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The Effect of Air Pressure and Nozzle Distance on the Quality of Water-Based Painting Using a Gravity-Feed Spray Gun

Pengaruh Tekanan Udara dan Jarak *Nozzle* Terhadap Kualitas Pengecatan *Water-Based* Menggunakan *Gravity-Feed Spray Gun*

Mochammad Hildad Ajiban[1], Heru Arizal[1*], Rachmad Syarifudin Hidayatullah[1], Firman Yasa Utama[2]
[1]Pendidikan Teknik Mesin, Universitas Negeri Surabaya, Surabaya 60231, Indonesia
[2]Teknik Mesin, Universitas Negeri Surabaya, Surabaya 60231, Indonesia

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Abstract

Environmental influences can cause corrosion or damage to materials, which is why paint coating is used to protect them. Some of the factors that affect the quality of the paint are technical, such as setting the air pressure and spray gun nozzle spacing. The experimental research aims to determine how air pressures of 1.5, 2.0, and 2.5 bar and nozzle spacings of 10 cm, 15 cm, and 20 cm affect the gloss and thickness of the water-based paint layer. A gravity-feed spray gun was used for this purpose. The luster test method uses an AMTAST AMN60 glossmeter with the ASTM D523-08 standard, and the thickness test uses a coating thickness gauge with the ASTM E 376-96 standard. The air pressure and the distance of the spray gun nozzle affect the gloss and thickness of the paint layer. Parameter 2 bar/15 cm yielded the highest gloss of 92.77 GU, while parameter 2.5 bar/10 cm resulted in the highest coating thickness of 0.26 mm.

Keywords: glossiness, nozzle distance, layer thickness, air pressure, water based.

***SDGs*:**

Abstrak

Pengecatan adalah proses melapisi material dengan cat untuk melindunginya dari korosi atau kerusakan akibat pengaruh lingkungan. Beberapa faktor yang mempengaruhi kualitas pengecatan adalah pada aspek teknis seperti penyetelan tekanan udara dan jarak *nozzle spray gun*. Penelitian dilakukan secara eksperimen dengan tujuan untuk mengetahui dampak tekanan udara 1,5 , 2,0 , 2,5 bar dan jarak *nozzle* 10 cm , 15 cm , 20 cm terhadap daya kilap dan ketebalan lapisan cat *water-based* menggunakan *gravity feed spray gun*. Metode pengujian kekilapan menggunakan *glossmeter* AMTAST AMN60 berstandar ASTM D523-08 dan pengujian ketebalan menggunakan *coating thickness gauge* berstandar ASTM E 376-96. Tekanan udara dan jarak *nozzle spray gun* mempengaruhi daya kilap serta ketebalan lapisan cat. Daya kilap tertinggi di dapatkan pada parameter 2 bar / 15 cm dengan hasil 92,77 GU dan ketebalan lapisan tertinggi di dapatkan pada parameter 2,5 bar / 10 cm dengan tebal 0,26 mm.

Kata Kunci: daya kilap, jarak nozzle, ketebalan lapisan, tekanan udara, water based.

*Correspondence Author
email : heruarizal@unesa.ac.id

1. INTRODUCTION

In the current era of automotive development, it is important to balance the increase in the quality of transportation equipment, particularly motorized vehicles, which serve as the primary means of land transportation. Vehicle maintenance is crucial to ensure that the vehicle is in good condition and suitable for use. One type of maintenance required for vehicles is painting the body (Salim, 2019).

Painting involves coating metal or non-metal materials with colored paint to create a protective layer that prevents corrosion or damage from external environmental factors (Ardyanto and Utama, 2018). This paint can be in liquid or powder (Kristanto, Rubiono and Mujianto, 2017).

Liquid paint available: solvent-based and water-based. In 1987-1988, the European, US, and Japanese automotive industries began using water-based paint as a coating technology due to its environmentally friendly nature and superior characteristics (Streitberger and Dössel, 2008).

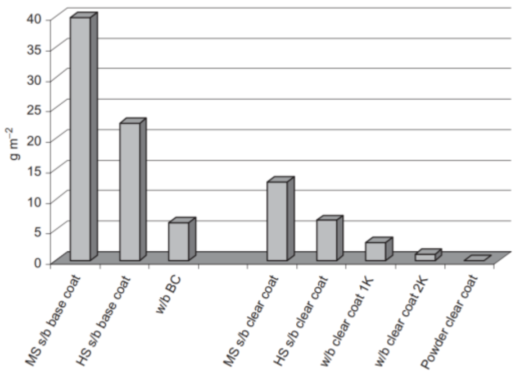

Figure 1. Contribution (g m^{-2}) to solvent emissions from base coat and clear coat (Streitberger and Dössel, 2008).

Over time, the paint layer may deteriorate due to color fading or scratches, reducing the aesthetic value of the object. This is particularly common in motor vehicle bodies (Fajrah and Perdana, 2019).

Periodic repainting is necessary to protect the object from external environmental factors that can affect the quality of the paint job. Coating defects are a common result of various factors that affect the quality of painting (Haryanto and Ichtiarto, 2019). These factors include humidity levels in the room, temperature during drying, excessive layers of paint and varnish, nozzle application distance, nozzle air pressure, and others (Khasanov, Rassokha and Kabanova, 2019).

According to Harahap's research, the thickness of the solvent-based paint layer is affected by the distance of nozzle application (Harahap, 2018). The thickness of the coating decreases as the distance between the nozzle and the panel increases.

Hutama et al. also noted that other factors, such as nozzle diameter, air pressure, and drying temperature, affect the coating thickness. The study found that a larger nozzle diameter results in a thinner paint layer (Hutama, Darsin and Mulyadi, 2019). Additionally, the application of high pressure during the painting process can lead to a reduction in the thickness of the paint layer. Moreover, high pressure can cause the paint to melt, resulting in imperfect painting outcomes where the paint fails to adhere properly to the intended surface.

Dzikriansyah and Rasyid et al., conducted a study that demonstrated the impact of air pressure and nozzle distance on coating thickness (Dzikriansyah, 2017; Rasyid, Santoso and Utama, 2017). Similarly, Wirojanupatump et al., explained that higher air pressure can increase droplet velocity, leading to an increase in the number of droplets reaching the substrate surface and, consequently, an increase in coating thickness (Wirojanupatump, Jiansirisomboon and Sopadang, 2006). The absorption process increases as the material layer thickens, due to the increase in absorbent particles and absorption area within the layer (Kaur and Aul, 2014).

Tyagita et al., found that high paint viscosity affects spray atomization (Tyagita, Pratama and Aprianto, 2019). If the viscosity of the paint mixture is too high, it can reduce the effectiveness of paint atomization, resulting in a less smooth paint surface and lower paint gloss value.

Bahtiar and Bahar found that increasing the thinner content significantly affected the gloss level (Bahtiar and Bahar, 2022). The study found that the highest glossiness was achieved when using a ratio of 1 : 1.3 between PU paint and PU thinner, resulting in a glossiness value of 87.4 GU. Varying amounts of nitrocellulose in the paint affected the paint's viscosity, with higher nitrocellulose content resulting in better base material function and higher color intensity durability. However, this can also impact the paint's glossiness value (Sriyana and Sudrajat, 2020).

Amookht et al., found that the thickness of the coating affects the glossiness of the paint (Amookht *et al.*, 2013). A thickness of 0.0 ± 0.0 µm resulted in a gloss of 43.3, while the highest gloss of 99.4 was achieved with a coating thickness of 87.2 ± 9.7 µm.

Therefore, painting quality remains a pressing concern. It is widely acknowledged that further exploration and research is necessary to develop optimal formulas and techniques in the field of body and paint.

Previous studies on solvent-based materials have prompted researchers to investigate the use of water-based materials, which are more environmentally friendly. Given the demands and advancements in the automotive body and paint industry, this research aims to provide valuable literacy material for both present and future use.

2. METHODOLOGY

The study was conducted on April 14, 2023, at Honda Citra Cakra (Emerald Mansion Citraraya TX 6 - CitraLand, Surabaya 60123). The data for this study were obtained through experiments, subject testing, and data recording (see Figure 2).

2.1. Research Variables

2.1.1. Independent Variable

Variables that cause changes or cause unreliable variables to appear are independent variables. Nozzle application distance and air pressure are independent variables in this study as shown in Table 1.

The variable nozzle distance of 10, 15, and 20 cm was used based on research by Dzikriansyah, which found that nozzle distances of 10 and 20 cm affect coating thickness (Dzikriansyah, 2017). In field practice, Honda Citra Cakra applied a nozzle distance of 15 cm as a parameter to achieve the best gloss and thickness according to standards. Meanwhile, Sopiyan et al. used a fixed parameter of 15-25 cm for painting (Sopiyan, Iqbal and Susetyo, 2022).

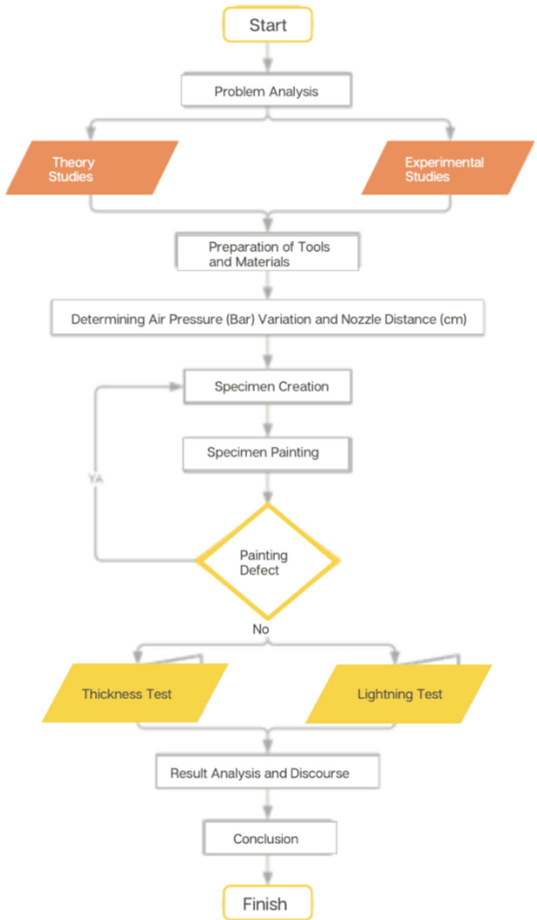

Figure 2. Research flow diagram.

Table 1. Independent variable.

No.	Independent Variable	Variation		
		1	2	3
1	Nozzle Distance (cm)	10	15	20
2	Air Pressure (bar)	1.5	2	2.5

Air pressure variables are used 1.5, 2.0, and 2.5 bar is used because field practice at Honda Citra Cakra applies a standard air pressure of 2 bar to get the best gloss results and thickness according to standards. In a study conducted by Hutama et al., it was found that the maximum thickness achieved was 112.4719 µm with a nozzle diameter of 1.2949 mm and an air pressure of 2 bar (Hutama, Darsin and Mulyadi, 2019).

2.1.2. Dependent Variable

The dependent variable is the variable discussed and examined by researchers in various studies to determine whether there is a benefit from using the independent variable. The dependent variables in this study are glossiness and thickness.

2.1.3. Control Variable

Control variables are variables manipulated by researchers to keep the relationship between the independent variable and the dependent variable constant. The control variables in this study as shown in Table 2.

Table 2. Control variable.

No	Control Variable
1	Using the same tools and materials
2	Cleaning the equipment when it will be refilled and reused
3	Color paint coating method 3 layers, that is ½-1-½
4	E-poxy sanding method using wet sanding
5	Coating of varnish and e-poxy using 2 wet layers
6	Drying using micro-oven
7	Drying temperature ± 60°C
8	Flash off 5 minutes per layer

2.2. Research Tools and Materials

The equipment required is shown in Table 3. This study uses a gravity fed spray gun, as shown in Figure 3, which exhibits variation in the amount of paint dispensed that can be minimized.

Table 3. Research tools.

No	Tools	Specification
1	Spray gun e-poxy coatings	HV-LP (nozzle 1,7)
2	Paint coating spray gun	Devilbiss GTI Pro (nozzle 1,3)
3	Varnish coating spray gun	Devilbiss GTI Pro Lite (nozzle 1,4)
4	Micro-oven	MASPION MOT-600
5	Random orbital sander (Double Action)	3M ROS 8.0 mm Elite Series 28510
6	Compressor	Custom (industrial standard)
7	Digital weigher	Mettler Toledo BBA242

Figure 3. Feed spray gun (Devilbiss GTI Pro Lite Gravity).

The following materials were utilized for the research as shown in Table 4.

Table 4. Materials.

No	Materials	Specification
1	Color Paint	Glasurit
2	E-poxy	Glasurit
3	Varnish	Glasurit
4	Wax and silicone remover (Degreaser)	Glasurit (541-5)
5	Sandpaper grid 600-800-1000	Taiyo KSCW SS
6	Strainer paint	3M
7	Test picies plate	SPPS Glasurit
8	White mothballs	T-shirt cotton

2.3. Color Paint, E-poxy, and Varnish

The color used is Modern Steel Metallic with the e-poxy coating used is series 02 (grey) because series 02 has good hiding power on Modern Steel Metallic color paint. The higher the hiding power, the less paint film required to cover the painted surface. Conversely, the lower the hiding power, the thicker the paint film required to cover the surface (Dwiyati, 2015). For the varnish composition shown as in Table 5.

Table 5. Varnish composition.

No	Materials	Quantity (ml)
1	Glasurit - HS Multi Celar Coat (923-255)	94.2
2	Harderner (Glasurit 929-94)	47.5
3	Normal Thinner (Glasurit 929-94)	8.3
	Σ	**150**

2.4. Research Instruments

Research instruments are means or tools used to collect data needed for research. Table 6 is a list of research instruments.

Table 6. Research instruments.

No	Instruments	Specification
1	Glossmeter	AMTAST AMN60
2	Coating Thickness Gauge	RICHMETERS RM-660

2.5. Specimen Preparation

In this study using SPSS plate specimens measuring 10 x 15 cm with a thickness of 0.9 mm. In this specimen preparation, the surface of the specimen plate is sanded using a random orbital sander (double action) with 600 grits (see Figure 4). The purpose of this is to create a texture on the surface so that the adhesion of the e-poxy to the surface is better (Yulliyanti, Susanty and Wahyono, 2016).

Figure 4. SPSS specimen after being sanded random orbital sender.

Conversely, if no pre-treatment process is performed on the specimen, contaminants such as oil, rust, and other impurities will reduce the adhesion of the e-poxy coating to the specimen plate (Mulyanto, Supriyono and Arta, 2020).

2.6. E-poxy Coating Process

The first step is the preparation of tools, materials, and rooms, such as the activation of the exhaust fan and the use of personal protective equipment (PPE). A flow chart of the E-Poxy coating process is shown in Figure 5.

Drying is carried out for 5 minutes with open air to allow time for the thinner to evaporate (Hermawan and Juhana, 2020). Drying using a micro-oven with the aim of maintaining a constant temperature (Arif, Eviningsih and Widyanto, 2023). In the micro-oven setting with a temperature of 60°C and a timer of 25 minutes (Khan and Hadromi, 2020). The sanding process is carried out with graded sandpaper, namely 600-800-1000 grit, until the surface of the sample looks smooth (no orange peel). Figure 6 is the process of free-air drying of specimens after e-poxy coating process.

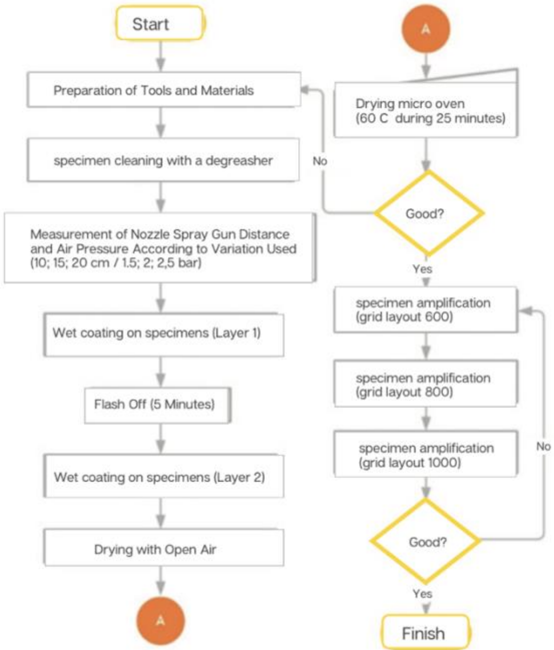

Figure 5. The flow chart of the e-poxy coating process.

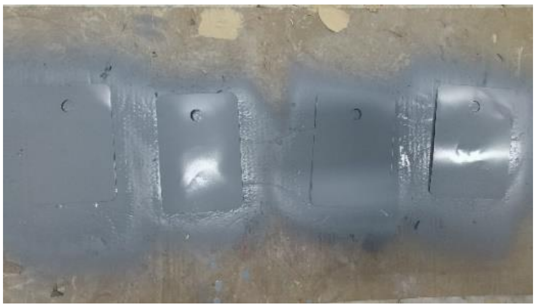

Figure 6. Free air drying of specimens.

2.7. Color Paint Coating Process

Some of the steps in the color coating process are shown in Figure 7. In the sample cleaning process, a degreaser is used to remove dirt and rubber from the surface.

2.8. Varnish Coating Process

Figure 8 is a flow chart of the coating process. The preparation of the paint materials is the process of mixing the paints as shown in Table 5. In the drying process, the micro oven is set with a drying temperature of 60°C with a time of 25 minutes, because at this temperature the rate of solvent evaporation increases, thus helping to dry the paint faster. In addition, this temperature was chosen to avoid the risk of damaging the painted material or object, as too high a temperature can cause the paint to dry unevenly or damage the physical or chemical properties of the material (Khan and Hadromi, 2020). The drying time of 25 minutes is based on the recommendations and standards of the Glasurit paint brand.

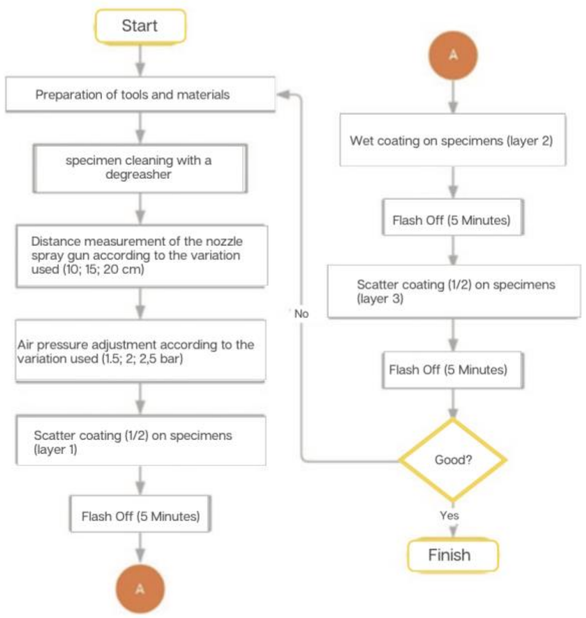

Figure 7. Flow chart of color paint coating process.

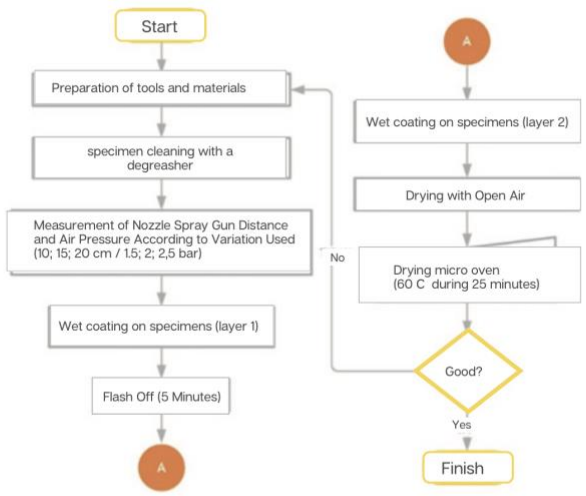

Figure 8. Flow chart of varnish coating process.

2.9. Characteristic Testing Proces

2.9.1. Glossiness Testing

To measure the gloss results of the coating, use a gloss meter as shown in Figure 9. This test refers to ASTM D523-08 Standard Test Method for Specular Gloss (ASTM, 2014).

Figure 9. Glossmeter AMTAST AMN60.

The following are the steps for testing gloss:

1) Divide the test points on the surface of the sample. This division is shown in Figure 10.

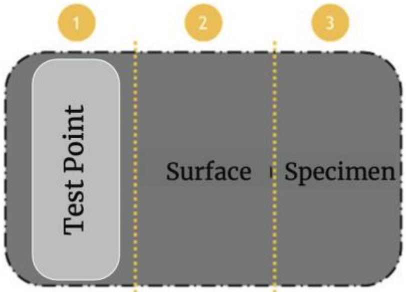

Figure 10. Gloss data collection method.

2) Clean the surface of the calibration instrument and calibrate the gloss meter.
3) Turn on the glossmeter by pressing the ON-OFF button.
4) Take data by placing the glossmeter on the surface of the sample.
5) Record and calculate the test result data according to the following equation (1):

$$GC = \frac{(n1+n2+n3)}{\Sigma n} \qquad (1)$$

where:

GC = Glossy Coating (GU)
n1-3 = Results of test points (1, 2, and 3)
Σn = Number of test points

2.9.2. Thickness Testing

In this thickness test, use the Coating Thickness Gauge tool as shown in the Figure 11. This test procedure refers to the standard ASTM E 376-96 Standard Practice for Measuring Coating Thickness by Magnetic-Field or Eddy- Current (Electromagnetic) Examination Methods 1 (ASTM, 1996).

Figure 11. Coating thickness gauge.

The following are the steps for thickness test:

1) Divide the data collection area as shown in Figure 12.

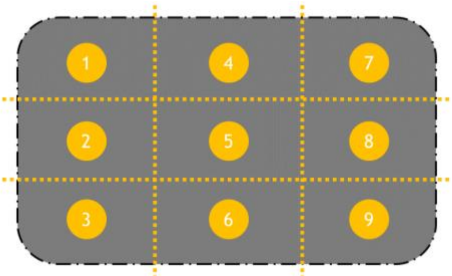

Figure 12. Thickness data collection method.

2) Clean the sample with a white cloth.
3) Turn on the coating thickness gage by pressing the ON-OFF button.
4) Set the material type Fe and thickness unit mm.
5) Take data by placing the sensor tip of the Coating Thickness Gauge on the surface of the specimen with light pressure.
6) Record and calculate the test result data according to the following equation (2):

$$TC = \frac{(n1+n2+n3+n..+n9)}{\Sigma n} \quad (2)$$

where:

TC = Coating Thickness (mm)
n1-9 = Result of test points (1,2,3, to 9)
Σn = Number of test points

3. RESULTS AND DISCUSSION

3.1. Specimen Glossiness Test Results

Based on Figure 13, the highest gloss results were obtained in the 2 bar / 15 cm variation with a result of 92.77 GU. This is because the combination of 2 bar air pressure and 15 cm distance produces good paint atomization, so that the droplets or particles of paint will not stick to the surface of the specimen in the state of sowing. Flash off drying at a good 2 bar / 15 cm variation makes the coating dry perfectly.

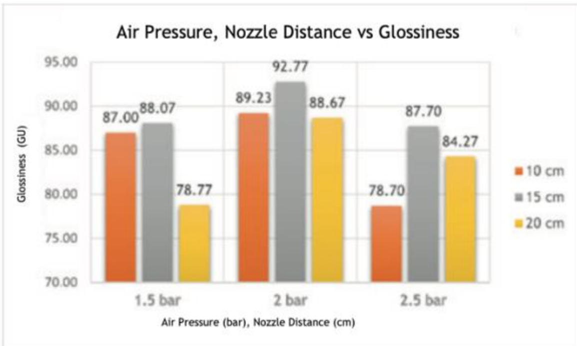

Figure 13. Experimental results from testing air pressure, nozzle distance vs. glossiness.

The lowest results were obtained at 1.5 bar / 20 cm variation with a result of 78.77 GU. This is because the air pressure is too low, resulting in poor atomization of the paint. Another factor is the distance between the nozzle and the sample surface. As a result, it takes longer for the paint droplets to reach the surface of the specimen, which reduces the hiding power of the paint. Poor paint atomization results in an orange peel effect, which also results in low gloss (Rasyid, Santoso and Utama, 2017).

In the 2.5 bar / 10 cm variation with the 2.5 bar / 15 cm variation, the gloss dropped dramatically by 09.00 GU. This is because the 2.5 bar/10 cm variation uses an air pressure that is too high, and the nozzle distance is too close. This causes the droplets to reach the surface of the sample too quickly, making the paint layer too thick. The thickness of this layer causes the coating to take longer to flash off (Sopiyan, Iqbal and Susetyo, 2022). The flash off applied for 5 minutes is not enough to dry the coating, so the color paint layer becomes wet. This phenomenon makes the coating result absorbent and results in poor gloss.

There is a significant decrease in gloss in the 1.5 bar / 15 cm and 1.5 bar / 20 cm variations. This is due to poor atomization of the coating. Poor atomization in the 1.5 bar / 20 cm variation causes the paint on the surface of the sample to be scattered so that the droplets are not well structured (Streitberger and Dössel, 2008).

These results are the same as the research of Wijaya and Anwar, that the results of nozzle distance variation will get a diagram of up and down results, where the peak results are at the best nozzle distance variation (Wijaya and Anwar, 2014). According to Wijaya and Anwar, the optimal nozzle distance results for each paint material will be different according to the paint material used (Wijaya and Anwar, 2014). The same thing is obtained that the optimum nozzle distance is at about 15 cm. At the lowest distance of 10 and 20 cm, the quality of painting results will be damaged.

Figure 14 shows that the variable nozzle distance of 15 cm has results with a flat trend line (consolidation) and the highest results in each air pressure variation, so the nozzle distance of 15 cm is a good distance to perform the painting process.

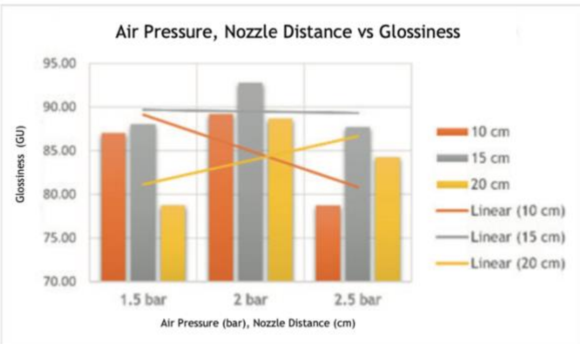

Figure 14. Trendline of gloss test results on nozzle distance variables.

3.2. Sample Thickness Test Results

Figure 15 shows that air pressure and nozzle distance affect the film thickness. It was found that the highest thickness was obtained in the 2.5 bar / 10 cm variation with a thickness of 0.26 mm. Air pressure and nozzle distance affect the thickness of the coating because the farther the nozzle distance or the lower the air pressure.

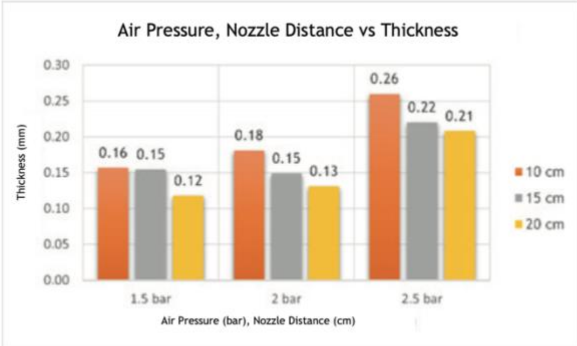

Figure 15. Experimental results from testing air pressure, nozzle distance vs. thickness.

The lower the air pressure, the longer it takes for the droplets to reach the surface of the sample, so the fewer the droplets that reach the surface of the sample (Dzikriansyah, 2017). Conversely, if the air pressure is high and the nozzle distance is closer, the coating will be thicker. The lowest thickness is obtained in the 1.5 bar / 20 cm variation with a coating thickness of 0.12 mm.

The thickness of the coating must be considered because the thicker the coating, the better the protection of the car body against environmental influences. However, other issues such as increasing vehicle weight and difficult handling must also be considered. The standard thickness of automotive panel coatings (e-poxy, paint and lacquer) is 150 μm or 1.15 mm (Streitberger and Dössel, 2008). According to these standards, the appropriate thickness is in the range of 2 bar / 15 cm.

These results are similar to the research by Dzikriansyah and Rasyid et al., that the larger the air pressure and the smaller the nozzle distance to the panel results in the coating will have a significant thickness compared to the small air pressure and nozzle distance to the large panel (Dzikriansyah, 2017; Rasyid, Santoso and Utama, 2017).

4. CONCLUSION

The conclusion from this research is that air pressure and nozzle distance to the panel affect the gloss and thickness of the coating. From the gloss graph, the difference in results is due to absorbent paint and orange peel effect.

Another thing about the thickness of the paint layer is also because the thickness of the paint layer will increase with the high air pressure. In other aspects, the smaller the distance between the nozzle and the panel, the more the thickness of the paint layer will increase.

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