were steel grit and silica. The spray pressure variations used were 2.5, 3.5, and 4.5 bar. The result of corrosion rate testing on variation with steel grit abrasive material and spray pressure of 4.5 bar has the lowest corrosion rate, with the value of 0.00124 mm/a. The highest adhesion strength test result of 9.07 MPa was obtained from variations with steel grit abrasive material and spray pressure of 4.5 bar. Impact test result using a variation with steel grit abrasive materials and a spray pressure of 4.5 bar yield the highest value, with the value of 2.287 joules.

Keywords: *coating, abrasive material, spray pressure, corrosion, adhession, impact.*

1. INTRODUCTION

In offshore building fabrication industry, iron and steel are commonly used as the main material for constructing an offshore structure. However, iron and steel can be easily corroded. Corrosion is damage to the material caused by the influence of the surrounding environment [1]. In the field of engineering, corrosion is a serious problem so that it is necessary to suppress the rate of corrosion that occurs. One way to reduce the rate of corrosion is by applying a coating system.

In the marine operation process, we often encounter ship's hull collision with the edge of the dock that is not protected by fenders. When carrying out practical activities in PT. Dumas Tanjung Perak, the author found damaged coating layer on the hull due to impact. This certainly causes damage to the coating layer so that the coating function could be weakened.

One factor that can affect coating quality is the choice of abrasive material in the sand blasting process. Abrasive materials consist of various types, such as steel grit, garnet, steel shot, and silica. Variations in abrasive material in the blasting process result in different surface qualities [2]

In the application of coating, there are several methods that can be used, such as brushes, roll, and spray. The spray method has the best adhesion test value compared to other coating methods [3].

Based on the problems above, this final project is aimed at further researching the effect of variations in spray size and abrasive material on impact resistance, adhesion strength, and corrosion rate of ASTM A36 steel material. Variations in abrasive materials used were steel grit and silica. Furthermore, the coating process used spray pressure variations of 2,5; 3,5; and 4.5 bar.

2. MATERIAL AND METHODS

2.1. Material Preparation

In this study, the material used was ASTM A36 steel. The dimensions of the specimens used were 120 x 90 x 10 mm (6 pieces) for adhesion testing, 40 x 20 x 10 mm (6 pieces) for corrosion rate testing, and 80 x 80 x 10 mm (18 pieces) for impact testing. The coating material used was Jotun Penguard Gray epoxy primer paint.

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2.2. Code Table of Specimen

To simplify the working process, the authors implemented codes as naming scheme for each specimen with the treatment received. The codes used were shown in Table 2.

Table 2. Specimen's Code

Spesimen Code	Abrasive Material	Testing	Spray Pressure
GA1	Steel Grit	Adhesion Test	2,5 bar
GA2			3,5 bar
GA3			4,5 bar
GI11		Impact Test	2,5 bar
GI12			
GI13			
GI21			3,5 bar
GI22			
GI23			
GI31			4,5 bar
GI32			
GI33			
GK1		Corrosion Rate Test	2,5 bar
GK2			3,5 bar
GK3			4,5 bar

Spesimen Code	Abrasive Material	Testing	Spray Pressure
LA1	Silica	Adhesion Test	2,5 bar
LA2			3,5 bar
LA3			4,5 bar
LI11		Impact Test	2,5 bar
LI12			
LI13			
LI21			3,5 bar
LI22			
LI23			
LI31			4,5 bar
LI32			
LI33			
LK1		Corrosion Rate Test	2,5 bar
LK2			3,5 bar
LK3			4,5 bar

2.3. Environmental Test

This process was carried out to measure the room's temperature and humidity level. This process was done so that the process of blasting and coating does not cause condensation on the material. Monitoring environmental conditions which includes the wet temperature, dry temperature, and temperature of the specimen used. The instrument used were a spychrometer to measure wet and dry temperatures, a thermometer to measure the temperature of a test specimen, a DEW Point and RH table. The DEW Point and RH tables were used to find the Relative Humidity and DEW Point values by entering the value of the dry bulb and the difference between the dry bulb and the wet bulb.

2.4. Sand Blasting Process

The blasting process was used to clean the surface of the material from dirt, rust, and dust. In addition, the blasting process provides a roughness profile on the surface of the material. The level of cleanliness to be achieved was SA 2.5 using the ISO 8501-1 standard [5]. In this process two types of abrasive material were used, namely steel grit and silica. Figure 2 show steel grit and figure 3 show the silica.

Figure 2. *Steel grit*

Figure 3. *Silica*

2.5. Blasting Inspection

Visual inspection was carried out by comparing the results of blasting with the intended level of cleanliness which was SA 2½ according to ISO 8501-1 [5]. The dust impurities inspection was also carried out on the maerial surface. The level of dust impurities on the surface must be at least level 3 according to ISO 8502-3 [6]. The picture of cleanliness level 2 ½ and dust pollution can be showed this picture bellow.

Figure 4. Cleanliness Level of SA 2 ½ [5]

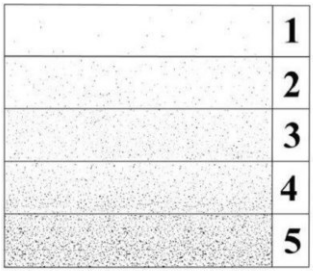

Figure 5. Dust Pollution Level [6]

2.6. Surface Roughness Test

This test aim to find out the hardness profile of each specimens that had gone through the blasting process. The tool used was the roughness meter. This test used the standard specified in ASTM D4417 “Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel” [7]. Figure 6 bellow show test process.

Figure 6. Test Process

2.7. Coating Process

The coating process must be carried out immediately to avoid rust that rapidly develop after the sand blasting process. The coating used was the Jotun Penguard Gray Primary epoxy paint. This product has 2 components, namely component A and B. In the process, different spray pressure variations used were 2,5; 3.5; and 4.5 bar.

a

b

C

Figure 7. (a) Pressure of 2,5 bar, (b) Pressure of 3,5 bar, (c) Pressure of 4,5 bar

2.8. Coating Thickness Measurement

In the coating process, there were two kinds of thickness used, which were wet film thickness and dry film thickness. The coating layer that had been applied will shrink according to the technical data sheet of each paint. So, it is necessary to determine the thickness of the dry paint first, after that the wet thickness can be obtained. In this test, the thickness of dry paint was determined at 170 µm. To obtain the wet film thickness value, the formula used were:

$$Wet\ Film\ Thickness = \frac{DFT\ x\ (100\%+\ thinner\ percentage)}{\%\ Solid\ volume} \quad (1)$$

$$Wet\ Film\ Thickness = \frac{170\ x\ (100\% + 5\%)}{51 \pm 2\%} \quad (2)$$

$$Wet\ Film\ Thickness = \ 350\ \mu m \quad (3)$$

2.9. Impact Test

This test was carried out to determine the strength of the specimen that has been applied to a coating for a given impact. By applying load so that the maximum height that can cause damage or failure in the coating layer was obtained. This test referred to ASTM 2794 "Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact) [8]

2.10. Corrotion Rate Test

This test was intended to determine the prediction of the corrosion rate that occurs in the steel plate even though it has received coating treatment. This test used 3.5% NaCl as a substitute solution for sea water. The method used in this test is 3 cell electrodes, which used potentiostat equipment connected to the computer and CS Studio 5 software.

2.11. Adhesion Test

This test was carried out to determine the adhesion strength (binding capacity) of the coating that has been applied to each specimen. This test was carried out according to ASTM D4541 standard "Standard Test Method for Pull-off Strength of Coatings Using Portable Adhesion Testers" [9]. The tool used for strength adhesion testing was a portable adhesion tester.

3. RESULTS ANALYSIS

3.1. Enviromental Data

Before blasting and coating process, it was necessary to measure the condition of the surrounding environment because it could affect the results of the coating. The following were the results of the measurement:

- *Steel Temperature* : 34°C
- *Wet Temperature* : 28°C
- *Dry Temperature* : 33°C
- *Relative Humidity* : 69%
- *Dew Point* : 26°C

3.2. Blasting Result

Blasting process was a process that determines the success rate of using a coating method in controlling corrosion. In this research, the method used was dry abrasive blasting by using steel grit and silica abrasive material. The level of cleanliness of the material to be achieved in this process was SA-2 [5]. The level of dust content on the surface of the test was carried out using a dust tape device and produced a level of dust content at level 1 [6].

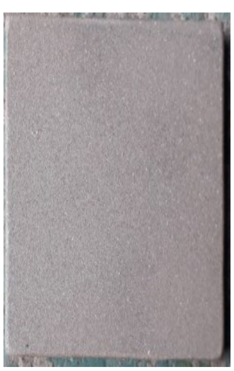

Figure 8. *Blasting with Steel grit*

Figure 9. *Blasting with Silica*

Figure 10. Dust Level

3.3. Roughness Test Result

Surface roughness of the material due to the blasting process has one purpose, which was to bind the coating layer that cover it. Measurements were made by placing roughness meters at 3 points on the surface of the material. The results of measurements can be seen in Table 3 and Table 4.

Table 3. Roughness value of blasting material using silica

Spesimen Code	Surface Roughness (μm)			Average Value (μm)
	1	2	3	
LA1	62	65	63	63,3
LA2	68	67	64	66,3
LA3	61	65	62	62,3
LI11	63	61	67	63,7
LI12	68	64	64	65,3
LI13	68	67	67	67,3
LI21	68	68	63	66,3
LI22	65	63	68	65,3
LI23	67	64	64	65
LI31	67	68	64	66,3
LI32	66	66	68	66,7
LI33	64	62	67	64,3
LK1	68	67	63	66
LK2	64	62	68	64,7
LK3	62	68	68	66
Total Average Value				65,53

Table 4. Roughness value of blasting material using steel grit

Spesimen Code	Surface Roughness (μm)			Average Value (μm)
	1	2	3	
GA1	79	77	81	79
GA2	82	80	80	80,7
GA3	78	79	82	79,7
GI11	81	82	81	81,3
GI12	82	79	77	79,3
GI13	80	81	79	80
GI21	78	79	82	79,7
GI22	80	79	82	80,3
GI23	81	82	77	80
GI31	78	81	79	79,3
GI32	80	83	82	81,7
GI33	79	82	81	80,7
GK1	81	81	79	80,3
GK2	82	82	77	80,3
GK3	80	78	81	79,7
Total Average Value				80,1

3.4. Coating Process Result

The coating process was carried out after determining the wet film thickness. Coating process was done usingvaritions of spray pressure of 2,5 ; 3,5 and 4,5 bar. The tool used for the coating process was an air spray gun. The result of the coating process can be seen in Figure 11.

Figure 11. Coating Result

After the coating process was carried out, then the dry film thickness was measured. DFT measurements were carried out to determine the thickness of the paint when it is dry whether it is in accordance with the desired DFT level.

3.5. Adhession Test Result

This test was carried out using the pull off test method using the ASTM D4541-02 standard "Standard Test Method for Pull-Off Strength of Coating Using Portable Adhesion Tester" [9]. The results of the adhesion strength testing for each specimen with variations in abrasive material and spray pressure can be seen in Table 5 and the results in the form of a graph of average power values can be seen in Figure 12.

Table 5. Adhession Strength

Spesimen Code	Abrasive Material	Spray Pressure	Adhesion Strength (Mpa)			Average Value (Mpa)
			1	2	3	
GA1	Steel Grit	2,5 bar	8,13	6,76	7,54	7,48
GA2		3,5 bar	8,3	8,45	8,48	8,41
GA3		4,5 bar	8,98	9,44	8,79	9,07
LA1	Silica	2,5 bar	6,8	5,5	6,42	6,24
LA2		3,5 bar	7,54	7,08	7,55	7,39
LA3		4,5 bar	7,47	7,16	9,1	7,91

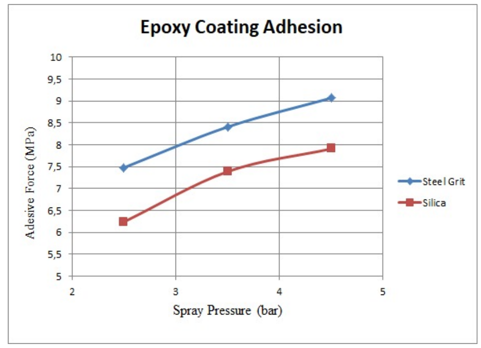

Figure 12. Graph of Adhesion Test Average

Based on Table 3, it was known that the highest value of adhesion strength in specimens that went through the blasting process using steel grit abrasives with a spray pressure of 4.5 bar that is equal to 9.07 Mpa.

The results of the adhesion test using the Pull Off method, showed that the abrasive material and spray pressure in the coating process affect the value of the adhesion of the coating to the specimen. The use of high pressure spray results in smaller particle sizes when spraying [10]. The use of steel grit abrasive material makes the surface roughness profile of the material higher so that the coating can be more attached to the surface. This caused surface roughness gap to be filled more evenly.

3.6. Impact Test Result

Impact test was carried out to determine the value of the failure energy of the coating against a given load. Coating layer is considered to function well if it can withstand cracking against collisions [3]. This test refers to the standard ASTM D2794, 1993 "Standard Test Method for Resistance of Coating to the Effect of Rapid Deformation (Impact)" [8].

The value of maximum failure energy as the endurance limits of the coating against impact received as shown in Table 6. From the table of the impact testing results, then the graphs of the failure number were made as shown in Figure 13.

Table 6. Failure Number of Specimen

Spesimen Code	Abrasive Material	Spray Pressure	Impact Resistance	Average	MHE (Joule)
GI11	Steel Grit	2,5 bar	400	333,33	1,63
GI12			300		
GI13			300		
GI21		3,5 bar	300	366,67	1,79
GI22			400		
GI23			400		
GI31		4,5 bar	400	466,67	2,28
GI32			500		

GI33			500		
LI11	Silica	2,5 bar	300	266,67	1,3
LI12			200		
LI13			300		
LI21		3,5 bar	300	300	1,47
LI22			400		
LI23			200		
LI31		4,5 bar	300	333,33	1,63
LI32			400		
LI33			300		

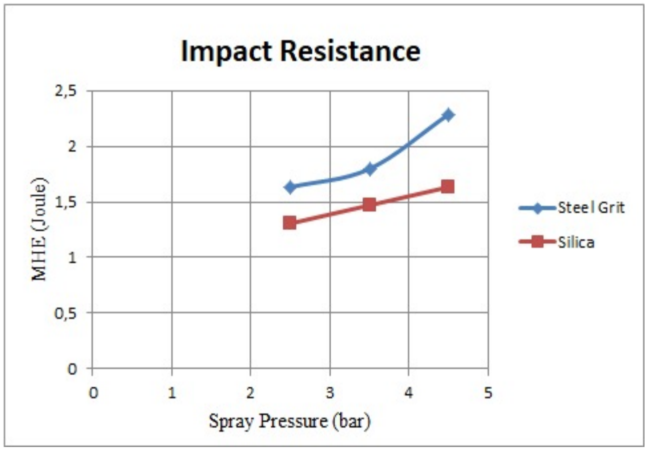

Figure 13. Graph of Failure Number

The results of impact resistance testing show that the abrasive material and spray pressure in the coating process affect the coating resistance of the specimen. The use of steel grit abrasive material resulted in higher roughness values compared to silica. This caused the coating adhesion force to be stronger. The use of a large spray pressure reduced the porosity on the surface of the material [10]. This would lead to a greater ability to stick to the coating and increase the resistance of the coating layer against the impact load.

4.7 Corrosion Rate Test Result

Corrosion rate prediction method was carried out to find-out how quick the corrosion would be formed on the test specimen. The method used was to use the three-cell electrode method by applying the electrochemical theory.

In this test, it was also found that the coated material continued to undergo corrosion. This is supported by the current density or Icorr detected on the surface of the material being tested. The corrosion rate values obtained were shown in Table 7 and Figure 14 below:

Table 7. Corrosion Rate Number

Spesimen Code	Abrasive Material	Spray Pressure	Corrosion Rate (mm/a)			Average Value (mm/a)
			a	b	c	
GK1	Steel Grit	2,5 bar	0,000134	0,001228	0,005496	0,00229
GK2		3,5 bar	0,002429	0,003591	0,000347	0,00212
GK3		4,5 bar	0,000116	0,000115	0,003493	0,00124
LK1	Silica	2,5 bar	0,001881	0,017771	0,19518	0,07161
LK2		3,5 bar	0,000859	0,0192	0,15176	0,05727
LK3		4,5 bar	0,000138	0,03975	0,045334	0,02841

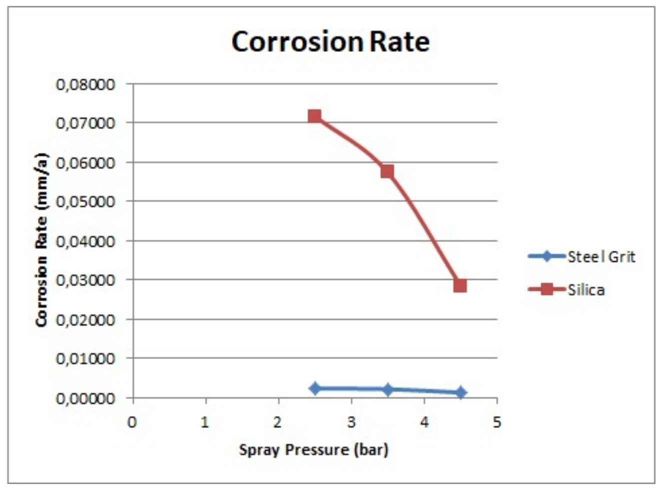

Figure 14. Graph of Corrosion Rate Average

Figure 14 show the influence of variations in research variables on the corrosion rate of the specimen. It was observed that the rate of corrosion will decrease when the abrasive material used forms rougher surface profile. In addition, the higher spray pressure would produce smaller paint droplet [10]. Both explain that the more attached the coating layer to the material surface, the harder for electrons to penetrate so that the corrosion rate becomes lower. The lowest value was found in specimen using steel grit abrasive material and spray pressure of 4.5 bar, with a corrosion rate of 0.00124 mm/a.

4.8 Selection of Abrasive Material and Spray Pressure Variations

This final project would analyze the selection of abrasive material and spray pressure variations that would be applied to ASTM A36 steel. This selection was carried out using parameters of the results from testing the adhesion force, impact pressure, corrosion rate and the cost of abrasive material on ASTM A36 steel. Before the decision selection procedure is performed, Table 8 which contains the test results be used as a selection parameter.

Table 8. Test Result and Price of Material Abrasive

Number	Abrasive Material	Material Cost	Spray Pressure	Average Test Value		
				Adhesion (MPa)	Impact Resistance (Joule)	Corrosion Rate (mm/a)
1	Steel Grit	Rp. 16.500,00	2,5 bar	7,48	1,633	0,00229
2			3,5 bar	8,41	1,797	0,00212
3			4,5 bar	9,07	2,287	0,00124
4	Silica	Rp. 3.000,00	2,5 bar	6,24	1,307	0,07161
5			3,5 bar	7,39	1,47	0,05727
6			4,5 bar	7,91	1,633	0,02841

After the test results and cost for each method collected, the converted value for each test result and cost can be determined by providing scores on each value. The highest value on the results of the impact resistance test and adhesion force gets a score of 5. Similarly, the lowest value on the results of the corrosion rate and the cost gets a score of 5. Table 9 which contains the test results and the test costs as well as criteria in the selection of decisions made.

Table 9. Penilian Kriteria Uji dengan Metode Perbandingan Eksponensial

Number	Alternative	Criteria				Decision Score
		Adhesion Strength	Impact Resistance	Corrosion Rate	Material Cost	
1	Steel Grit 2,5 bar	4,12	3,57	2,71	0,91	136,29
2	Steel Grit 3,5 bar	4,64	3,93	2,92	0,91	186,13
3	Steel Grit 4,5 bar	5	5	5	0,91	375,83
4	Silica 2,5 bar	3,44	2,86	0,09	5	89,04
5	Silica 3,5 bar	4,07	3,21	0,11	5	125,81
6	Silica 4,5 bar	4,36	3,57	0,22	5	153,43
Criteria Weight		3	3	3	2	

After evaluating each abrasive material and spray coating pressure used with the exponential comparison method, the best results are steel grit abrasive with a spray pressure of 4.5 bar with a score of 375,83.

4. CONCLUSSION AND SUGGESTION

4.1. Conclusions

Based on the research that has been done, the following conclusions are obtained

1. The best adhesion force test results were found on ASTM A36 steel material that uses steel grit abrasive material during the sand blasting process and spray coating pressure of 4.5 bar with a value of 9.07 MPa. This happens because the surface of the material has a high level of roughness and a large spray pressure causes reduced porosity on the surface of the material. Because of that, the adhesion of the coating to the surface of the material becomes high.
2. The highest failure energy results obtained on specimen using steel grit in the sand blasting process and spray pressure of 4.5 bar with a value of 2.287 Joules. The use of steel grit abrasive material will result in higher roughness valuecompared to silica. The use of high-pressure spray will also result in smaller paint droplet. This will lead to a greater ability to stick to the coating and increase the resistance of the coating layer against the impact load.
3. Corrosion rate will get smaller when the abrasive material used can form a rougher surface profile material. Besides that, the higher spray pressure will result in smaller corrosion rate. Both explain that the more attached the coating layer to the material surface, the harder for electrons to penetrate so that the corrosion rate becomes lower. The lowest corrosion rate value is 0.00124 mm / a
4. Through the calculation of the exponential comparison method, the result is that the best abrasive material to be used in the sand blasting process is steel grit. In addition, the use of a spray pressure of 4.5 bar is the most appropriate compared to other pressures. The decision score of these combinations yields the best results of 375,83.

4.2. Suggestion

In this thesis report, the author wants to provide suggestions for further research and more in-depth research in the future.

1. Continue this research by conducting further testing in the form of abrasion testing.
2. Analyzing the effect of steel grit and steel shot abrasive materials on blasting against roughness test.

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