International Journal of Offshore and Coastal Engineering
Vol. 5 | No. 1 | pp. 10-17 | May 2021
e-ISSN: 2580-0914

Submitted: January 10, 2021 | Revised: March 21, 2021 | Accepted: April 06, 2021

Analysis of the Effect of Abrasive Material and Polyurethane Coating Thickness Variations on ASTM A36 Steel Towards Corrosion Rate in Sea Water Environment

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ABSTRACT
An unavoidable phenomenon of using steel as the main material in offshore structures and floating vessels is corrosion. One method of preventing corrosion is by coating and using polyurethane is one type of coating that is currently being developed in the maritime industry. But the success of this coating process is very dependent on the surface preparation process. The usual method used is blasting using an abrasive material. This study aims to find the response to the corrosion rate of polyurethane coating with thickness variations of 60 µm, 80 µm, and 100 µm by first blasting using abrasive material variations in the form of silica sand and steel grit. The result of the corrosion rate test showed that the lowest corrosion rate value was obtained in the variation of abrasive material in the form of steel grit. with a 100. µm of polyurethane coating thickness, that is 0,00008 mm/a. While the highest corrosion rate value was obtained in the variation of abrasive material in the form of silica sand with a 60 µm of polyurethane coating thickness, that is 0,02202 mm/a.

Keywords: *ASTM A36, Abrasive Materials, Polyurethane coating, Corrosion Rate*

1. INTRODUCTION

Steel metal is the main material that usually used in the oil and gas industry, especially in the construction of offshore structures and floating vessels. The type of steel metal that many used in this industry are low carbon steel because it has high tenacity and is easily machined [1]. But along with the increasing operating time of offshore structures and direct and continuous contact with seawater, steel can also decrease its quality in the form of corrosion.

Corrosion is the damage or degradation of metals due to electrochemical reactions between metals that has the function as anodes and other substances in the environment that has the function as cathodes so that oxidation-reduction reactions (redox) are created and produce undesirable compounds. Corrosion is one of the main causes of failure of a structure, especially in structures that are involved in Maritime Industry [2]. Corrosion can reduce the physical and mechanical strength of the material and can affect changes in the surface of the material which will have an impact on decreasing productivity and reducing the life of the structure. In offshore structures, the usual types of corrosion are fatigue corrosion, bio-corrosion, and uniform corrosion [3]. The process of corrosion can not be avoided and stopped, but can only be controlled by slow it down. There is a way to control corrosion is to separate metals and corrosive environments by using a protective layer or coating [4].

The coating is a process to coat a substrate that aims to protect the material from corrosion and provide protection to the material [11]. A good quality coating must have properties including having high adhesion strength on metal surfaces, resistance to large electron flow, and having sufficient thickness to protect the material against greater corrosion. There is one type of paint that is being developed is polyurethane. Polyurethane coatings have good adhesion and corrosion resistance to be applied to maritime environments. However, it still needs further research to be done on the right thickness of polyurethane coating for applications in maritime environments, then the paint can provide perfect protection so that the paint can provide perfect protection to lower the corrosion rate that occurs in the structure. The thicker layer of a coating does not guarantee the coating can protect the material perfectly [7].

The success of the coating process is highly dependent on the surface preparation process, where this process will affect the adhesion strength of the material [8]. The techniques of surface preparation are very diverse, but the blasting technique is a method that often used in the oil and gas industry. Blasting is the process of firing abrasive particles onto the surface of a material, so it causes friction or collision to remove materials contaminated by rust, paint, salt oil, and others [9]. The selection and use of the right abrasive material can increase the adhesion of the paint.

The value of surface roughness and coating thickness significantly influence the corrosion resistance of the material [10][11]. Therefore, this research will analyze the effect of variations in abrasive material and thickness of the polyurethane coating on ASTM A36 steel towards the corrosion rate in the seawater environment.

2. BASIC THEORY

2.1. Steel

Steel is an alloy metal with iron (Fe) as the base element and carbon (C) as the alloy element. The carbon element can make steel hard and brittle, therefore the hard and soft nature of steel depends on the percentage of carbon [12]. Carbon content in steel ranges from 0.2% - 2.1% according to the grade. The more carbon content in steel, it makes the steel harder and the tensile strength greater, the more carbon content, the steel will be more brittle and its tenacity will be reduced so it becomes easily broken. If one or more metals are added to carbon steel in sufficient quantities, new steel properties will be obtained, this result is known as alloy steel. Commonly used alloys are nickel (Ni), manganese (Mn), chromium (Cr), and vanadium (Vn). Steel can be classified as follows:

1. Low Carbon Steel

   Low carbon steel is steel that has a carbon content of less than 0.3%. This steel is easy to be forged, easy to be machined, and also easy to be given welding treatment. Although relatively soft, low carbon steel has high toughness and tenacity. In the oil and gas industry, this type of steel is commonly used as the main material in the manufacture of offshore structures and floating vessels.
2. Medium Carbon Steel

   Medium carbon steels have higher strength and hardness than low carbon steels. It is because medium carbon steels have carbon concentrations ranging from 0.3% to 0.6%. Medium carbon steel is often used for bolts, nuts, pistons and gears.
3. High Carbon Steel

   High carbon steels have greater carbon content, ranging from 0.7% to 1.3%. This steel has high tensile strength, so it is widely used as tools such as springs, tools, saws, etc.

ASTM A36 steel material which used in this study belongs to the category of low carbon steel because it has a carbon composition of less than 0.3%.

2.2. Corrosion

Corrosion is a process of metal destruction or deterioration in the quality of a metal due to environmental influences. In detail, corrosion is damage or degradation of metals due to electrochemical reactions between metals that has a function as anodes and other substances in the environment that function as cathodes so that oxidation-reduction (redox) reactions are created and produce undesirable compounds. Corrosion can not be stopped but can only be slowed down. Environmental conditions greatly affect the level of corrosivity of a material. Environmental conditions that are too acidic, hot, humid and the presence of microorganisms around the material will further accelerate the occurrence of corrosion. The factors that can affect the rapid rate of corrosion are:

1. Electrolytes

   Electrolytes (acids or salts) are good media for charge transfer. This makes it easier for electrons to be bound by oxygen in the air. Rainwater contains a lot of acids, while seawater contains a lot of salt. Therefore rainwater and seawater are the main causes of corrosion.
2. Water and air humidity

   From the reactions that occur in the corrosion process, it can seem that water is one of the important factors for corrosion to take place. Moist air that contains a lot of water vapour will accelerate the corrosion process.
3. Temperature

   Corrosion will be easier at high temperatures than at low temperatures. This is caused by the speed of particles which also increases so which triggers many chemical reactions.
4. Environmental acidity (pH)

   In acidic conditions, the smaller the pH, the faster the corrosion rate will be. This is evidenced by a graph about the effect of acidity on the corrosion rate.

2.3. Corrosion Prevention

The process of corrosion can not be stopped but only be controlled or slowed down [13]. As mentioned above that corrosion is the result of a reaction between an alloy and its environment, the corrosion prevention method can focus on environmental control or determine the appropriate alloy material. Corrosion prevention methods can be grouped as follows [14]:

1. Coating

   In this method, electrochemical elements are used but only to protect the material from a corrosive environment. There are two types of coating :
   a. Liquid coating is to paint on the surface of the steel so that the steel can be protected by corrosion.
   b. Concrete coating is a coating of steel by coating of steel with concrete, usually, this is done in building construction

   There are 3 basic components in the coating, namely pigment as a base paint that inhibits corrosion attack, binder as a determinant of the character of the paint layer, and solvent as a component for finishing.
2. Good Material Selection

   The use of corrosion resistant materials can be considered as an increase in anodic control.

3. Cathodic Protection
   When there are two different alloy metals combined in an electrolyte, one of them generally rusts at a higher rate while the other is protected. Steel is generally corroded at a higher rate but when it is joined with certain metals, especially aluminium, magnesium and zinc, the steel will be protected and the metals combined will be corroded first.
4. Control the Environment
   If the environment can be changed to be less corrosive, then of course this will reduce corrosion of the existing alloy material. This method can generally only be used in confined spaces or closed water systems.
5. Design
   From the perspective of corrosion problems, design can be considered as one of the methods of preventing corrosion with proper project planning and implementation. This includes the process of making construction drawings, material selection and control measures.

2.4. Surface Preparation

Surface preparation is the earliest stage performed on the material before the coating process is carried out. Surface preparation is the process of removing old paints, rust and other contaminants from the surface and forming a roughness profile for adhesion to new paint [15]. This stage is very influential on the ability of the material to bind the coating layer. The presence of small amounts of contaminants on surfaces such as oil, oxide etc. can damage and reduce the physical adhesion strength of the coating on the substrate [8].

Dry abrasive blast cleaning is a surface preparation method commonly applied to the oil and gas industry to remove rust, old paint and other impurities [15]. Dry abrasive blast cleaning also called sandblasting is the process of cleaning rust, old paint or other impurities on the surface of the material by spraying abrasive material at high speed on the surface [16]. The types of abrasive materials commonly used are silica sand, steel grit, steel shot, garnet, and aluminium oxide.

2.5. Abrasive Material

The abrasive material is one important component in the blasting process. Several types of abrasive material can be used in the surface preparation process, including:

Tabel 1. Types of Abrasive Material [17]

Abrasive Material	Mesh Sizes (µm)	Hardness (MOHS)	Density (g/ml)
Silica Sand	6-270	5-6	2.65
Garnet	8-300	7-8	3.5-4.3
Coal Slag	12-80	6-7.5	2.7
Aluminum Oxide	16-220	7-8	2
Steel Shot	7-200	8	7
Volcanic Sand	12-120	5.5-6.5	1.6
Steel Grit	10-235	8-9	7

2.6. Polyurethane

Polyurethane is a polymer that is produced from a chemical reaction between isocyanate with high alcohol. Isocyanates are molecules containing isocyanate (NCO) radical groups, while high degree alcohols are usually called polyols. Polyurethane coating has been applied to various things because they have good corrosion resistance, high chemical and abrasion resistance, have high flexibility as well as are easy to apply. These excellent polyurethane coating properties result from a synergistic effect between the polyester or polyether and the urethane hydrogen bonding group [18]. The table below shows the index of resistance of several types of paint to different environments.

Tabel 2. The Durability of Several Types of Paint in Different Environments [19]

Type of Paint	Durability with							
	Acid	Bases	Salt	Solvent	Water	Wheater	Oxidation	Abration
Oil	1	1	6	2	7	10	1	4
Alkyd	6	6	8	4	8	10	3	6
Chlorinated Rubber	10	10	10	4	10	8	6	6
Coaltar Epoxy	8	8	10	7	10	4	5	4
Catalyzed Epoxy	9	10	10	9	10	8	6	6
Silicone Alkyd	4	3	6	2	8	9	4	4
Vinyl	10	10	10	5	10	10	10	7
Polyurethane	9	10	10	9	10	8	9	10
Zn	1	5	5	10	5	10	10	10

1 : The Worst
10 : The Best

2.7. Corrosion Rate

The corrosion rate is the propagation speed or speed of decline in quality of material with time. Ways to calculate the corrosion rate include using the weight loss method and the electrochemical method. The weight loss method is a calculation of the rate of corrosion by measuring the weight shortage due to corrosion that occurs. Meanwhile, in the electrolysis method, an electrochemical aid using three cells of the electrode is tasked with giving potential to the material so that the material will be corroded, on the other hand, the value of the corrosion rate can also be found. Corrosion rate is calculated using a formula as below:

$$CR = 0{,}00327 \frac{i(EW)}{D} \quad (1)$$

With,
CR = Corrotion Rate (mmpy)
EW = Mass of the steel (grams)
i = Current density (μA / cm^2)
D = Corroded metal density (gram / cm^3)

The smaller the corrosion rate of a material, the more difficult it is to corrode. Material corrosion resistance can be classified based on its corrosion rate values as follows :

Table 3. Material resistance criteria differ in corrosion rates [19]

Relative Corrosion Resistance	*Approximate Metric Equivalent*				
	mpy	*mm/year*	*μm/year*	*nm/year*	*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	50-1000	20-50
Poor	50-200	1-5	1000-5000	150-500	50-200
Unacceptable	>200	>5	>5000	>500	>200

3. RESEARCH METHODS

3.1 Literature Study

A literature study is carried out as a deepening of research by referring to journals and books that discuss surface preparation especially blasting techniques, the use of abrasive material in blasting, application of polyurethane coating types and corrosion rate testing method.

3.2 Material Preparation

In this study, the material used is ASTM A36 steel. Specimens used amounted to 18 pieces with a size of 40 x 20 x 10 mm. Abrasive materials used in the blasting process are silica sand and steel grit. While for the coating material, it used JOTUN Futura Classic type polyurethane paint with a variety of thickness applications that are 60 μm, 80 μm, and 100 μm. The following is the naming table for the test specimens used:

Tabel 4. Naming Test Specimens

Thickness	Abrasive Material	
	Silica Sand	Steel Grit
60	PK 1	SK1
	PK 2	SK2
	PK 3	SK3
80	PK 4	SK4
	PK 5	SK5
	PK 6	SK6
90	PK 7	SK7
	PK 8	SK8
	PK 9	SK9

3.3 Environmental Test

Before the experiment process begins, several things need to be considered, one of that things is environmental conditions such as steel temperature, wet temperature, dry temperature, Dew Point (DP), and Relative Humidity (RH). The purpose of this environmental test is to measure the humidity level of the environment in which the test is carried out. ISO 12944-5 "*Corrosion Protection of Steel Structures by Protective Paint System*" [21] states that Relative Humidity (RH) must be below 85% and the specimen temperature is at least 3 °C from the Dew Point (DP). The instrument used to measure RH is called the sling psychrometer.

3.4 Blasting Process

Before coating or coating, the material is first given surface preparation through one of the methods, namely Dry Abrasive Blast Cleaning or blasting using abrasive materials. The purpose of doing blasting is to clean the material from dirt or dust so that afterwards the paint can stick well. In this research, 2 variations of abrasive material, among others, silica sand and steel grit with the level of cleanliness of the specimen following ISO 8501-1 "*Corrosion Protection of Steel Structure by* Painting" [22] standards listed on the Jotun Cat Technical Data Sheet, namely SA 2 ½

Figure 1. Cleanliness level SA 2,5 [22]

3.5 Surface Roughness Measurement

This measurement is carried out to determine the roughness profile of each specimen after the blasting process is carried out. The roughness profile of this material will affect the level of adhesion of the paint on the test material. This test uses a roughness meter using the D4417 standard "Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel" [23]. This test is carried out at three points on each specimen and the average value is calculated.

Figure 2. Surface Roughness Testing Process Specimens

3.6 Coating Process

The coating process is done by paying attention to the Technical Data Sheet provided so that the results obtained are optimal. The coating method used is the spray method using an air spray gun. In this study, the application of coatings was given thickness variations consisting of 60 µm, 80 µm, and 100 µm. JOTUN Futura Classic brand polyurethane paint has 2 components, component A as base and component B is curing agent with a mixture ratio of 9: 1 (by volume). The thinner uses Jotun thinner product no. 10.

3.7 Measurement of Coating Thickness

In the coating process, there are 2 types of thickness that need to be considered, including wet film thickness and dry film thickness. The instrument used to measure wet film thickness is the wet film comb. While the tool used to measure dry film thickness is a thickness gauge coating. The coating that has been applied will shrink so that it is necessary to calculate the wet thickness to get the desired dry thickness. The percentage of paint shrinkage or commonly called solid volume is found on the Technical Data Sheet. For JOTUN paint used, the solid volume indicated is 61±2%. In this study, the desired variation of dry film thickness is 60 µm, 80 µm, and 100 µm. So, the wet film thickness value can be obtained using the formula:

$$WFT = \frac{Dry\ Film\ Thickness(100 + persentase\ thinner)}{\%\ Volume\ Solid} \quad (2)$$

Tabel 5. Wet Film Thickness Calculation

Dry Film Thickness (µm)	Volume Solid (%)	Wet Film Thickness (µm)
60	61±2	±120
80	61±2	±150
100	61±2	±10

3.8 Corrosion Rate Testing

In this study, the prediction of corrosion rate is done as an indicator of the influence of the use of variations in abrasive materials and polyurethane coating thickness using the three electrode cell method based on ASTM G102 "Standard Practice for Calculation of Corrosion Rates and Related Information from Electrochemical Measurement" [24]. In this test, NaCl solution with 3,5% salinity that has been generalized with seawater is the real condition in the field.

Figure 3. The Corrosion Rate Testing Process using 3 Electrode Cell Method

4. RESULTS AND DISCUSSION

4.1. Roughness Measurement

Table 6. Roughness Measurement Result Using Silica Sand

Specimen Code	Roughness Result (µm)			Average
	Point 1	Point 2	Point 3	
PK1	68	69	62	66.3
PK2	61	63	68	64.0
PK3	65	67	62	64.7
PK4	62	64	67	64.3
PK5	65	62	65	64.0
PK6	64	67	68	66.3
PK7	70	65	68	67.7
PK8	65	63	69	65.7
PK9	66	65	65	65.3
Total Average				65.4

Table 7. Roughness Measurement Result Using Steel Grit

Specimen Code	Roughness Result (µm)			Average
	Point 1	Point 2	Point 3	
SK1	80	83	80	81.0
SK2	79	80	76	78.3
SK3	76	75	82	77.7
SK4	78	80	80	79.3
SK5	80	76	82	79.3
SK6	79	77	80	78.7
SK7	76	82	82	80.0
SK8	81	78	80	79.7
SK9	80	77	80	79.0
Total Average				79.2

From the roughness test results contained in Table 6 and Table 7, it can be seen that the difference in the use of abrasive materials in the blasting process results in different surface roughness values. This can be caused by differences in the value of material violence. Table 1 shows the size of the hardness value of silica sand is smaller, namely 5-6 MoHS than steel grit which has a hardness value of 8-9 MoHS. Therefore, at the time of blasting, the use of steel grit abrasive material can create a greater surface roughness than silica sand.

4.2. *Coating* Thickness Measurement

After all, the specimens were given a coating application according to the wet film thickness calculations in Table 5 and they dried completely, then dry film thickness testing of each specimen was performed. The test results showed in the table below

Table 8. Dry Film Thickness Measurement Result

Abrasive Material	Coating Thickness (µm)	Specimen Code	DFT (µm)			Average
			Point 1	Point 2	Point 3	
Silica Sand	60	PK1	63	64	66	64.3
		PK2	59	61	63	61.0
		PK3	63	61	65	63.0
	80	PK4	85	81	83	83.0
		PK5	86	84	86	85.3
		PK6	83	86	85	84.7
	100	PK7	98	103	105	102.0
		PK8	101	105	104	103.3
		PK9	110	107	106	107.7
Steel Grit	60	SK1	65	61	64	63.3
		SK2	58	63	62	61.0
		SK3	64	65	62	63.7
	80	SK4	84	81	83	82.7
		SK5	86	84	87	85.7
		SK6	79	82	84	81.7
	100	SK7	99	103	104	102.0
		SK8	105	108	104	105.7
		SK9	102	98	104	101.3

From the test table above, it can be seen that the average dry thickness value of each specimen still occupies the ISO 12944 standard tolerance of 25% of the desired thickness.

4.3. Corrosion Rate Testing

Table 9. Corrosion Rate Result

Abrasive Material	Coating Thickness (µm)	Specimen Code	Potential (V)	Average of Potensial (V)
Silica Sand	60	PK1	-0.51332	-0.4919
		PK2	-0.44899	
		PK3	-0.51332	
	80	PK4	-0.44009	-0.4423
		PK5	-0.43103	
		PK6	-0.45564	
	100	PK7	-0.43196	-0.4315
		PK8	-0.43496	
		PK9	-0.42758	
Steel Grit	60	SK1	-0.43261	-0.3792
		SK2	-0.34108	
		SK3	-0.36398	
	80	SK4	-0.35482	-0.3482
		SK5	-0.29160	
		SK6	-0.39832	
	100	SK7	-0.36287	-0.3270
		SK8	-0.27667	
		SK9	-0.34153	

Table 10. Corrosion Rate Value

Abrasive Material	Coating Thickness (µm)	Specimen Code	Corrotion Rate (mm/a)	Average of Corrotion Rate (mm/a)
Silica Sand	60	PK1	0.033514	0.0220290000
		PK2	0.018543	
		PK3	0.01403	
	80	PK4	0.0029401	0.0022034667
		PK5	0.0017887	
		PK6	0.0018816	
	100	PK7	0.00013357	0.0002340233
		PK8	0.00032442	
		PK9	0.00024408	
Steel Grit	60	SK1	0.0098966	0.0096462667
		SK2	0.0068692	
		SK3	0.012173	
	80	SK4	0.00085976	0.0008587367
		SK5	0.00075896	
		SK6	0.00095749	
	100	SK7	0.00011645	0.0000812703
		SK8	0.000086807	
		SK9	0.000040554	

As we can see in Table 10, the specimen that has the lowest corrosion rate is specimen blasted with steel grit with a polyurethane coating thickness of 100 µm which is 0,00008 mm/a. While the specimen that has the highest corrosion rate value is the specimen blasted with silica sand with a polyurethane coating thickness of 60 µm which is 0,02202 mm/a. This result shows that the higher the roughness value of the material during blasting, the lower the corrosion rate will be. Besides that, the greater the thickness of the goating, the lower the corrosion rate will be.

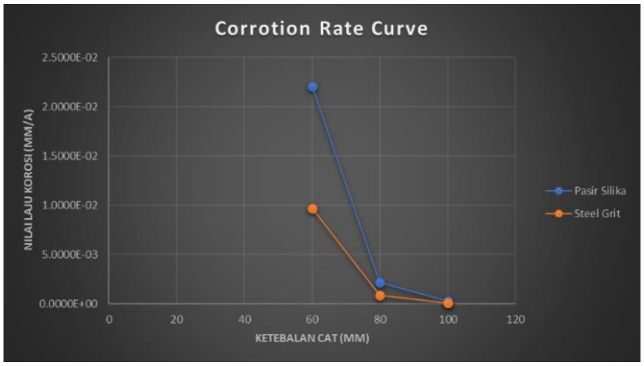

Figure 4. Comparison Corrosion Rate Curve

Figure 4 shows that With the same coating thickness, the specimen that was blasted with steel grit has a lower corrosion rate than the specimen that was blasted with silica sand. This also means the harder abrasive material are used, the lower corrosion rate will be.

5. CONCLUSION

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

1. From the surface roughness test, after blasting was done, it was found that the specimens that were blasted using steel grit abrasive material produced a higher surface roughness value of 79,2 µm. whereas specimens that were blasted using silica sand abrasive material produced a smaller roughness value of 65,4 µm
2. From the corrosion rate testing, the result shows that the specimen which has the smallest corrosion rate value is the material that was blasted with steel grit abrasive material with 100 µm of polyurethane coating thickness that is 0,00008 mm/a. Meanwhile, the highest value of corrosion rate is found in the material which was blasted with silica sand abrasive material with 60 µm of polyurethane coating thickness that is 0,02202 mm/a.
3. With the same coating thickness, the specimen that was blasted with steel grit has a lower corrosion rate than the specimen that was blasted with silica sand.

THANKS TO

The author would like to express my thank to parents, CV. Cipta Agung, Corrosion Laboratory of Material and Metallurgical Department ITS also all the people who involved in carrying out this research both directly and indirectly. So that this research can be completed and hopes to be utilized as appropriate research for wide audiences.

REFERENCES

[1] Debrita, C. 2017. *Analisis Pengaruh Variasi Coating pada Pelat Baja ASTM A36 terhadap Prediksi Laju Korosi, Kekuatan Adhesi dan Ketahanan Impact*. Tugas Akhir. Surabaya : Institut Teknologi Sepuluh Nopember.

[2] Rialdo, T.Y. 2019. *Analisis Pengaruh Variasi Ketebalan Cat dan Komposisi Magnesium Karbonat Serbuk pada Campuran Coating Epoxy terhadap Kekuatan Adhesi, Metalografi, dan Prediksi Laju Korosi pada Baja ASTM A36.* Tugas Akhir. Surabaya : Institut Teknologi Sepuluh Nopember.

[3] Manurung, S.F. 2017. *Analisis Pengaruh Proses Blasting terhadap Kekuatan Adhesive pada Coating Sambungan Pipa.* Tugas Akhir. Surabaya : Institut Teknologi Sepuluh Nopember.

[4] Candrasasi, A. G. 2018. *Analisis Pengaruh Material Abrasif dan Variasi Tekanan Sand Blasting pada Baja ASTM A36 terhadap Daya Lekat Coating.* Tugas Akhir. Surabaya: Institut Teknologi Sepuluh Nopember.

[5] Nasoetion, R. 2012. Penggunaan Sistem Lapis Lindung Jenis Polyuretan untuk Aplikasi di Daerah Maritim. *Majalah Metalurgi*, Vol 27 No 3 : 213-224.

[6] Widhawardhana, D. K. 2017. *Analisis Polyurethane Coating pada Pelapisan Material Baja ASTM A36 dengan Beberapa Media Korosi.* Tugas Akhir. Surabaya: Institut Teknologi Sepuluh Nopember.

[7] Afandi, Y. K., Arief, I. S., & Amiadji. 2015. Analisa Laju Korosi pada Pelat Baja Karbon dengan Variasi Ketebalan Coating. *Jurnal Teknik ITS*, Vol 4 No. 1 : 1-5.

[8] Hudson, R. 1982. *Surface Preparation for Coating.* New York: The National Physical Laboratory.

[9] Aji, S. B. 2018. *Analisis Daya Lekat Coating terhadap Variasi Tekanan dan Sudut Blasting serta Prediksi Laju Korosi pada Pelat Baja ASTM A36.* Surabaya: Institut Teknologi Sepuluh Nopember.

[10] Pratama, R. A., & Kromodiharjo, S. 2016. Studi Eksperimen Pengaruh Tebal Cat dan Kekasaran pada Pelat Baja Karbon Rendah terhadap Kerekatan Cat dan Biaya Pross di PT. Swadaya Graha. *Jurnal Teknik ITS*, Vol 5 No 2 : 311-315.

[11] Nugroho, C. T. 2016. *Analisa Pengaruh Material Abrasif pada Blasting terhadap Daya Lekat Cat dan Ketahanan Korosi di Lingkungan Air Laut.* Tugas Akhir. Surabaya: Institut Teknologi Sepuluh Nopember.

[12] Bangun, W. P., Widiyarta, I. M., & Parwata, I. M. 2017. Pengaruh Waktu dan Ukuran Partikel Dry Sand Blasting terhadap Kekasaran Permukaan pada Baja Karbon Sedang. *Jurnal Ilmiah Teknik Desain Mekanika* , Vol 6 No 1 : 138-141.

[13] Ardianto, P. 2017. *Pengaruh Cacat Coating dan Perbedaan Salinitas terhadap Laju Korosi pada Daerah Splash Zone menggunakan Material Baja A36.* Tugas Akhir. Surabaya: Institut Teknologi Sepuluh Nopember.

[14] Chandler, K. A. 1985. *Marine and Offshore Corrosion.* London: Butterworth & Co Ltd Publisher.

[15] Kambham, K., Sangameswaran, S., Datar, S., & Kura, B. 2007. Copper Slag : Optimization of Productivity and Consumption for Cleaner Production in Dry Abrasive Blasting. *Journal of Cleaner Production*, 15 : 456-473.

[16] Parashar, S., & Parashar, A. K. 2015. Presurface Treatment of All Materials by Sandblasting. *International Jurnal of Advance Engineering and Research Development*, Vol 2 : 38-43.

[17] Momber, A. 2008. *Blast Cleaning Technology.* Berlin: Springer.

[18] Gao, T., He, Z., Hihara, L. H., Mehr, H. S., & Soucek, M. D. 2019. Outdoor Exposure and Accelerated Weathering of Polyurethane/Polysiloxane Hybrid Coatings. *Progress in Organic Coatings*, 130 : 44-57.
[19] Fontana, M. G. 1987. *Corrosion Engineering International Edition*. United States of America: The Ohio State University.
[20] ASTM D4541. 2002 *Pull-off Strength of Coatings Using Portable Adhesion Testers*. Washington : ASTM Publishing.
[21] ISO 12944-5. 2017. *Corrosion Protection of Steel Structures by Protective Paint System.* England: International Organization for Standardization.
[22] ISO 8501. 2011. *Corrosion Protection of Steel Structure by Painting.* England: International Organization for Standardization.
[23] ASTM D4417. 1999. *Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel*. Washington: ASTM Publishing.
[24] ASTM G102. (1994). *Standard Practice for Calculation for Corrosion Rates and Related Information from Electrochemical Measurements.* Washington: ASTM Publishing.