Analysis the Effect of Size Variation and Spraying Pressure of Steel Grit on Corrosion Rate of Astm A36 Steel Materials

Ari Wibawa Budi Santosa[1], Iqbal Fahrudin[2], Ocid Mursid [3], Imam Pujo Mulyatno[4], Joko Subekti[5]
(Received: 20 December 2022 / Revised: 10 February 2023 / Accepted: 02 March 2023)

***Abstract*—ASTM A36 steel is a steel commonly used in shipbuilding construction. The property of steel that is highly avoided is susceptible to corrosion or corrosive which can reduce the strength of the structure. Over time, technology has developed, and methods have been found to inhibit the rapid rate of corrosion, coating process is one of them. The success rate of coating process is also strongly influenced by the surface preparation process. The surface preparation process in this study was by differentiating the size variations of the SG18, SG25, and SG40 steel grit abrasive materials and the spraying pressure of the 5 bar, 6 bar, and 7 bar abrasive materials and the provision of scratch defects on the specimens that had been coated with epoxy primer paint. The purpose of the research conducted was to analyze variations in size of the abrasive material, the spraying pressure of the abrasive material, and which combination of variations is the best for specimens considered to have been scratched. In each variation, the value of the corrosion rate will be increased when the size of the material increased and the value of the corrosion rate increases when the spraying pressure decreases. The results obtained from this study indicate that the lowest corrosion rate value is 0.0027 mmpy with the outstanding category of the variation used, which is grit SG40 steel abrasive material and at a pressure of 7 bar.**

Keywords—**Corrosion rate, Spraying pressure, ASTM A36 Steel, Steel Grit**

I. Introduction

Factors influenced in the competitiveness of the shipbuilding industry are factors related to shipping components including quality, availability, and costs. The fundamental problem with the domestic shipping industry is that between 70 and 80 percent of the components used in ships are imported components [1].

The maritime industrial environment places metals as basic materials commonly used in offshore buildings and shipbuilding. The metal itself is a chemical element that has properties that are hard, strong, hot and able to conduct electricity, and has a high melting point. However, the shortage of metals is still a scourge in the maritime industry, which is corrosive or easily corroded [2].

Corrosion is generally interpreted as something that causes damage to steel construction in its usage time. Corrosion that affects the quality of infrastructure results in the quality or nature and safety of infrastructure being affected to deteriorate. In the case of ship hulls, for example, a standard maximum reduction of 20% of plate thickness is applied [3][4].

The process of corrosion or rusting of metal must be prevented or at least slowed down because the corrosion process cannot be stopped. Solutions to the desired results require a thorough and total approach. One way is to use a protective coating or a coating process [5].

The success rate of coating process is also strongly influenced by the surface preparation process, which will affect the speed of the corrosion rate of the material. Blasting is the most frequently used method in the surface preparation process. The blasting process itself is a process of cleaning the surface of material or metal by spraying abrasive material onto the surface of the material with great pressure, causing roughness [6][7].

Previous research with the theme of coating and similar to this study obtained the corrosion rate value with steel grit abrasive material having the lowest value and from previous studies, the research was continued based on suggestions and combined with other variations in the form of variations in size and pressure based on the level of cleanliness at the time of surface preparation plus scratch defects on the specimen after being coated with paint [6].

The renewal was carried out by providing scratch defects on the coated specimens. Continuing from the existing problems, this study has the objective of analyzing variations in the size of the abrasive material, the pressure of spraying the abrasive material, and which combination of variations is the best. The results obtained will be useful for coating operators and ship owners as a reference in the coating process.

Ari Wibawa Budi Santosa is with Department of Naval Architecture, Diponegoro University, Semarang, Indonesia. arikapal75@gmail.com
Iqbal Fahrudin is with Department of Naval Architecture, Diponegoro University, Semarang, Indonesia. arikapal75@gmail.com
Ocid Mursid is with Department of Naval Architecture, Diponegoro University, Semarang, Indonesia. arikapal75@gmail.com
Imam Pujo Mulyatno is with Department of Naval Architecture, Diponegoro University, Semarang, Indonesia. arikapal75@gmail.com
Joko Subekti is with Sekolah Tinggi Maritim Yogyakarta , Yogyakarta, Indonesia. Joksub31@gmail.com

II. METHOD

A. Research Objects and Variations

ASTM A36 steel plate is used as an object in this study. The size of the specimen used was 50 mm x 50 mm x 10 mm and a total of 9 specimens were tested.

TABLE 1
RESEARCH VARIATION DESIGN

No	Size / Mesh	Spraying Pressure
1	SG18	5 bar
2	SG18	6 bar
3	SG18	7 bar
4	SG25	5 bar
5	SG25	6 bar
6	SG25	7 bar
7	SG40	5 bar
8	SG40	6 bar
9	SG40	7 bar

Information:
SG18 : Steel Grit Mesh 18
SG25 : Steel Grit Mesh 25
SG40 : Steel Grit Mesh 40

Variations in size and pressure of steel grit abrasive materials are shown in table 1 with steel grit 18, steel grit 25, and steel grit 40 each with an increasing level of fineness from SG18, SG25, and SG40. The spray pressure used is 5 bar, 6 bar, and 7 bar and the spray pressure of 6 bar is the pressure commonly used in the blasting process.

B. Surface Preparation

The coating process is very important to pay attention to specimen readiness before it is applied with paint or as known as surface preparation. One of the usual processes is the blasting process. Blasting itself is a process to remove traces of rust, dust, paint, or dirt remaining on steel plates. The abrasive material used in the blasting process of this research is steel grit with 3 size variations. The blasting process itself has several success parameters, one of which is the spraying pressure. The variation of spraying pressure used is 5 bar, 6 bar, and 7 bar.

The next process, after the blasting process has been completed, is the specimen is being checked for its level of cleanliness, the level of cleanliness used is a minimum of SA2.5 (ISO 8501-1 "Preparation of Steel Substrates Before Application of Paints and Related Products - Visual Assessment of Surface Clineliness").

Specimens were aligned with the cleanliness guidebook and then concluded the cleanliness level category [8].

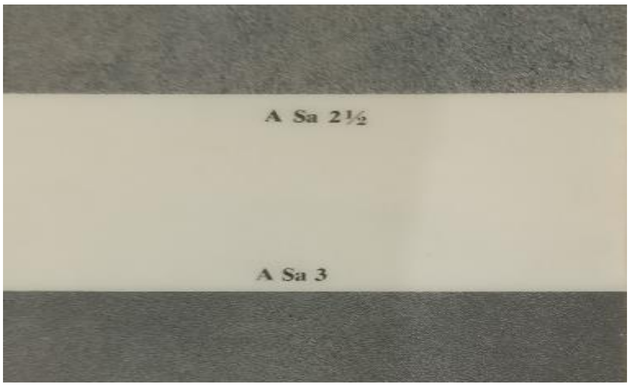

Figure 1 Cleanliness level SA2.5 and SA3

The level of cleanliness used is in accordance with ISO 8501-1 with a minimum level of cleanliness, namely SA 2.5 as shown in Figure 1. The next step is to measure the roughness level of the material after blasting with a surface roughness meter as shown in Figure 2. Measurements were made at three different points to get a value that can represent the entire area. The roughness standard used is based on ISO 8503 "Preparation of Steel Substrates Before Application of Paints and Related Products" [9].

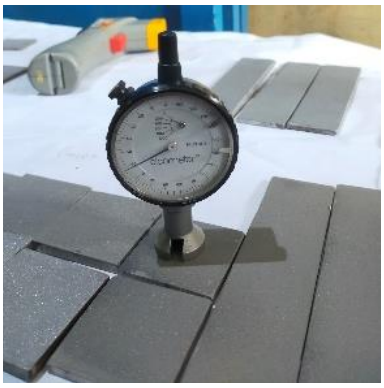

Figure 2 Roughness Value Measurement

C. Coating Process

The stage in the surface preparation process is completed, the next stage is the coating process. Environmental conditions must meet the paint manufacturer's recommended standards. So first of all the environmental conditions is checked. For environmental conditions that meet the criteria from the product data sheet, it is recommended that the specimens to immediately be subjected to the coating process, to avoid the specimens are no longer ready or dirty again due to dust or moisture adhering to them. The painting method used is the spray method. The paint used is a base paint or epoxy primer with the Chugoku Marine Paint Bannoh 1500 brand. According to the product data sheet, the mixture between the base and hardener used is 4.3 : 0.7.

The thickness of the paint must be calculated according to the product datasheet. The formula used in determining how thick the paint is when wet to get dry paint thickness uses the formula below.

$$\mathrm{DFT} = \frac{WFT\ x\ VS}{100} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\mathrm{WFT} = \frac{DFT}{VS} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .. (2)$$

Where:

DFT : Dry Paint Thickness

WFT : Wet Paint Thickness

VS : Solid volume

Where VS is the solid volume of the paint product, namely 73%. The DFT to be used is 250 μm. so the WFT according to the formula is 342.47 μm or in the tool it is rounded to 350 μm.

Figure 3 Paint Application Process

The thickness of the paint that has been applied to the specimen must be directly measured with a wet film comb. If it still does not reach the target, then continue until a value of 350 mm is obtained as shown in Figure 3. How to use this tool is to attach it to the teeth of the tool and attach it onto paper and see which teeth are affected by the paint [10].The wet paint thickness that is in accordance to the calculation must be left until it can be processed further or in a product data sheet called fully cured. Dry paint thickness or DFT is carried out using a surface profile gauge at 3 (three) different points as shown in Figure 4 and the average value is taken based on the ASTM D4138 standard [11]. Three dots are also used to represent the entire area and a standard deviation is also used to see deviations in values that occur.

Figure 4 DFT measurement

D. Corrosion Rate Testing

Corrosion rate testing is carried out to obtain an approximate value of the corrosion rate of a specimen. For a corrosive solution, instead of seawater, 3.5% NaCl solution is used. Corrosion testing for this final project uses a 3-electrode cell that has been connected to CorrTest as shown in Figure 5. This test is based on electrochemical theory referring to the ASTM G102 standard "Standard Practice for Calculation of Corrosion Rates and Related Information from Electrochemical Measurements" [12].

Figure 5 Corrosion Rate Testing

Figure 6 Granting Scratch Defects

The corrosion rate test will be carried out immediately after applying a scratch to the specimen with the same dimensions, namely 10 mm as shown in Figure 6. The results obtained from the corrosion rate test range from unacceptable to outstanding [13]. The provision of scratch defects is given when a corrosion test is to be carried out to obtain conditions that are more or less in accordance with those that occur in the field or those that occur on ships that are scratched after the coating process.

E. Research sites

The location of research was carried out in two places, which are CV Cipta Agung Surabaya for testing surface preparation for the coating process and the Corrosion and

Material Failure Laboratory of the ITS Sepuluh Nopember Institute of Technology for testing corrosion rates.

III. RESULTS AND DISCUSSION

A. Surface preparation results

The results of the blasting process in Figure 7 show that the surface of the steel plate is whitish (white metal). The color change indicates the effectiveness of the blasting process at the surface preparation stage before the coating process. The results have also been obtained at least SA2.5.

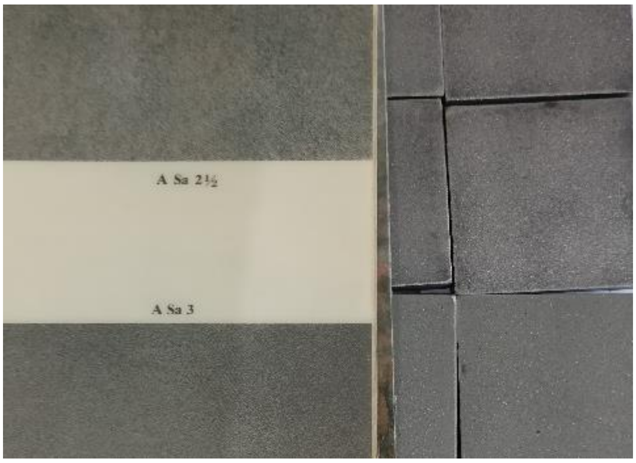

Figure 7 Visual Inspection Results

Roughness testing was carried out using a roughness meter, with 3 repetitions of the roughness test for each variation of spraying pressure and grain size on the ASTM A36 steel plate. The results obtained are shown in table 2.

TABLE 2
HARDNESS TESTING DATA

No	Specimens	Roughness Value (µm)				
		1	2	3	$\bar{x}$	σ
1	SG18-5 bar	85	75	50	70.00	14.72
2	SG18-6 bar	65	79	45	63.00	13.95
3	SG18-7 bar	65	65	40	56.67	11.79
4	SG25-5 bar	100	80	55	78.33	18.41
5	SG25-6 bar	65	85	55	68.33	12.47
6	SG25-7 bar	50	50	65	55.00	7.07
7	SG40-5 bar	95	70	100	88.33	13.12
8	SG40-6 bar	90	80	80	83.33	4.71
9	SG40-7 bar	70	82	72	74.67	5.25

Information,
SG18 : Steel Grit Mesh 18
SG25 : Steel Grit Mesh 25
SG40 : Steel Grit Mesh 40

The roughness test with the values shown in table 2 produces a value that is within the limits, which is at a value of 40 µm -100 µm based on BKI Vol. G, Ch. 1, sec. 4 [3].

TABLE 3
HARDNESS TESTING DATA BASED ON ABRASIVE MATERIAL SIZE

No	Specimens	Roughness Value (µm)				
		1	2	3	$\bar{x}$	σ
1	SG18	71.67	73	45	63.22	12.9
2	SG25	71.67	71.67	58.33	67.22	6.29
3	SG40	85	77.33	84	82.11	3.4

TABLE 4
HARDNESS TEST DATA BASED ON SPRAYING PRESSURE

No	Specimens	Roughness Value (µm)				
		1	2	3	$\bar{x}$	σ
1	5 Bar	93.33	75	68.33	78.89	10.57
2	6 Bar	73.33	81.33	60	71.56	8.8
3	7 Bar	61.66	65.67	59	62.11	2.74

Roughness testing is divided based on the variation in size and spraying pressure of the abrasive material shown in table 3 and table 4. The roughness value in the distribution based on the size variation shows that the roughness value decreases starting from SG40, SG25, and SG18, or the larger the abrasive material particles on steel grit, the roughness value will decrease.

The roughness value in the division based on the spraying pressure shows that the roughness value decreases when the spraying pressure increases, this is because the hills and valleys formed as a result of the collision will disappear again due to the large spraying pressure.

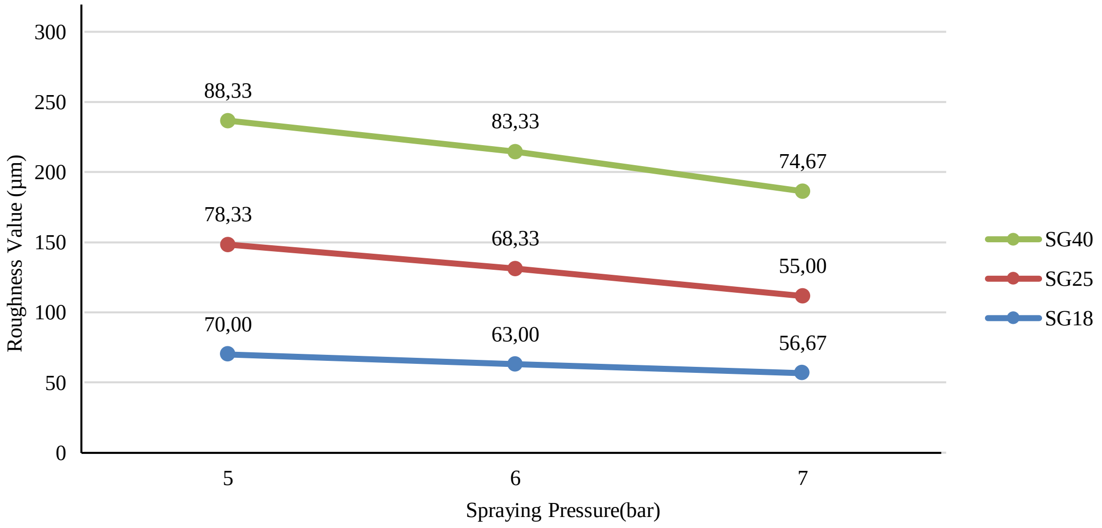

Figure 8 Graph of Roughness Testing Data

The surface roughness value in graphical form is shown in Figure 8 with the highest value obtained from the size of the abrasive material steel grit 40 and a pressure of 5 bar which is 88.33 µm, followed successively by steel grit 25 and steel grit 18 and a pressure of 6 bar and 7 bar.

The test results shown from the roughness value show that the finer the abrasive material on the steel grit and the smaller the pressure, the higher the roughness value. This result can occur because the greater the spraying pressure will remove the hills and valleys that have occurred and cause an even roughness.

B. Coating Process Results

The results of the next test are environmental conditions measurements. The importance of checking environmental conditions can affect the results obtained during and after the coating process. Checking environmental conditions includes several aspects, such as specimen temperature, wet air temperature, dry air temperature, humidity, and dew point.

Limitation of environmental conditions mentioned in the product data sheet that the relative humidity and steel temperature must be below 85% and a minimum of 3°C respectively from the dew point.

TABLE 5
RESULTS OF MEASUREMENT OF ENVIRONMENTAL CONDITIONS

No	Measurement	Results
1	Dry Bulb Temperature	26°C
2	Wet Bulb Temperature	32°C
3	Relative Humidity	58 %
4	Dew Point	17°C
5	Steel Temperature	35°C

The results of measurements of environmental conditions, the results obtained are in accordance with table 5 and the results of the specimens can be continued to the next stage, which is the coating process.

Tests carried out during the coating process was WFT with a value of 350 mm and DFT with a value of 250 mm. According to the WFT and DFT product data sheets obtained in table 6 and figure 9.

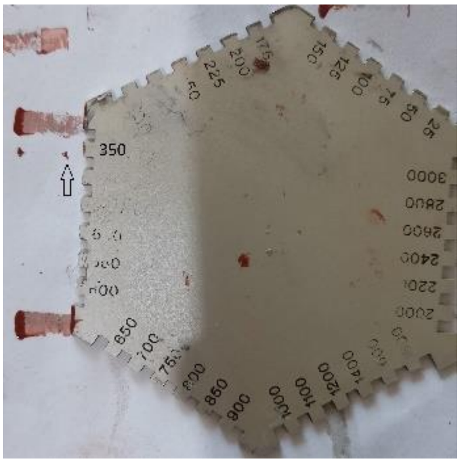

Figure 9 WFT Measurement Results

TABLE 6
WFT AND DFT TEST RESULTS

No	Specimens	DFT Value (μm)				
		1	2	3	$\bar{x}$	σ
1	SG18-5 bar	236	210	218	221.33	10.87
2	SG18-6 bar	220	206	242	222.67	14.81
3	SG18-7 bar	228	224	224	225.33	1.88
4	SG25-5 bar	212	234	256	234	17.96
5	SG25-6 bar	276	254	264	264.67	8.99
6	SG25-7 bar	244	248	238	243.33	4.10
7	SG40-5 bar	234	236	200	223.33	16.51
8	SG40-6 bar	190	272	254	238.67	35.18
9	SG40-7 bar	238	242	220	233.33	9.56

Information,
SG18 : Steel Grit Mesh 18
SG25 : Steel Grit Mesh 25
SG40 : Steel Grit Mesh 40

The resulting paint thickness values are shown in Figure 9 and Table 6. It can be seen that the DFT values obtained are in agreement with the product data sheet. The standard deviation is also used to see the deviation of the value from the average value so that it does not cause bias [14].

C. Corrosion rate test data

TABLE 7
CORROSION RATE TEST DATA

No	Specimens	Corrosion Rate Value (mmpy)	Category
1	SG18-5 bar	0.23403	*Good*
2	SG18-6 bar	0.033445	*Excellent*
3	SG18-7 bar	0.005674	*Outstanding*
4	SG25-5 bar	0.059457	*Excellent*
5	SG25-6 bar	0.007191	*Outstanding*
6	SG25-7 bar	0.003425	*Outstanding*
7	SG40-5 bar	0.023612	*Excellent*
8	SG40-6 bar	0.00853	*Outstanding*
9	SG40-7 bar	0.002685	*Outstanding*
10	*Raw Material**	0.5831	*Fair*

Information,
SG18 : Steel Grit Mesh 18
SG25 : Steel Grit Mesh 25
SG40 : Steel Grit Mesh 40

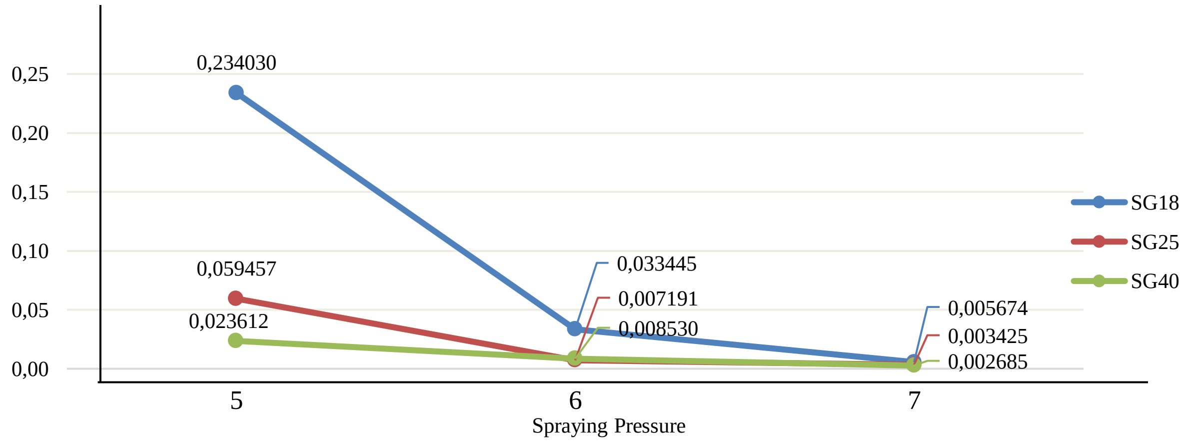

Figure 10 Graph Corrosion rate test

Scratch defects also greatly affect the existing results. The rust that has formed in Figure 6 is made as a result of the scratches made. Meanwhile, on the specimen that was still protected by paint, no rust was seen at all.

The corrosion rate values shown in table 7 and figure 10 show the relationship between the influence of the size of the abrasive material and the pressure of blasting spraying on the value of the corrosion rate. Figure 10 shows that the expected corrosion rate value is the smallest, which is found in the combination of steel grit 40 and a pressure of 7 bar and the highest corrosion rate value is found in the combination of steel grit 18 and a pressure of 5 bar. In the graph, it can also be seen that the value of the resulting corrosion rate has a tendency to decrease with the order of steel grit 18, steel grit 25, and steel grit 40. The value of the corrosion rate also decreases with the order of 5 bar pressure, 6 bar pressure, and 7 bar pressure. According to BKI Vol. G, Ch. 1, sec. 3, the allowable corrosion rate is 0.12 mmpy for wet surfaces and 0.06 mmpy for surfaces that are only affected by the seawater environment [3].

IV. Conclusion

Tests carried out with variations in the mesh/size of the abrasive material and spraying pressure can prove that the surface preparation process in the coating process is very influential. The value of the corrosion rate will decrease when the spraying pressure increases and when the size/mesh of the material gets finer/smaller. The highest corrosion rate value is 0.23403 mmpy from the steel grit 18 variations and 5 bar pressure. While the value of the lowest corrosion rate is 0.002685 mmpy from the variation of steel grit 40 and 7 bar pressure.

References

[1] T. Prasetyo, M. Buana, and A. Sulisetyono, "Analysis of Local Ship Component Industry Development," J. Wave, vol. 10 Nomor 2, no. Desember 2016, pp. 39–46, 2016, [Online]. Available: https://media.neliti.com/media/publications/299033-analisis-pengembangan-industri-komponen-180d4062.pdf
[2] M. B. Beyer, S. M. Copley, M. E. Sbank, C. A. Wert, and G. L. Wilkes, McGraw-Hill Series in Materials Science and Engineering Editorial Board. 1987.
[3] BKI, "Guidance For Classification And Construction-Part 1 Seagoing Ship-Volume G-Guidance For The Corrosion Protection And Coating Systems," vol. G, 2019.
[4] Biro Klasifikasi Indonesia, "RULES FOR MATERIALS Consolidated Edition 2021," vol. V, p. Sec 4, 2021.
[5] A. M. Das, "Jurnal Ilmiah Universitas Batanghari Jambi Vol.12 No.2 Tahun 2012 STUDI DAMPAK KOROSI TERHADAP MATERIAL BAJA Amsori M Das 1," vol. 12, no. 2, pp. 11–15, 2012.
[6] C. T. Nugroho, H. Pratikno, and A. Purniawan, "Analisa Pengaruh Material Abrasif Pada Blasting Terhadap Kekuatan Lekat Cat dan Ketahanan Korosi di Lingkungan Air Laut," J. Tek. ITS, vol. 5, no. 2, 2017, doi: 10.12962/j23373539.v5i2.18090.
[7] Y. K. Afandi, I. S. Arief, J. Teknik, S. Perkapalan, and F. T. Kelautan, "Jurnal Korosi (Abdi)," vol. 4, no. 1, pp. 1–5, 2015.
[8] International Organization for Standardization, "STANDARD ISO 8501 Corrosion Protection of Steel Structures by Painting," vol. 33, no. February, pp. 1–4, 2011.
[9] ISO 8503-2, "Preparation of steel substrates before application of paints and related products - Surface roughness characteristics of blast-cleaned steel substrates Part 2: Method for the grading of surface profile of abrasive blast-cleaned steel - Comparator procedur," Standards, vol. 2012, 1988.
[10] S. Practice, "Standard Practice for Measurement of Wet Film Thickness by Notch Gages 1," Measurement, vol. 06, no. January 1996, pp. 6–8, 2001.
[11] F. Metals and N. Coat-, "Standard Practices for Measurement of Dry Film Thickness of Protective Coating Systems by Destructive , Cross-Sectioning Means 1," vol. 94, no. C, pp. 6–11, 2011.
[12] ASTM-Standards, "Standard practice for calculation of corrosion rates and related information from electrochemical measurements," Astm G 102-89, vol. 89, no. Reapproved, pp. 1–7, 1999, doi: 10.1520/G0102-89R10.2.
[13] M. G. Fontana, "Corrosion engineering. Third edition.," 1986.
[14] S. P. J. E. A. Dharma, Aplikasi Spss Dalam Analisis Multivariates. 2020.
[15] C. T. Nugroho, H. Pratikno, J. T. Kelautan, and F. T. Kelautan, "Blasting Terhadap Daya Lekat Cat Dan Ketahanan Korosi Di Lingkungan Air Laut Blasting on Paint Adhesion Strength and," 2016.