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Effect of Activator Spraying Amount on The Thickness and Appearance of Water Transfer Printing Film Coating Results

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Abstract

Water Transfer Printing (WTP) is a coating technique that transfers decorative film patterns onto complex substrates using water and an activator. The amount of activator is critical because insufficient or excessive application may affect film dissolution, pattern adhesion, coating thickness, and visual quality. This study aimed to determine the effect of the number of activator sprays on the thickness and appearance of WTP film coatings on Aluminum Alloy 5052. An experimental method was applied using four activator spray variations, two, three, four, and five sprays. The controlled parameters included substrate type, WTP film type, activator type, spraying distance, spraying angle, spraying speed, activation time, drying time, temperature, and transfer medium. Coating thickness was measured at five points using a Coating Thickness Tester, while appearance was assessed by ten experienced painting experts using criteria of surface cleanliness, substrate coverage, and pattern neatness. The results showed that coating thickness increased from 22.2 μm with two sprays to 36.2 μm with five sprays, representing a 63.06% increase. The five-spray variation also produced the highest visual scores: 88% for surface cleanliness, 90% for substrate coverage, and 98% for pattern neatness. Therefore, five activator sprays provided the best WTP coating performance under the tested conditions.

1. INTRODUCTION

Painting is a coating process on the outer part of an object that aims to protect the substrate underneath, or can also function as an aesthetic enhancement of an object. According to Darsin et al. (2019) painting is the process of coating a surface with a liquid coating for protection and beauty. In general, this process involves the use of various types of paints and application techniques that can improve the durability and appearance of objects, both in industry and art. The correct use of paint and efficient application techniques are very important to achieve the desired final result, ensuring that no defects occur.

Pre-treatment is necessary to ensure optimal results in painting or coating materials (Utama, 2018). Pre-treatment aims to remove dirt adhering to the object to be coated, such as oil, dust, rust, or other contaminants that can interfere with the painting process. The presence of these impurities can cause the paint not to adhere and result in a less visually appealing appearance. Therefore, a thorough cleaning process must be carried out using various methods to ensure the object's surface is completely clean before painting.

After pre-treatment, the painting process will be carried out. In this process, several factors must be considered, such as the spraying distance, spraying angle, and spraying speed of the paint (Rasyid et al., 2017). In addition to factors directly related to the paint spraying process, environmental conditions also play a large role in the quality of the painting results. Air temperature and humidity around the application area can affect the drying process and the formation of the paint layer. Too low a temperature can slow down the drying process, while too high a temperature can cause the paint to dry too quickly. High humidity can also affect the physical properties of the paint and its adhesion to the surface.

There are various ways to adhere paint to a substrate, such as wiping, smearing, brushing, spraying, and dipping (Saputra & Yohan, 2023). According to Rochmat et al. (2016) metal coating is a process used to protect surfaces from corrosion and improve material properties. Some common techniques used in the coating process include painting, electroplating, electroless plating, hot dipping, and powder coating (Kostrada et al., 2023).

Water Transfer Printing (WTP) is a liquid-assisted manufacturing technique that involves the release and assembly of a thin film from a donor substrate to a target substrate using water as a medium (Zhang et al., 2019). TP is a versatile technique for conformally coating complex 3D surfaces with various materials, including electronics and patterns. This technique utilizes the surface tension of water to transfer the film to the object without creases or deformation. This method is often applied to materials such as plastic, metal, glass, ceramics, and wood, making it popular in the automotive industry. In other words, WTP is a surface coating using image or pattern transfer with a special film onto an object by utilizing water. The film is placed on the water surface, then the activator is sprayed, which will dissolve the film, allowing the film pigments to adhere to the object when the object is immersed. The use of an activator plays a central role. Activator is a chemical compound that functions to dissolve the WTP film so that the pattern can adhere perfectly to the water surface and is ready to be transferred to the substrate. The quality of the activator and its application method greatly determine the success of the transfer process and the final quality of the coating.

Previous research has discussed the optimization of the WTP coating process on metal surfaces. For example, in the research by Suhartono & Susilawati (2020) explained that several factors influence the results of WTP painting, such as windless room conditions, clean water, good WTP film quality, and appropriate temperature. In addition, Rifai & Utama (2020) shows that the amount of activator (in ml) affects the final result of WTP coating; using too little activator makes the film not dissolve perfectly, resulting in defects and peeling. If too much is used, the film will melt.

The purpose of this study is to determine the effect of the amount of activator spray on the thickness and appearance of WTP film coatings. This research is expected to provide more insight into how the amount of activator spray can affect the final result of WTP coating, and it is also hoped that this can contribute to the painting industry to know how to properly maximize WTP coating.

2. RESEARCH METHOD

This research used an experimental method. According to Pratama et al. (2024) the experimental method is a research method used to determine the effect of certain treatments on variables under controlled conditions. This research was conducted in April-May 2025. The research was carried out at HJM Purworejo Workshop, Central Java.

In this study, Certain treatments given to the independent variables to determine the impact on the dependent variables. Basically, the experimental research method is included in quantitative methods. In research with experimental methods, the effect of one variable on another variable will be tested, in this case, the independent and dependent variables.

The independent variables in this study were the number of activator sprays (2, 3, 4, and 5 times). The dependent variables were the thickness and appearance of the WTP film. The control variables used included the type of Aluminum Alloy 5052 metal, the type of Diton Premium Clear + Activator activator with code 9128, the type of WTP film (code Y0258), a spraying distance of 15 cm at a 90-degree angle, medium spraying speed, a one-second spray time, a 30-second film activation time, a minimum drying time of 8 hours at a temperature of 32°C – 40°C, and distilled water as the transfer medium.

The main materials used included Aluminum alloy series 5052 plates as substrates, carbon pattern WTP film (code Y0258), Diton Premium brand activator with code 9128, which functions as a clear coat and activator, and distilled water as the WTP film transfer medium. The independent variable in this study was the number of activator sprays (2, 3, 4, and 5 times).

The WTP coating process includes: material preparation by cutting aluminum alloy 5052 into 10 cm x 10 cm rectangles, then smoothing them with P500 sandpaper to clean dirt on the surface. A basin is filled with water as a WTP transfer medium and separated with paper tape. The WTP film is placed on the water surface and smoothed. The WTP film is sprayed evenly with activator. The specimen is slowly immersed in the WTP film, then the remaining film on the water surface is cleaned before the specimen is lifted. The WTP coating results are then dried.

Thickness data collection was carried out by measuring at five different points for each sample using a Coating Thickness Tester, then finding the average value.

Figure 1. Coating Thickness Tester

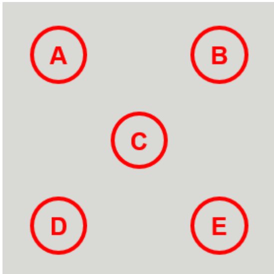


Figure 2. Test Point

To determine the appearance value of the test results, an assessment was carried out using Expert. Expert Judgment is the opinion of experts who was experienced in certain matters. In this case, those with at least five years of experience in painting using a questionnaire for appearance assessment with data obtained using a positive Likert scale of 1-5:

Table 1. Appearance Assessment

Spray Variation	Surface Cleanliness	Substrate Surface Coverage	Pattern Neatness
Total Score			

Description

Very poor = 1
Poor = 2
Enough = 3
Good = 4
Very good = 5

Samples will be assessed by 10 people experienced in the field of painting. These 10 people were selected based on a minimum of five years of experience in material painting. Then the values will be analyzed using Likert scale calculations. After data collection, calculations will be performed. The total score (T) for each criterion is 50, with 10 respondents. Then to interpret the score, it can be converted into a percentage and compared with the determined categories. The calculation steps are as follows:

1. Calculate the maximum and minimum ideal scores (Likert scale 1-5).

   Ideal maximum score (Y) :

   $$\mathrm{Y} = \text{highest likert score} \times \text{number of respondents}$$
   $$Y = 5 \times 10$$
   $$Y = 50$$

   Ideal minimum score (X)

   $$\mathrm{Y} = \text{lowest likert score} \times \text{number of respondents}$$
   $$Y = 1 \times 10$$
   $$Y = 10$$

2. Calculate the percentage index (%)

   Index formula:

   $$\text{index} = \frac{\text{total score obtained}}{\text{ideal maximum score}} \times 100\%$$
   $$\text{index} = \frac{\mathrm{T}}{50} \times 100\%$$

3. Determine the category interval (I)

   5-point interval formula:

   $$\mathrm{I} = \frac{100\ \%}{5}$$
   $$\mathrm{I} = 20\%$$

So the interval of the category is 20%. The breakdown can be seen in Table 2. as follows :

Table 2. Interval Score

Percentage	Category
0 – 19,99%	Sangat Kurang
20 – 39,99%	Kurang
40 – 59,99%	Cukup
60 – 79,99%	Baik
80 – 100%	Sangat Baik

The collected data is presented in tables and graphs, then analyzed using descriptive data analysis techniques to describe the characteristics and phenomena studied.

3. RESULTS AND DISCUSSION

This research uses an experimental method to determine the results of the effect of the amount of activator spray on the thickness and appearance of Water Transfer Printing (WTP) film coatings. The number of sprays performed was 2, 3, 4, and 5 activator sprays. The specimen material used was an Aluminum series 5052 plate, which is commonly used for vehicle bodies, components, and accessories. The visual appearance value will be assessed by an observer with 5 years of experience in painting.

Table 3. WTP Film Composition

Component	Percentage
Polyvinyl Alcohol	50 – 70 %
Pigmen	10 – 20 %
Resin and Stabilizing Polymer	10 – 15 %
Binder and Additional Layer	5 – 10 %

Table 4. Coating Thickness Test Results

Spary Variation	Test Point (µm) A	B	C	D	E	Average Value (µm)
2 sprays	17	22	26	28	18	22,2
3 sprays	25	34	24	28	26	27,4
4 sprays	32	35	32	36	28	32,6
5 sprays	38	40	35	38	30	36,2

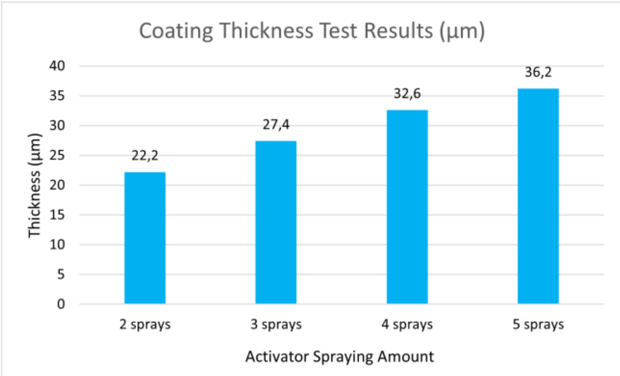


Figure 3. Coating Thickness Test Results

Based on the coating thickness test results in Table 3 and Figure 3., using a Coating Thickness Tester, it shows that there are differences in coating thickness values with varying amounts of activator spray. The coating thickness values presented are the average values from five test points performed on each variable. The highest coating thickness value was found in samples using 5 activator sprays, which was 36.2 µm. The lowest coating thickness value was found in samples using 2 activator sprays, which was 22.2 µm.

Specifically, samples with 2 activator sprays resulted in the lowest average thickness of 22.2 µm. Then, the thickness increased to 27.4 µm with 3 sprays, showing an increase of 23.42% from 2 sprays. Furthermore, the thickness reached 32.6 µm with 4 sprays, which was an increase of 18.98% from 3 sprays. The highest thickness value was recorded in samples using 5 activator sprays, which was 36.2 µm, showing an increase of 11.04% from 4 sprays. Overall, there was an increase in coating thickness of 63.06% from 2 sprays to 5 activator sprays. So, the average percentage effect of adding 1 activator spray on coating thickness is approximately 17.81%.

ith a small number of sprays (2 times), too little activator causes the film to not dissolve perfectly. This means that not all pigments or ink on the film can be released and adhere to the object's surface. As a result, the adhered pattern areas may be uneven, broken, or even empty in some parts, which overall results in a thinner pattern layer than it should be. An incomplete or blurry layer certainly has a lower effective thickness. This is in line with research Putra & Abizar (2022) which states that variations in paint thickness can occur due to technical factors in painting, highlighting the importance of appropriate application parameters for consistent thickness.

With a larger number of sprays (4 or 5 times), an increase in the amount of activator ensures more even and perfect film dissolution (Rifai & Utama, 2020). This allows the entire ink pattern on the film to activate and adhere optimally to the substrate surface. When the entire pattern adheres well and intact, the thickness of the formed pattern layer will also be maximal and consistent. This increase in thickness reflects the successful transfer of the pattern entirely to the object.

Thus, the results of this study strengthen the understanding that optimizing the amount of activator is very important to achieve consistent and maximal WTP coating thickness and good final results (Rifai & Utama, 2020). An adequate amount of activator ensures effective film dissolution and complete pattern transfer, which directly contributes to the final coating thickness.

Table 5. Coating Appearance Values

Spray Variation	Surface Cleanliness	Substrate Surface Coverage	Pattern Neatness
2 sprays	3,8	4,2	4,4
3 sprays	4,6	5,0	5,2
4 sprays	6,6	7,4	8,2
5 sprays	8,8	9,0	9,8

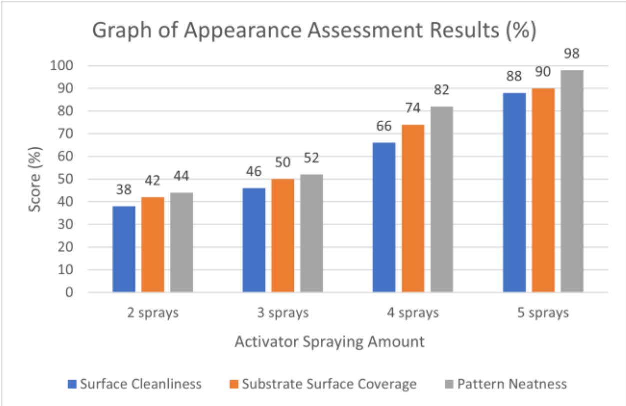


Figure 4. Appearance Assessment Results (%)

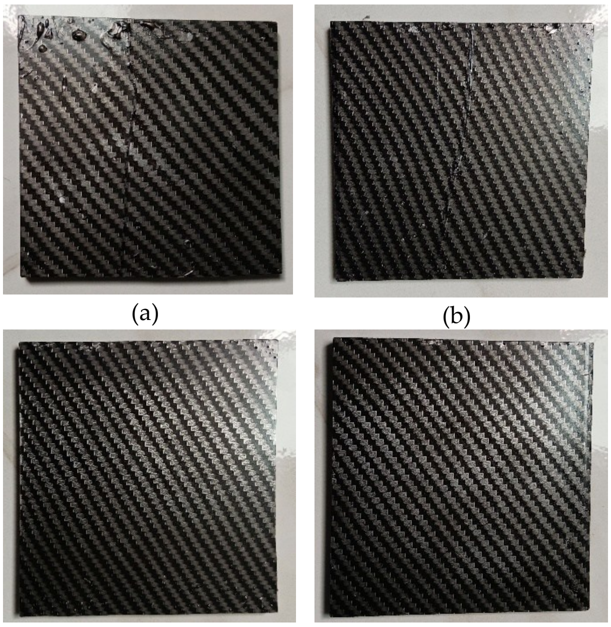
Based on the visual appearance assessment results in Table 4 and Figure 4, there is an influence of different activator spray quantities on the appearance of WTP film coatings. This is because the activator plays a role in dissolving the film on the water surface before immersion; insufficient activator can lead to imperfect dissolution and affect the pattern, and poor adhesion to the substrate. The highest value for surface cleanliness criteria was found in the 5-spray activator variation, which was 8.8, while the lowest value was in the 2-spray activator variation, which was 3.8. The highest value for substrate surface coverage criteria was found in the 5-spray activator variation, which was 9.0, while the lowest value was in the 2-spray activator variation, which was 4.2. The highest value for pattern neatness criteria was found in the 5-spray activator variation, which was 9.8, while the lowest value was in the 2-spray activator variation, which was 4.4.

For the surface cleanliness criterion, according to the score interval category in Table 2., the 2-spray activator variation received a value of 38%, which means it falls into the "poor" category, the 3-spray activator variation received a value of 46%, which means "enough", the 4-spray activator variation received a value of 66%, which means "good", and for the 5-spray activator variation received a value of 88%, which means "very good". This indicates that a larger amount of activator helps in dissolving the film more cleanly and evenly, reducing the possibility of undissolved film residue or defects such as dirty spots that can interfere with surface cleanliness. Surface cleanliness is one of the important aspects of painting quality.

For the substrate surface coverage criterion, according to the score interval category in Table 2., the 2-spray activator variation received a value of 42%, which means it falls into the "enough" category, the 3-spray activator variation received a value of 50%, which means "enough", the 4-spray activator variation received a value of 74%, which means "good", and for the 5-spray activator variation received a value of 90%, which means "very good". This shows that sufficient activator allows the film to dissolve and adhere thoroughly to the entire substrate area, without leaving uncovered or mottled areas. The activator functions as an adhesive for the ink to the object's surface. Even surface coverage or paint hiding power is one of the visual qualities that can be assessed in painting results.

For the pattern neatness criterion, according to the score interval category in Table 2., the 2-spray activator variation received a value of 44%, which means it falls into the "enough" category, the 3-spray activator variation received a value of 52%, which means "enough", the 4-spray activator variation received a value of 82%, which means "good", and for the 5-spray activator variation received a value of 98%, which means "very good". The right activator ensures that the pattern can adhere neatly and is not distorted during the immersion process. When there is insufficient activator, imperfect dissolution can cause the pattern to become blurry, unclear, or even damaged when adhering, which directly impacts pattern neatness. The regularity or neatness of the painting pattern is one indicator of good painting quality.

On average, each additional 1 activator spray has a positive effect on the visual quality of the Water Transfer Printing (WTP) coating, with an increase in surface cleanliness of approximately 32.62%, substrate surface coverage of approximately 29.56%, and pattern neatness of approximately 31.79%, indicating that adding activator per spray has a consistent and positive impact on the visual aspects of the final WTP result.



(a) (b) (c) (d)

Figure 5. Spray Variation

This phenomenon can be explained by the mechanism of the activator in the Water Transfer Printing process. Activator is a chemical compound that functions to dissolve the WTP film so that the pattern can adhere perfectly to the water surface and is ready to be transferred to the substrate. The type of activator also has an effect here; this research uses Diton Premium activator with code 9128, which is an activator that can also be used as a clear coat (Diton, 2020). When the activator is sprayed on the film floating on the water, it dissolves the plastic layer of the film, allowing the pattern ink to detach and activate on the water surface.

In general, these results are consistent with the principle that an activator is a solvent that activates the ink on the film so that it can adhere to the object. If the amount of activator is insufficient, the film dissolution will be imperfect, which can cause the pattern to not adhere well or be distorted, resulting in a poor appearance. Conversely, an optimal amount of activator will ensure effective film dissolution, strong adhesion, and smooth pattern transfer, resulting in a good appearance. This is in line with the statement by Pratama (2012) who identified various painting errors, such as dirty spots, pinholes, blisters, or mottled colors, which directly affect the quality of the appearance. In WTP coating, this cleanliness also includes the absence of damage to the film pattern and a non-rough surface after the painting process (Rifai & Utama, 2020).

This finding is also in line with the main purpose of painting, which is protection and beauty. A good visual appearance can increase the aesthetic appeal of an object. Therefore, optimizing the amount of activator spray not only affects the functional aspects of the coating (such as thickness) but also the aesthetic aspects that are crucial for the final quality of the WTP product. The flexibility of WTP in decorating objects with high-quality aesthetic results is one of its advantages. The WTP process is used extensively to decorate items ranging from entire off-road vehicles and car dashboards to small items such as bicycle helmets or other automotive trim (Suhartono & Susilawati, 2020).

4. CONCLUSION

Based on the research findings, it can be concluded that the number of activator sprays affects the thickness and appearance of the Water Transfer Printing (WTP) film coating on Aluminum Alloy 5052 substrate. The greater the number of activator sprays, the higher the coating thickness obtained, increasing from 22.2 μm with two sprays to 36.2 μm with five sprays, representing a total increase of 63.06%. In addition, the five-spray variation produced the best visual quality, with surface cleanliness reaching 88%, substrate surface coverage reaching 90%, and pattern neatness reaching 98%, all of which fall into the very good category. These results indicate that an adequate amount of activator can dissolve the WTP film more effectively, improve pattern adhesion, and produce a more uniform and aesthetically pleasing coating. Therefore, it is recommended that the WTP coating process use an optimal number of activator sprays, particularly five sprays under the conditions of this study, while still considering spraying distance, spraying angle, activation time, temperature, and environmental humidity. Future studies are recommended to examine variations in activator type, WTP film type, substrate material, and other quality parameters, such as adhesion strength, hardness, corrosion resistance, and scratch resistance, so that the findings become more comprehensive and applicable to the painting and surface decoration industries.

5. DECLARATION/STATMENT

5.1. Acknowlegment

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5.2. Author Contribution

Conceptualization: Gilang Supanto and Ahmad Roziqin. Methodology: Gilang Supanto and Ahmad Roziqin. Investigation: Gilang Supanto. Writing–Original Draft Preparation: Gilang Supanto. Writing – Review & Editing: Gilang Supanto and Febrian Arif Budiman. Visualization: Gilang Supanto.

5.3. Conflict of Interest

Authors declare that they have no conflicts of interest.

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