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Quantitative Image of Roller

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Introduction

Coatings' application performance, such as ease of application, superior coverage, and faster return-to-service, continue to be a key consideration for both consumers and contractors when choosing architectural coating products. Based on the claim analysis of commercial architectural coatings, paint application related properties are among the top claimed product performance in architectural coatings, as shown in **Figure 1**.[1] The rheological properties of coatings play critical roles in determining various aspects of coatings application, including sag and leveling balance, spatter resistance, application feel, roller pattern, and applied hide. In addition to rheology of coatings, paint application process and results are highly dependent on environmental conditions, roller cover, paint applicator, and substrates. Traditionally, evaluating the appearance of coating and spatter resistance has heavily relied on visual assessment, which could be influenced by inconsistencies in human visual perception. To address this, we have conducted a series of roller application studies in different formulation spaces and employed advanced image analysis technologies to enable more reliable and quantitative evaluation of spatter resistance and roller patterns. In this article, we will share the insights gained from our study and discuss the impact of rheology modifiers on the performance of roller applications.

Introduction of Spatter Resistance

Spatter resistance is an important roller application property. Paint spatters are tiny droplets of liquid paint that can be ejected from the roller/substrate as coatings are applied on substrates. The liquid droplets can land on adjacent surfaces or areas not meant to be painted. Coatings with good spatter resistance will reduce the work associated with preparing the surface and cleaning up after painting as well as help painters get the work done more efficiently.

Spatter resistance is highly influenced by the rheology of the coatings. A series of rheology modifiers were evaluated in four different formulations, including standard acrylic interior flat formulations with or without hydroxyethyl cellulose (HEC), premium acrylic flat formulation, premium composite-forming acrylic flat formulation, and economy acrylic/PVA blend flat formulations with or without HEC. In addition, nine commercial paints from leading paint manufacturers were also included in the study as benchmarks.

Rheology modifiers that were evaluated included both hydrophobically modified ethoxylated urethanes (HEURs) and hydrophobically modified alkali-swellable emulsions (HASEs), with rheology profiles spanning from shear-thinning to more Newtonian. Roller application was conducted on primed drywall (4' x 4') using woven roller cover, 7" long, 3/8" nap. A professional painting contractor conducted all roller applications. For each roller application trial, two vinyl charts are taped at the bottom of the drywall panel to capture spatter of the coating. **Figure 2** shows an example of paint spatters on a black vinyl chart from a commercial interior flat paint, which has poor spatter resistance. The white dots on the charts are the spattered paint droplets. The top portion of the chart is closer to the drywall, which showed more paint spatters. The number of paint spatters decreased as the distance from the drywall increased.

Image Analysis Algorithm Overview

Spatter resistance is rated by evaluating the paint spatter on vinyl charts. Several factors are included for evaluation, including the number of paint droplets, the size of droplets, and the intensity or contrast of droplets vs. background. Traditionally, this evaluation is done by visual assessment, where an operator would assign a score based on a set of standards or industry guidelines. However, this approach is prone to inconsistencies due to human visual perception.

A robust method has been developed for quantifying spatter resistance using image analysis for the detection and rating. To ensure consistent lighting and imaging condition among different spatter charts, images are captured using an imaging station under controlled light environment and imaging parameters. The captured images undergo image-processing techniques, such as image thresholding, to remove background noise. A blob-detection algorithm is then applied to identify individual spatter droplets. The algorithm identifies the blobs or a group of white pixels to capture the spatter. The algorithm was further refined based on fundamental

FIGURE 1
Top paint claims from commercial architectural coating products in the market in 2023.

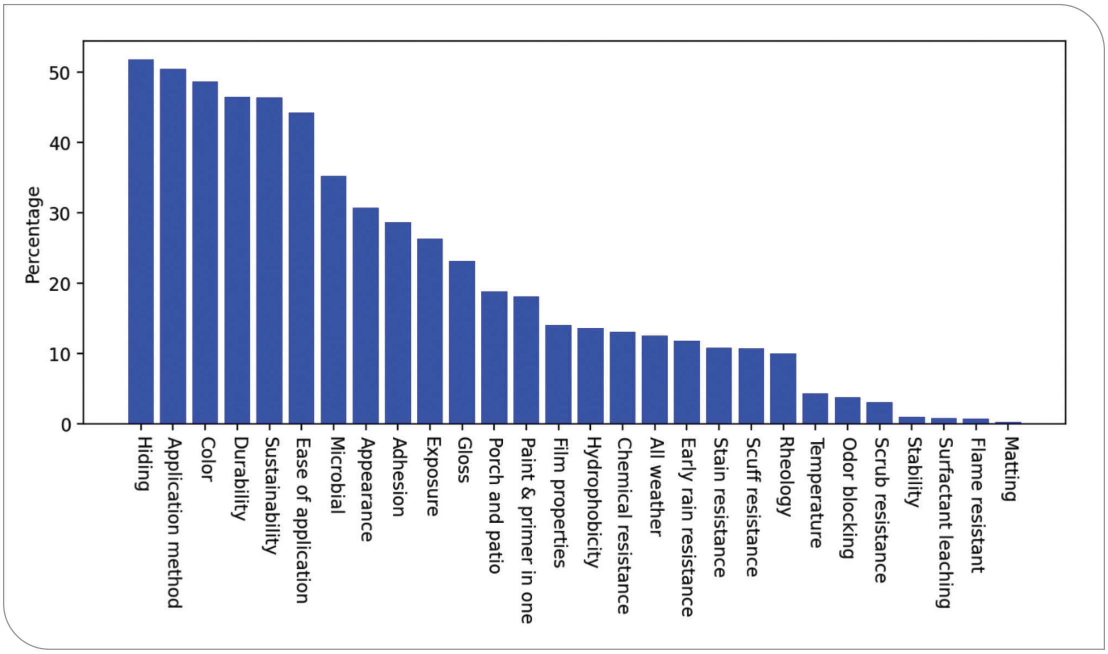


FIGURE 2
Example of paint spatters captured on a black vinyl chart.

FIGURE 3
Original image (left) and algorithm output (right). Detected spatters are circled in red.

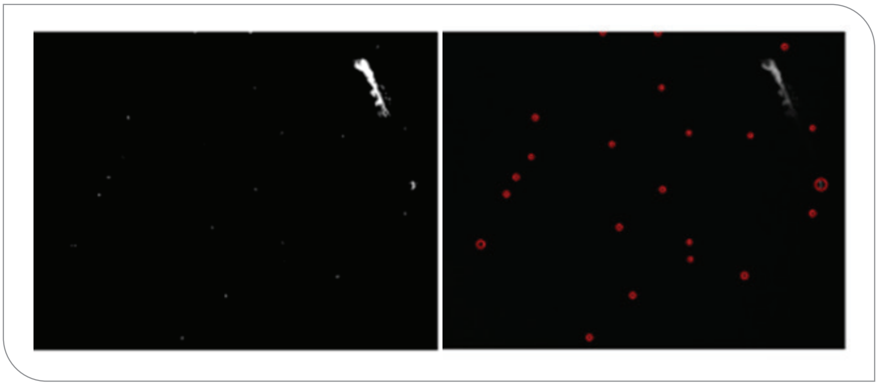


FIGURE 4
Bivariant fit of spatter resistance rating.

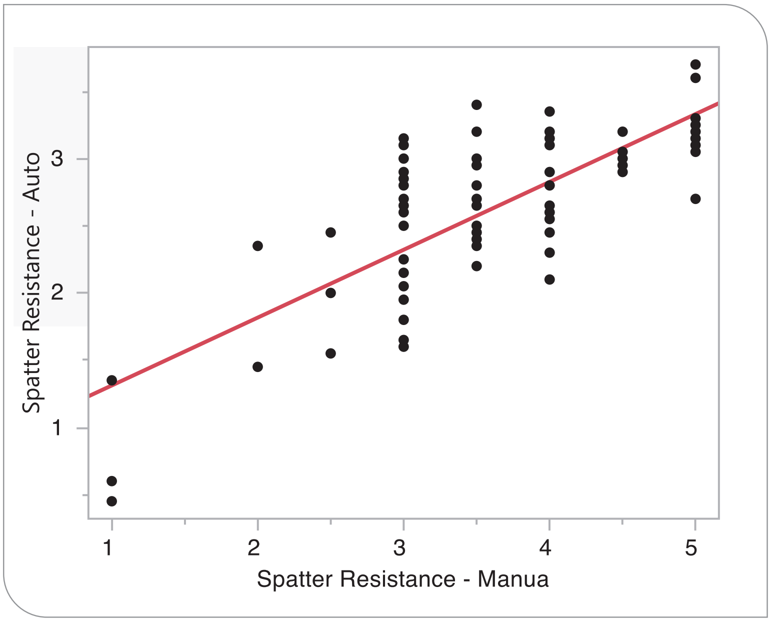
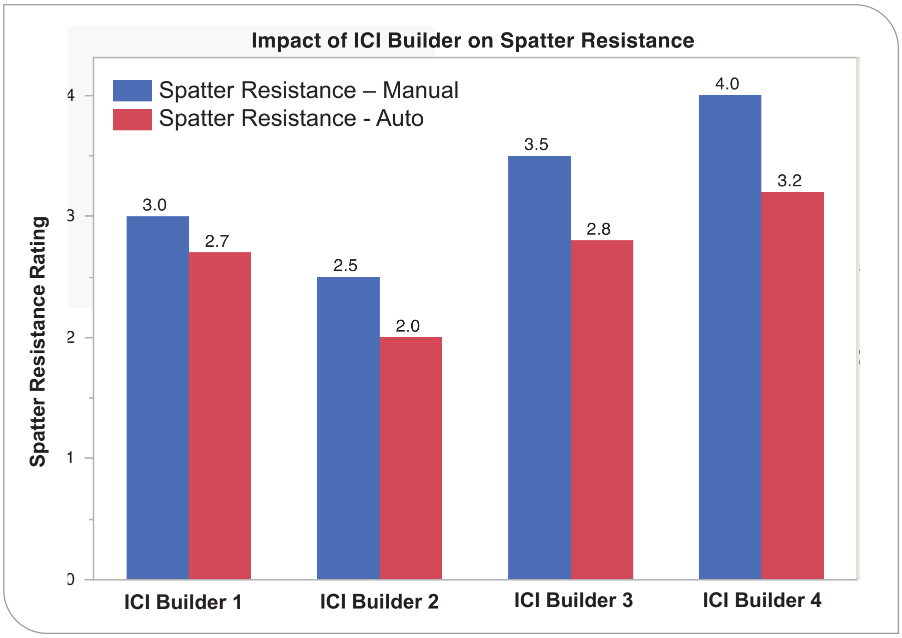


FIGURE 5
Comparison of spatter resistance rating results both manually and auto rating by algorithm.



physics of spatter-droplet generation to exclude the experimental artifacts from the group of detected spatters. Most of the spatters that result from the paint application will be circular shaped because the droplets experience free fall before landing on the test panel. The angle of incidence on these droplets can be assumed to be +/- 20 degrees, which will keep most of the droplets in a circular shape with constant diameter. On the other hand, experimental artifacts or unintentional paint marks on the test panel mostly occur in the form of streaks with large aspect ratio. **Figure 3** shows the original image of the black vinyl chart that has undergone spatter-resistance testing on the left and the processed image with the detected spatters on the right. The figure shows one of the experimental artifacts in a non-circular shape located in the upper right corner. The blob detection highlights paint spatters in red circles, and the algorithm successfully identifies the experimental artifact, which was not included in the detection.

The algorithm successfully identifies paint spatter droplets, some of which are not obvious to the naked eye. The key features (i.e., the number of droplets, the average radius of droplets, the average area of spatter, and the average color intensity of spatter) are used to evaluate the spatter resistance performance rating collectively. The spatter resistance of 73 paints is evaluated using the algorithm and compared with manual rating by human. The auto rating vs. the manual rating is plotted in **Figure 4**. The manual rating rated each panel from 1 to 5, with 5 being best in spatter resistance. The linear fit shows positive correlation between two methods, with Root Mean Square Error (RMSE) = 0.4, indicating that the model outputs differ from manual ratings by an average of 0.4 units. Auto rating was able to capture subtle differences better than human subjective rating. For example, with the same manual rating of 3 or 4, auto rating shows more detailed differentiations. **Figure 5** shows an example of how auto rating is compared to manual rating. It is shown that manual rating values are higher than auto rating. This is because manual rating normalizes the best spatter resistance within the series to 5, while auto-rating used a vinyl chart with zero paint spatter as highest rating of 5. Thus, it is rare to see a rating of 5, as there are aways some paint droplets/spatters on the vinyl chart. Nevertheless, the relative trend of spatter resistance is the same by both rating method, i.e., ICI builder 4 showed the best spatter resistance by both rating system, while ICI builder 2 showed the worst spatter resistance.

Formulation Impact on Spatter Resistance

The impact of thickener on spatter resistance can be evaluated in detail for different formulation spaces. Different thickeners performed differently in different formulation series. However, one consistent trend is that the addition of HEC as co-thickener hurt the spatter resistance. **Figure 6** shows the impact of HEC in two different formulation series. The one-way analysis of variance statistical test confirmed that paints containing HEC showed statistically significant worse spatter resistance in both standard acrylic formulations and economy PVC/Acrylic blend flat formulations.

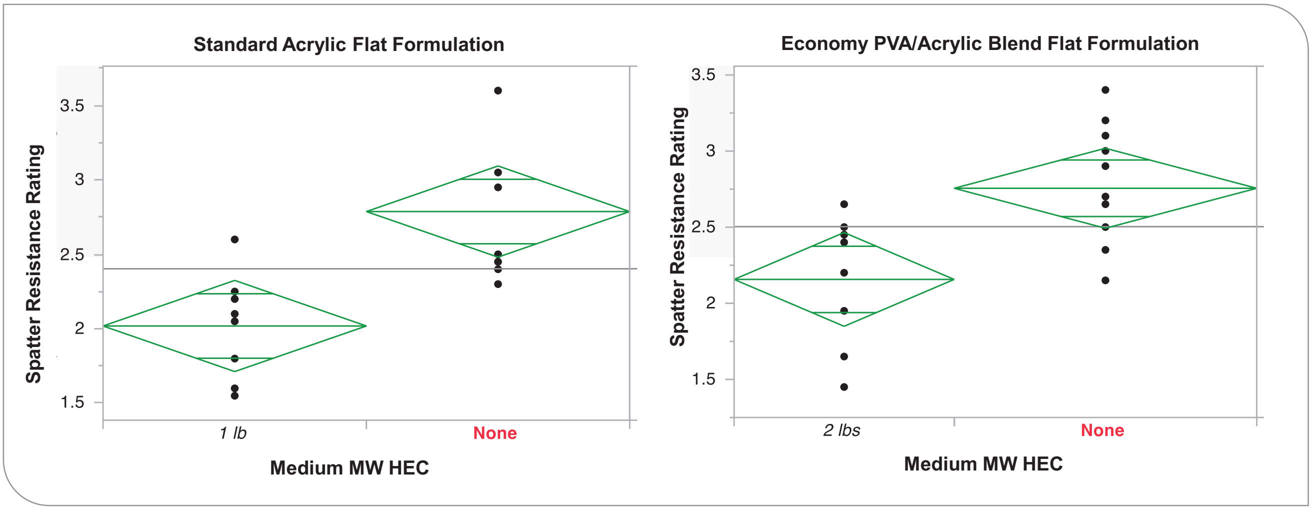
Surface Smoothness Analysis

Surface smoothness is another key performance attribute that paint applicators and consumers value. A coating with excellent surface smoothness typically exhibits a uniform and smooth appearance without application marks, ridges, or rough spots. Another key driver for improving surface smoothness is applied hiding. The varying thickness on the coating will result in the loss of the hiding at the thin spot, with little gain at thick spots. In addition, human eyes are more sensitive to the thin spots or defects. The overall result is that the applied hiding by roller application is lower than hiding by drawdown, even with the same amount of paint. Traditionally, the surface roughness is evaluated by visual inspection and hand touch. To obtain more quantitative information regarding the impact of rheology modifier on surface roughness, high resolution images of roller-applied paints were captured using optical tactile sensor. The tool uses a deformable elastomer to contact paint surface, and the embedded cameras to capture the deformation of the elastomer surface.[2] The surface roughness analysis can provide information about the height, depth, and profile of surface features and roughness.

The rough profile includes both long-range waviness and small-range surface roughness. The long-range waviness is greatly impacted by the roughness of the substrate, such as drywall. For comparison of the surface roughness of coatings, the long-range roughness is extracted using Gaussian filter (filter cutoff wavelength λc = 800 um). The surface roughness (Sa) can be calculated by the arithmetic mean of the absolute ordinate values Z(x, y) within a sampling area. It represents the mean of the average height difference for the average plan. Sa can be calculated using the following equation, where A is the sampling area:

$$Sa = \frac{1}{A}\iint_A |Z(x,y)|\,dxdy$$

FIGURE 6
Impact of HEC on spatter resistance of coatings.



Spatter resistance is highly influenced by the rheology of the coatings.

FIGURE 7
Surface roughness data (Sa, um) for PVA/Acrylic blend in flat formulation formulated with different KU builders.

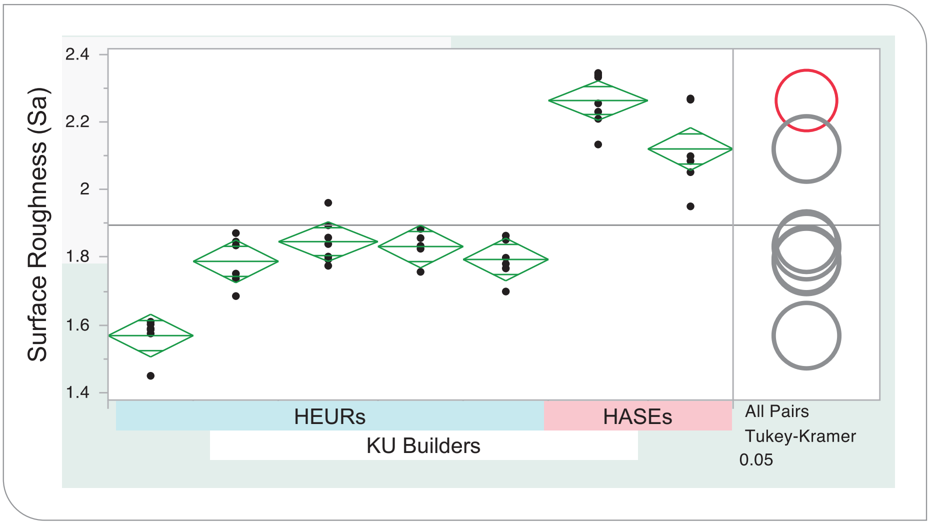


FIGURE 8
Impact of HEC on surface roughness in a PVA/Acrylic blend flat formulation.

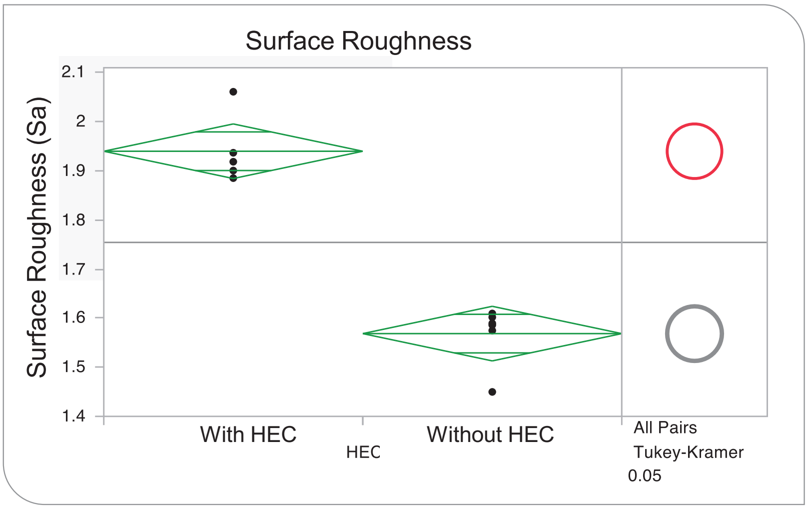


Figure 7 shows a comparison of surface roughness vs. Krebs Unit (KU) mid-shear builders in PVA/Acrylic blend flat formulation without HEC. The same ICI high-shear builder is used in this study. HEUR thickeners provide better surface smoothness than HASE thickeners. This can be attributed to better flow/leveling of HEUR KU builders compared to HASE KU builders. One of the HEUR KU builder showed the lowest surface roughness, and it is also a KU Builder with the least amount of low-shear viscosity contribution. **Figure 8** shows the impact the HEC has on the surface roughness in PVA/Acrylic blend formulations. These paints are formulated with the same KU and ICI builder, and the only difference is that one formulation contains 2 lbs. of medium molecular weight HEC and the other formulations do not contain HEC. As expected, HEC increased the surface roughness.

Summary

Coatings' roller-application performance is critical in architectural coatings. Evaluation of the roller application performances, such as spatter resistance and appearance, have traditionally relied on visual inspection by operators. This study established a quantifiable testing method for characterizing the spatter resistance of paint and used an optical tactile sensor to measure the surface roughness. For spatter resistance, image analysis was successfully employed on pictures of these panels to detect the presence and severity of spatter patterns. This analysis included a novel blob-detection algorithm with a focus on circularity that enabled the isolation of genuine spatter while excluding artificial imperfections. Images collected from the benchtop imaging station were used to identify four key characteristics of spatter including the number of droplets, the average radius of droplets, the average area of spatter, and the average color intensity of spatter. From these characteristics, a linear regression model was constructed to predict a spatter resistance score. In addition, the surface roughness analysis was able to provide quantitative information to evaluate the impact of thickeners on surface roughness. The test methods offer more objective and efficient means for characterizing paint-roller-application performance. ❊

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