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Influence of Several True-Solvent, Co-Solvent and Non-Solvent on Thinner in Coating Adhesion and Thickness Automotive Paint

Pengaruh True-Solvent, Co-Solvent dan Non-Solvent Terhadap Thinner Pada Daya Rekat Dan Ketebalan Lapisan Cat Otomotif

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Abstract

Indonesia has many coastal areas; sometimes coastal areas have a typical problem like seawater intrusion, causing seawater to be forced to be used as a solution, replacing fresh water in concrete mixtures. However, using seawater can be harmful to the reinforcement because of the chloride ion content in seawater. The result of this study is to determine the effect of seawater on reinforced concrete, as well as examine corrosion inhibitors that can reduce the corrosion rate of concrete reinforcement, the effects of reinforcement on corrosion rate, and the effect of concrete on compressive strength when added inhibitor material. Research method using experimental by making concrete specimens using seawater as a mixing agent for concrete mortar, adding calcium nitrate to it, and in other concrete specimens adding crushed tea leaves. Concrete bar using a plain round reinforcing bar with a diameter of 10 mm and 280 MPa tensile strength. The results of the analysis showed that concrete with a mixture of tea leaves weighing 1.6 kg/m^3 of concrete produced the smallest iron weight loss; the largest compressive strength for concrete with inhibitor was produced by concrete specimens with tea leaves weighing 0.8 kg/m^3 of concrete.

Keywords: thinner, coating thickness, paint automotive, solvent, surface roughness.

***SDGs*:**

Abstrak

Pemilihan pelarut organik dalam memberikan rasio pencampuran terbaik merupakan permasalahan yang sangat penting untuk diteliti terutama dalam industri otomotif cat. Objek penelitian antara lain *true-solvent* yang terdiri atas butil asetat, dan aseton, *co-solvent* alkohol terdiri dari isopropil alkohol, isobutil alkohol, dan *non-solven* meliputi n-heptana, propilen glikol, dan mineral spirit. Pengujian dilakukan terhadap daya rekat, ketebalan lapisan cat melalui metode semprot, serta tingkat kekeruhan *thinner*. Laju pelarutan *thinner* dievaluasi dengan merendam pelat galvalum berlapis cat ke dalam thinner dan mencatat waktu yang dibutuhkan untuk melarutkan cat. Pengujian thinner dilakukan menggunakan metode semprot dari jarak 17 cm dengan sudut 90°, ketebalan lapisan diukur menggunakan thickness, dan daya rekat diuji berdasarkan metode tape test ASTM D3359. Kinerja terbaik diperoleh pada komposisi 5:3:3 (etil asetat : isopropil alkohol : mineral spirit) dengan nilai daya rekat 5B dan ketebalan lapisan 60,7 µm. Komposisi ini juga menunjukkan nilai kekeruhan terendah (0,11 ± 0,02 NTU). Berdasarkan analisis capability plot, komposisi ini memiliki kapabilitas proses tinggi (Cp = 3,06; Cpk = 2,52), sehingga layak dijadikan formulasi thinner optimal untuk aplikasi cat otomotif.

Kata Kunci: *thinner*, ketebalan lapisan, cat otomotif, pelarut, tingkat kekasaran

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1. INTRODUCTION

The coating process to meet the appropriate automotive industry demand makes using coatings on automotive bodies highly important. The components required in the painting process in the automotive industry are a superior solvent selector to remove residues and an appropriate mixing ratio.

The organic solvents used in thinners can be approximately categorized into three groups based on their effect, true solvents, cosolvents, and non-solvents. True solvents include ketone compounds: acetone, methyl ethyl acetone, ester compounds: methyl acetate and ethyl acetate, amide compounds, and nitroparaffins. Cosolvent is a type of latent solvent that cannot dissolve, but the solubility of the cosolvent will increase when combined with a true solvent. In general, the most prevalent cosolvent compounds that are frequently used are ethyl alcohol and isopropyl alcohol. Non-solvents are additional and unique solvents in their use, e.g., low-cost solvents and better solubility to paint and resin modifiers (Liang *et al.*, 2022; Osemeahon *et al.*, 2024).

A mixture of organic substances named "thinner" includes naphtha, various esters, aromatic hydrocarbons, and halogenated hydrocarbons (Xu *et al.*, 2020). In addition to being used as a paint thinner, thinner is frequently utilised in business and daily life to eliminate unwelcome mildew, oil, and dirt stains from home items.

Thinner is a common surface coating in our daily life, as the main film-forming agent, it can be homogenized with synthetic resins, plasticizers, organic solvents, and pigments (Agin *et al.*, 2016). Thinner is widely used in various aspects because it has several properties, such as drying quickly, and can be mixed with different materials (Gan *et al.*, 2017; Zhang *et al.*, 2021).

Thinner is a solvent commonly used in automotive paint finishing that can adjust the expansion and contraction of the paint (Sopiyan, Iqbal and Susetyo, 2022a). Although many environmentally friendly thinners are produced, there are still many automotive thinners being produced because they are widespread in the automotive industry and will continue to exist in the future (Luo *et al.*, 2018). This can happen because thinners have lower prices, high durability, ease of release after application, and other advantages. An increased proportion of solvent in the thinner formulation generally enhances the surface gloss of the paint film. This effect is attributed to the reduction in viscosity, which improves the leveling behavior of the coating during application and drying. Lower viscosity allows the paint to spread more uniformly, resulting in a smoother and more reflective surface, thereby increasing the gloss level. Thus, optimizing solvent content is a key factor in achieving superior visual quality in automotive coating applications (Sopiyan, Iqbal and Susetyo, 2022b).

Thinner consists of various organic solvents that have flammable and dangerous characteristics. Therefore, the risks of thinners in manufacture, storage, transportation, and application cannot be ignored. There have been various studies of thinners on the explosion of flammable liquids and vapors (Chen *et al.*, 2019). Based on the assessment of the dissolution rate, explosive properties, and environmental impact, three ester components, namely ethyl acetate (EA), butyl acetate (BA), and acetone (A), are better solvents compared to other true solvents (Xu *et al.*, 2020). Therefore, ethyl acetate, butyl acetate and acetone are selected as true solvents. Alcohol compounds are the most common type of cosolvent used as a raw material for thinners (Xi *et al.*, 2019).

Painting is done to extend the life of the painted object and improve the surface to which it is applied. Therefore, the properties of thinner, which extend the service life and smooth the painted automotive body, are very important (Mulyanto, Supriyono and Arta, 2020). Good automotive body characteristics from the paint coating process are needed to achieve this function, including gloss, flexibility, and adhesion resistance. A mixture of varnish and solvent with a ratio of 1:0.1 and 1:0.2 in various drying conditions produces varying thicknesses and adhesion (Sopiyan, Iqbal and Susetyo, 2022b). Based on these characteristics, the lower temperature of the dryer will cause a thicker layer to form. In addition, increasing the height of the solvent mixture will decrease the configured layer thickness. The optimum adhesion occurs at 40 °C for all compositions (Sopiyan, Iqbal and Susetyo, 2022b).

Adhesion testing was performed using the cross-cut method, following the ASTM D3359 standard. The results indicated that all surface pretreatments provided excellent adhesion levels, with the highest rating observed representing perfect bonding between the coating layer and the base metal substrate (Mulyanto, Supriyono and Arta, 2020).

There is currently minimal literature on the safety and environmental effects of true and non-solvent solvents in thinners. Another issue that develops in painting outcomes is poor paint quality, which results in less-than-ideal results, particularly in terms of fading paint colour or a lack of surface resilience of paint, which causes it to peel off easily. This study will integrate these two characteristics while considering their impact in practical applications, supplementing earlier studies.

This study addresses the limited research on the combined effects of true solvents, co-solvents, and non-solvents in automotive thinner formulations. Solvent composition significantly influences coating adhesion, stability, and environmental impact. By categorizing solvents based on their chemical functions, this research evaluates various mixing ratios to determine the optimal formulation that achieves strong adhesion, flexible coatings, low turbidity, and reduced environmental effects. The findings are expected to serve as a practical reference for developing more sustainable and high-performance automotive coating technologies.

2. METHODOLOGY

2.1. Materials

In this article, two alcohol components, isopropyl alcohol (IPA) and isobutyl alcohol (IBA), are used as cosolvents. These solvents were of analytical grade and purchased from PT Smart Lab Indonesia. The non-solvents used in this investigation were n-heptane (NH), propylene glycol (PG), and mineral spirits (MS). n-Heptane and propylene glycol were purchased from Merck. Mineral spirits (Stoddard solvent) were obtained from PT Bratachem, Indonesia. All three were of analytical grade to ensure consistent purity and experimental reliability.

The epoxy primer used for coating was Propan Primtop ET-1000, supplied by PT Propan Raya ICC, Indonesia, specifically designed for metal surface applications with high adhesion and chemical resistance. The plate type is galvalume plates (50 mm × 50 mm × 0.4 mm), which were used as substrates, coated with epoxy primer mixed with various thinner compositions.

2.2. Preparation of Thinner Formulations

Aliphatic and aromatic hydrocarbons are commonly employed as non-solvents in producing thinners. Aromatic hydrocarbon molecules like benzene, toluene, and xylene are toxic to both humans and the environment (Liang *et al.*, 2022). Aliphatic hydrocarbons such as VM&P naphtha and mineral spirits (Schweitzer, 2005; Gupta *et al.*, 2023). Basic information about these compounds is listed in Table 1.

Table 1. Basic information on selected substances (true solvents, cosolvents, and non-solvents).

Constituent	Boiling Point (°C)	Molecular Weight (g/mol)	Dielectric Constant	CAS Number
Ethyl Acetate	77	88.11	6.02	141-78-6
Butyl Acetate	126.1	116	5.07	123-86-4
Isopropyl Alcohol	82	60	21.8	67-63-0
Isobutyl Alcohol	108	74	16.68	78-83-1
n-Heptane	98,42	100	1.92	142-82-5
Acetone	56	58.08	20.7	67-64-1
Mineral spirits	149	223.11	2.1	8052-41-3

2.3. Thinner Dissolution Experiments

Ethyl acetate (true solvent), isopropyl alcohol (cosolvent), and mineral spirits (non-solvent) compounds are mixed based on volume ratio. Thinner was investigated to compare the effect of solvent ratio based on each ratio. The specimens used in this study were sheet galvalume plate material.

Galvalume material was chosen because it is often used in automotive vehicle bodies.

The dissolving rate is defined as the mass of dissolved thinner divided by the time it takes to dissolve. The weight of the paint adhered to the plate material affects the dissolving rate, such that the quantity of paint applied equals the amount of paint attached to the plate. To decrease experimental mistakes, the galvalume sheet is split into multiple groups based on the weight of the sample on the sheet. The average plate weight (SD) value was employed in this investigation, and two repetitions were performed. The tests were conducted in a room with a temperature of 27±3 oC and a relative humidity of 72±3%.

2.4. Coating Application

The test specimens were 50 mm × 50 mm in dimension and 0.4 mm thick in 18 sheets. Sandpaper with grit number 400 was used to clean and prepare the surface of the galvalume sheet plate material before coating. To ensure consistency in the epoxy coating thickness across all specimens, the paint was applied using a manual spray gun under controlled conditions, and all spraying parameters were standardised throughout the experiment. The paint layer thickness test was performed on all specimens with a paint and thinner mixture ratio of 1:1.4, a spraying distance of 17 cm, a paint inclination angle 90o, and temperature (27 ± 3°C) and humidity (72 ± 3%) were kept constant.

The surface of the steel sheet was coated with a paint thinner combination and allowed to dry for two days at room temperature. The solvent in the plate continues to evaporate, forming a strong plate. The painted steel sheet is immersed in a beaker glass holding 50 mL thinner, and the time it takes for all the paint to dissolve in the thinner is recorded.

2.5. Adhesion Testing

The thinner test refers to SNI 06-0174-1987 concerning Nitrocellulose Paint Thinner for Cars, ASTM E376 Standard Practice for Measuring Coating Thickness by Magnetic-Field or Eddy Current Testing Methods, and ASTM D3359-22 Standard Test Methods for Rating Adhesion by Tape Test.

Each specimen was subjected to three adhesion tests. The test is performed by scratching the plate's surface vertically and horizontally and then applying a plastic adhesive. The adhered scotch tape is then highlighted to ensure optimum stickiness. The perfectly bonded scotch tape is then withdrawn. This test yields data in the form of a grade of damage to the specimen based on the ASTM D3359 standard. Assessment is graded in six levels, from lowest to highest, are 0B, 1B, 2B, 3B, 4B, and 5B.

2.6. Coating Thickness Measurement

The thickness of the non-destructive coating on the surface of the painted material is measured using the Coating Thickness Gauge. The Coating Thickness test was performed using ten random measurement locations on a plate to determine the average thickness of the paint. The average value was recorded for each formulation.

2.7. Coating Thickness Measurement

Turbidity was measured using a Thermo Eutech TN-100 turbidity meter, and values were expressed in NTU (Nephelometric Turbidity Units). The samples were separated into three test points (see Figure 1). The thinner turbidity value was determined by measuring the thinner's turbidity level three times.

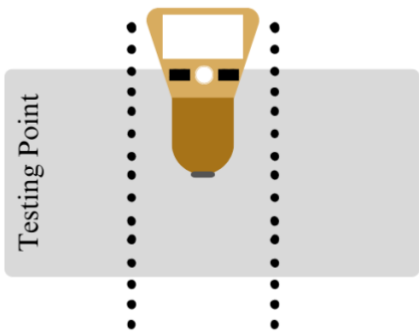

Figure 1. Testing point coating thickness gauge.

2.8. Statistical Analysis

Data for adhesion rating, coating thickness, and turbidity were analysed using descriptive statistics (mean ± SD). Capability analysis (Cp, Cpk) and control charts were applied to assess process Performance and stability using MINITAB 19 software. The data normality was verified through the Anderson-Darling test, and process consistency was evaluated using moving range and individual value control charts.

3. RESULTS AND DISCUSSION

The results and discussion thoroughly analyze the data, including cause-effect relationships supported by references. The best dissolving ability was found at a 4:1 true solvent to co-solvent ratio, determined using a thinner remover recovery method (Xu *et al.*, 2020).

Based on previous research, the preference for thinner composition, specifically ethyl acetate, isopropyl alcohol, and standard solvent, is based on the circumstances that isopropyl alcohol is a latent solvent that presents as a solvent (Rio *et al.*, 2020). Latent solvents cannot dissolve resin alone; thus, active solvents like ethyl acetate and acetone are essential. Adding isopropyl alcohol enhances solubility. Thinner compositions were varied to highlight the effects of dominant solvent types on paint dissolution behavior.

A solvent is a liquid used to dissolve or disperse substances utilized to make films, such as resins, pigments, or additives, which will evaporatively release their contents into the air upon drying (Schweitzer, 2005). Once the paint has dried, the solvent no longer affects the coating. However, during drying, solvents with varying boiling points can impact quality. Standard high-boiling solvents are typically used in low concentrations (1–10%), while low-boiling solvents like ethyl acetate may reach 20%. An ideal thinner contains minimal high-boiling solvents to ensure controlled evaporation and optimal film formation (Chen *et al.*, 2019). The ideal composition for EA: IPA: SS is 2:1:1, where the solvent has a lower boiling point and prevents dissolution from mixing with the paint after drying.

Based on Table 2, the turbidity values (NTU) of various true solvent (EA), co-solvent (IPA), and non-solvent (MS) compositions in thinners demonstrate the stability of each mixture. The minimum, maximum, and mean values with standard deviations indicate differences in homogeneity, which may affect coating adhesion and thickness. Compositions were arranged using Taguchi's orthogonal arrays to explore factor effects efficiently.

Table 2. Turbidity of thinner constituent.

Composition (EA : IPA : MS)	Min (NTU)	Max (NTU)	Mean ± SD (NTU)
1 : 1 : 1	0.22	0.29	0.26 ± 0.02
2 : 1 : 1	0.30	0.35	0.33 ± 0.02
3 : 2 : 2	0.27	0.50	0.34 ± 0.06
5 : 2 : 2	0.25	0.29	0.27 ± 0.01
5 : 3 : 3	0.06	0.14	0.11 ± 0.02
5 : 3 : 4	0.11	0.18	0.16 ± 0.02
5 : 3 : 5	0.26	0.34	0.29 ± 0.02
5 : 5 : 3	0.10	0.17	0.14 ± 0.02
5 : 5 : 4	0.18	0.22	0.20 ± 0.01
7.5 : 3 : 4	0.33	0.37	0.35 ± 0.01
7.5 : 3 : 5	0.28	0.33	0.30 ± 0.02
7.5 : 5 : 3	0.28	0.32	0.30 ± 0.01
7.5 : 5 : 4	0.27	0.35	0.32 ± 0.02
10 : 3 : 3	0.23	0.26	0.24 ± 0.01
10 : 3 : 4	0.25	0.29	0.27 ± 0.01
10 : 3 : 5	0.30	0.34	0.32 ± 0.01
10 : 5 : 3	0.23	0.29	0.27 ± 0.02
10 : 5 : 4	0.27	0.34	0.30 ± 0.02

The 5:3:3 composition exhibited the lowest turbidity (0.11 ± 0.02 NTU), suggesting greater stability and better coating performance. In contrast, the 3:2:2 composition had the highest turbidity (0.34 ± 0.06 NTU), implying incompatibility and potential defects in coating quality. The balance of true-solvent, co-solvent, and non-solvent strongly influences evaporation behavior. Compositions such as 7.5:3:4 and 10:3:5 exhibit stable turbidity values (0.35 ± 0.01 and 0.32 ± 0.01 NTU), indicating good formulation stability. This balance improves adhesion, minimizes surface defects, and promotes uniform, smooth coating formation.

Figure 2 shows the visual outcomes of the cross-cut adhesion test (ASTM D3359) for epoxy coatings applied using different thinner compositions. Each image represents a specific EA:IPA:MS ratio, indicating the extent of coating detachment or intactness, which reflects the formulation's adhesion performance. The thinner formulation with a 5:3:3 composition (EA:IPA:MS) produced the best result with a 5B rating, indicating no paint detachment and excellent adhesion. In contrast, some other formulations exhibited partial peeling, suggesting reduced adhesion strength due to instability in the thinner mixture.

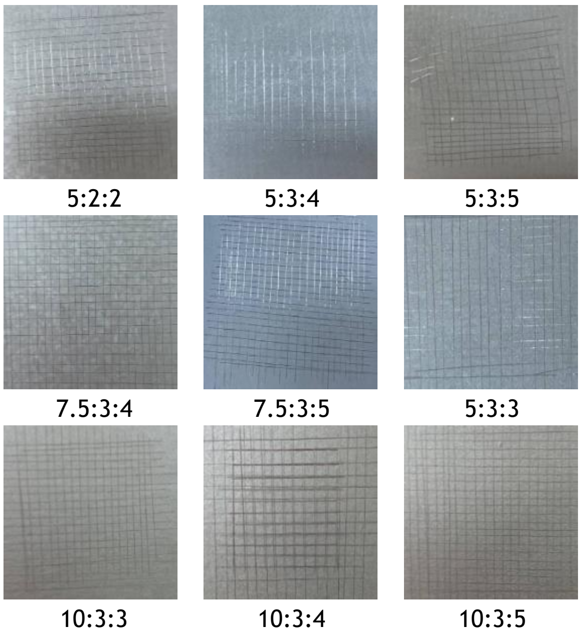

Figure 2. Cross-cut adhesion test results for various thinner compositions (EA:IPA:MS).

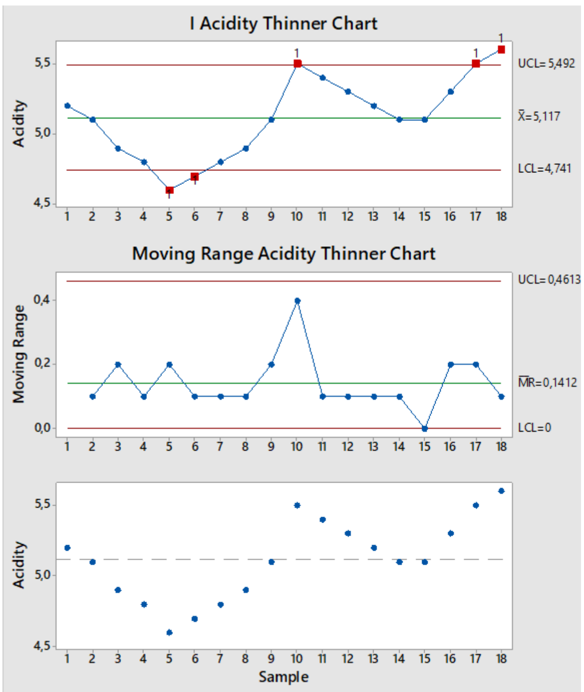

Figure 3. Statistical process control analysis of thinner acidity, monitoring stability and variability through control charts.

Based on Figure 3, the control charts illustrate the variability in acidity levels of thinner samples, which is a critical factor affecting formulation stability and coating performance in automotive applications. The first chart displays individual acidity values, with a process mean ($\bar{X}$) of 4.917, UCL of 5.482, and LCL of 4.441. Several points fall outside these limits, indicating process instability likely caused by raw material variations, storage conditions, or blending inconsistencies. A trend of initial acidity decline, a spike near sample 10, and continued fluctuations is observed. These shifts may impact coating adhesion, film thickness, and surface properties, as supported by previous studies on solvent-environment interactions. According to Liang et al., temperature fluctuations and differences in solvent evaporation rates can significantly affect coating performance, particularly through changes in viscosity, leveling, and solvent retention. These factors, in turn, impact the uniformity and thickness of the applied film (Liang *et al.*, 2022).

Similarly, Chen et al., oxidation of volatile components in thinner over time may alter chemical properties such as acidity, indirectly affecting curing and coating integrity (Chen *et al.*, 2019). In this study, thinner compositions with lower film thickness and greater variation (e.g., 7.5:3:4) may reflect such instability, possibly due to rapid evaporation or solvent incompatibility. The moving range of acidity values reveals variability between samples, with an average MR of 0.1742 and UCL of 0.4613. A sharp spike near sample 10 indicates a sudden acidity shift, likely from raw material or environmental inconsistencies. Uncontrolled acidity disrupts paint dissolution, leading to poor leveling, inconsistent thickness, and weakened adhesion.

Figure 4 provides a comprehensive statistical analysis of thinner acidity using three visual tools: a histogram, a normal probability plot, and a capability plot. The histogram in the upper section displays the frequency distribution of acidity values, overlaid with a normal curve. The data clusters near the mean, indicating a tendency toward normal distribution. Most data points fall within the specification limits—Lower Specification Limit (LSL) = 4.0 and Upper

Specification Limit (USL) = 6.3—suggesting that the process is largely stable and meets quality control standards.

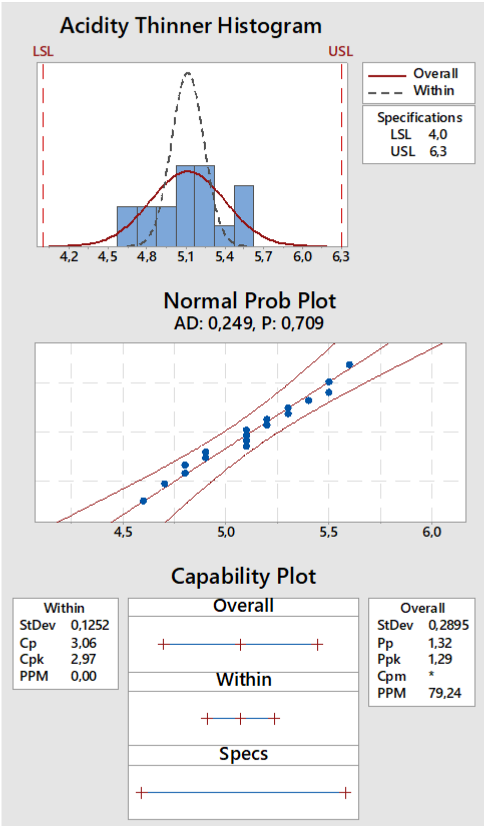

Figure 4. Statistical analysis of thinner acidity: histogram, normal probability plot, and process capability evaluation.

The normal probability plot in the middle section evaluates the distribution pattern. The data points align closely with the reference line, and the Anderson-Darling (AD) statistic is 0.249 with a p-value of 0.709, confirming that the acidity values follow a normal distribution. The confidence bands also indicate no significant deviation from normality. The capability plot at the bottom assesses process performance, revealing a within-process standard deviation (StDev) of 0.1252 and an overall StDev of 0.2895. The capability indices—Cp = 3.06 and Cpk = 2.52—demonstrate a highly capable and consistent process. The defect rate is also low (PPM = 79.24), indicating minimal variation.

These findings support the conclusion that acidity stability plays a crucial role in coating performance. Compositions such as 7.5:3:4 and 7.5:3:5, which produce thinner coatings, may reflect chemical instability due to acidity fluctuation, solvent incompatibility, or hydrolysis of resin—factors that ultimately reduce adhesion and uniformity.

To mitigate these risks, manufacturers must implement stringent quality control measures, including precise solvent blending, rigorous raw material selection, and controlled storage conditions. Real-time acidity monitoring and standardized formulation protocols can enhance the consistency and effectiveness of thinner formulations. Examined the dissolution rates of various ester components in thinners, demonstrating the influence of solvent evaporation characteristics on coating properties (Liang *et al.*, 2022).

In conjunction with the trends observed in the control charts, these findings underscore the necessity of maintaining consistent acidity levels in thinner formulations to achieve high-quality automotive coatings. By implementing precise formulation controls and continuous environmental monitoring, manufacturers can enhance the durability, adhesion, and uniformity of coatings, ultimately improving the performance and longevity of automotive finishes.

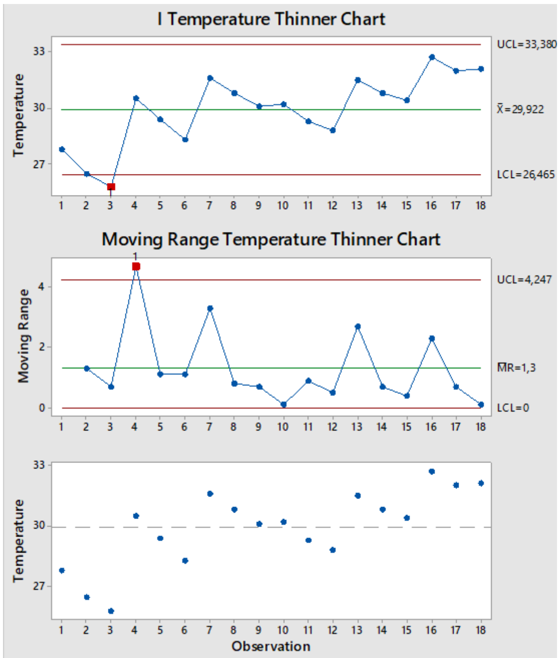

Figure 5. Control Chart Analysis of Thinner Temperature for Process Stability and Quality Monitoring.

Figure 5 presents the thinner temperature control chart with three key visualizations: the Individual (I) Chart, the Moving Range (MR) Chart, and the Scatter Plot. The I Chart shows individual temperature measurements across observations, with the process mean (X̄) = 28.43°C, UCL = 29.49°C, and LCL = 27.37°C. Most values fall within these limits, indicating natural process variation, while any point outside suggests possible anomalies caused by inconsistent solvent composition or environmental factors. The MR Chart quantifies variation between consecutive temperature readings, with an average moving range (MR) = 0.88°C and UCL = 2.58°C. A noticeable spike in early observations suggests sudden temperature shifts, potentially caused by rapid solvent evaporation, unstable mixing, or external thermal influences affecting thinner consistency (Xu *et al.*, 2020).

The control charts demonstrate that while the thinner temperature remains within acceptable limits, certain deviations highlight the need for improved process monitoring and control. Ensuring a stable thermal environment is crucial for achieving consistent coating adhesion and thickness, reinforcing the importance of precise temperature regulation in automotive paint applications.

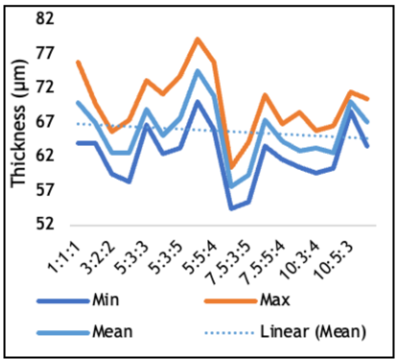

Figure 6. Coating thickness distribution at various thinner compositions.

Figure 6 presents the variation in coating thickness (in µm) across different thinner compositions based on the ratio of ethyl acetate (EA), isopropyl alcohol (IPA), and mineral spirits (MS). The chart displays the minimum, maximum, and mean thickness values measured at ten random points on each specimen using a non-destructive coating thickness gauge. A linear trendline of the mean thickness values is also included to observe the general pattern. The data indicate that certain formulations, such as 5:3:4 and 5:3:5, resulted in higher average thicknesses—reaching up to 77 µm—likely due to the solvent mixture's slower evaporation and better leveling behavior. Conversely, compositions such as 7.5:3:4 and 7.5:3:5 showed the lowest coating thicknesses, with minimum values below 55 µm, possibly due to faster evaporation or incompatibility in the solvent blend affecting film formation.

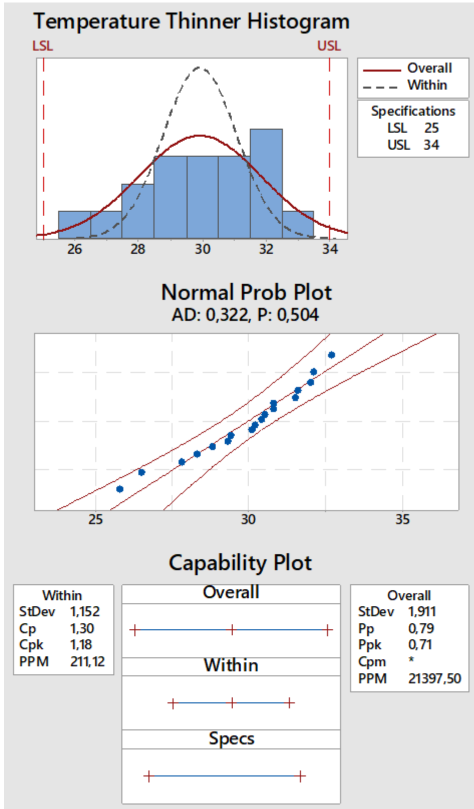

Figure 7. Evaluation of thinner temperature distribution and process capability analysis.

Figure 7 includes three statistical visualizations a Temperature Thinner Histogram, a Normal Probability Plot, and a Capability Plot. The histogram shows the temperature distribution with a fitted normal curve, where the observed values range between the Lower Specification Limit (LSL) = 25°C and the Upper Specification Limit (USL) = 34°C. The Normal Probability Plot indicates approximate normality, supported by an Anderson-Darling (AD) value of 0.322 and a p-value of 0.504, suggesting no significant deviation. The Capability Plot evaluates process performance with Cp = 1.18, Cpk = 1.10, and an overall Ppk = 0.79, indicating the process is capable but may benefit from improvement. The PPM (Parts Per Million) defect rate confirms that a notable portion of the data falls outside the defined limits.

3:2:2 5:3:3

Figure 8. Turbidity comparison of thinner samples with different solvent ratios.

Figure 8 shows the turbidity measurement of two thinner samples with different solvent compositions using a Thermo Eutech TN-100 turbidity meter. The first sample with a 3:2:2 (EA:IPA:MS) ratio displayed a turbidity value of 0.34 NTU, while the second sample with a 5:3:3 composition showed a significantly lower turbidity of 0.11 NTU. The NTU (Nephelometric Turbidity Unit) value indicates the level of light scattering caused by suspended particles in the solution. A lower NTU value suggests a more homogeneous and stable solvent mixture. Therefore, the 5:3:3 formulation demonstrates better clarity and mixing compatibility than the 3:2:2 sample. This improved stability will likely contribute to more uniform paint application and enhanced coating quality in automotive paint systems.

4. CONCLUSION

This study investigated the influence of various true solvents, co-solvents, and non-solvents in thinner formulations for automotive coatings. The analysis revealed that temperature control remained within the acceptable range ($\bar{X}$ = 28.43°C), with few fluctuations identified by control charts, indicating relatively stable processing conditions. The acidity analysis showed a mean value of 4.917 with Cp = 3.06 and Cpk = 2.52, confirming the process's high capability. However, fluctuations in pH near sample 10 suggest potential instability due to solvent oxidation or storage conditions. Regarding coating performance, the cross-cut adhesion test demonstrated that the 5:3:3 (EA:IPA:MS) composition achieved the highest rating (5B), indicating perfect adhesion, while other formulations showed partial delamination. Coating thickness measurements confirmed that the same composition produced a uniform film averaging 60.7 µm, while high-true-solvent formulations like 7.5:3:4 showed thinner and inconsistent coatings. The turbidity test identified 5:3:3 as the most stable formulation (0.11 ± 0.02 NTU), while 3:2:2 showed the highest instability (0.34 ± 0.06 NTU). The dissolution rate test further confirmed that optimal mixing ratios of true solvent to co-solvent (4:1) improved paint solubility and stability. These findings support the formulation of high-performance, consistent, and environmentally responsible automotive thinners

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