# DECODING
## Paint Application 'Feel'

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Paint application "feel" is a key performance attribute. Currently, it is determined empirically by a trained technician who rolls out the paint on a desired substrate and then assigns a perceived application "feel" rating to the paint. Commonly, this rating is characterized by a description of the quality of spreading and the ease of application of the paint. The subjective nature of the evaluation process presents a significant hurdle and uncertainty to rheology modifier selection and paint formulation.

Three commercial waterborne paint formulations were rolled out and the application feel was empirically evaluated. The roll-out experiments were performed by a trained evaluator on a substrate attached to the Sensorial Evaluation Device. The device does not interfere with the empirical feel evaluation and concurrently records the shear and normal forces exerted on the substrate along with the roller position and its speed during the roll-out experiment. The results indicate that the Sensorial Evaluation Device accurately captures the application data and that this data can be used in understanding the subjective paint feel. The rheological characterization of paint offers additional understanding of the empirical paint feel.

## OBJECTIVES

The aim of this work is to remove the element of subjectivity from the empirical paint feel evaluation by measuring and recording the forces exerted on the substrate along with the coordinates and speeds of the roller during paint roll-out. The underlying assumption in this approach is that the paint application technician paints over a substrate to a desired coverage quality in a reasonable painting time. The basis for establishing the paint feel is characterized by changes in the effort of delivering these results as compared to an accepted standard. Therefore, we propose that by digitally capturing the paint application process, we can uniquely identify the reasons behind the subjective description of

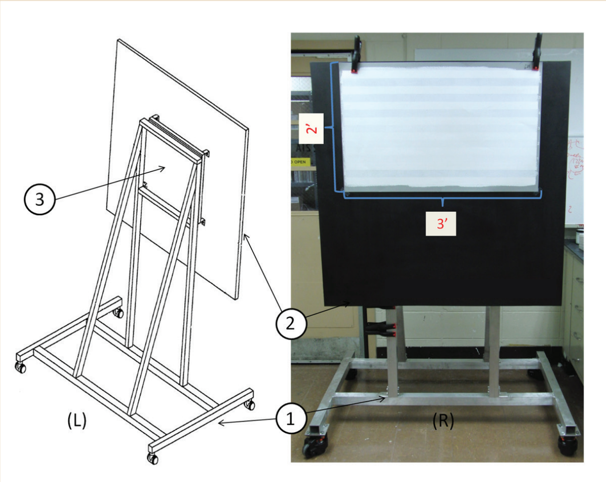


**Figure 1**—Sensorial Evaluation Device. (L): back view schematic of the assembly. (R): front view of the functional prototype. (1) is the portable frame, (2) is the mounting panel, and (3) is the force plate.

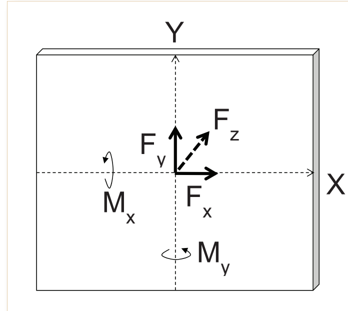


**Figure 2**—The force plate coordinate system illustrating the measured parameters.

paint "feel." Further, by bringing into consideration the rheological characterization of the paint, it is possible to begin understanding the underlying science behind paint application feel.

## SENSORIAL EVALUATION DEVICE

*Figure 1* depicts the back view (L) of the Sensorial Evaluation Device along with the front view photograph of the functional device (R). The device consists of a portable frame (1), a mounting panel (2), and a force plate (3). The force place is mounted onto the frame. The mounting panel is attached to the front of the force plate such that the force plate can measure all of the forces and moments experienced by the mounting panel during a roll-out. *Figure* 1 (R) shows the device with a 3 ft x 2 ft grayscale chart attached to the mounting panel.

*Figure* 2 depicts the coordinate system in which data is recorded by the force plate. The force plate measures shear forces ($F_x$ and $F_y$), a normal force ($F_z$), and three moments ($M_x$, $M_y$, $M_z$).The coordinates of the roller's center of pressure during the roll-out can be obtained by using the relationship between forces and moments, $X=M_y/F_z$ and $Y=M_x/F_z$. The combination of forces and coordinates enables calculation of parameters such as work and speed of application, along with other parameters as described in this article.

## EMPIRICAL PAINT APPLICATION FEEL EVALUATION

Three commercial paints, designated as Paint 1, Paint 2, and Paint 3 were rolled out on 3 ft x 2 ft grayscale charts using smooth surface 9 in. x 3/8 in. nap rollers by a trained evaluator. *Table* 1 summarizes the sensorial attributes of the paints. Paint 1 was described as having the most resistance to roll-out and the best spread. Paint 2 produced the application "feel" of being very "loose and shear thinning." Additionally, the operator mentioned reducing application speed due to spattering concerns. Finally, Paint 3 produced intermediate resistance to roll-out while exhibiting "some shear thinning."

## ROLL-OUT EXPERIMENT

The paint roll-out feel evaluation previously described was carried out on the 3 ft x 2 ft grayscale chart attached to the Sensorial Evaluation Device, as shown in *Figure* 1. Note that the bottom of the chart nearly coincides with the X-axis shown in *Figure* 2. The calculated X values range between approximately –0.3 and 0.3 meters and the Y values between zero and 0.5 meters. It can be seen that the changes in X and Y values unequivocally define the roll-out process. For example, a simultaneous increase in X and Y values would indicate an upward stroke in the right direction, whereas a simultaneous decrease in the values would indicate a downward stroke in the left direction. Increasing X while decreasing Y would indicate a downward stroke in the right direction, and so forth.

*Figure 3* shows a timeframe snapshot capturing approximately the first half of the roll-out experiment carried out with Paint 1. The X and Y coordinates in the figure are the roller positions and the numbers 1 through 10 illustrate sequential steps in the roll-out experiment. The lines are color coded to illustrate the direction of the roll-out: blue shows the direction of the roll motion to the right, green shows the direction of the roll motion to the left, and red represents the edge tracing vertical cycles.

*Figure* 3 shows that the roll-out begins at the bottom left corner. Three up and down strokes (1–3, blue) bring the roller from left bottom to the right bottom corner of the chart. This is followed by a vertical cycle (4, red), tracing the right border of the chart. The direction of the roll-out

**Table 1**—Paint Application Feel Evaluation

| | Stormer Viscosity | ICI Viscosity | Relative Paint Application Feel Evaluation |
|---|---|---|---|
| Paint 1 | 112 KU | 1.92 P | Rated #1: Highest resistance to roll, best spread |
| Paint 2 | 103 KU | 0.96 P | Rated #3: Very loose, shear thinning |
| Paint 3 | 102 KU | 1.37 P | Rated #2: Intermediate resistance to roll, some shear thinning |

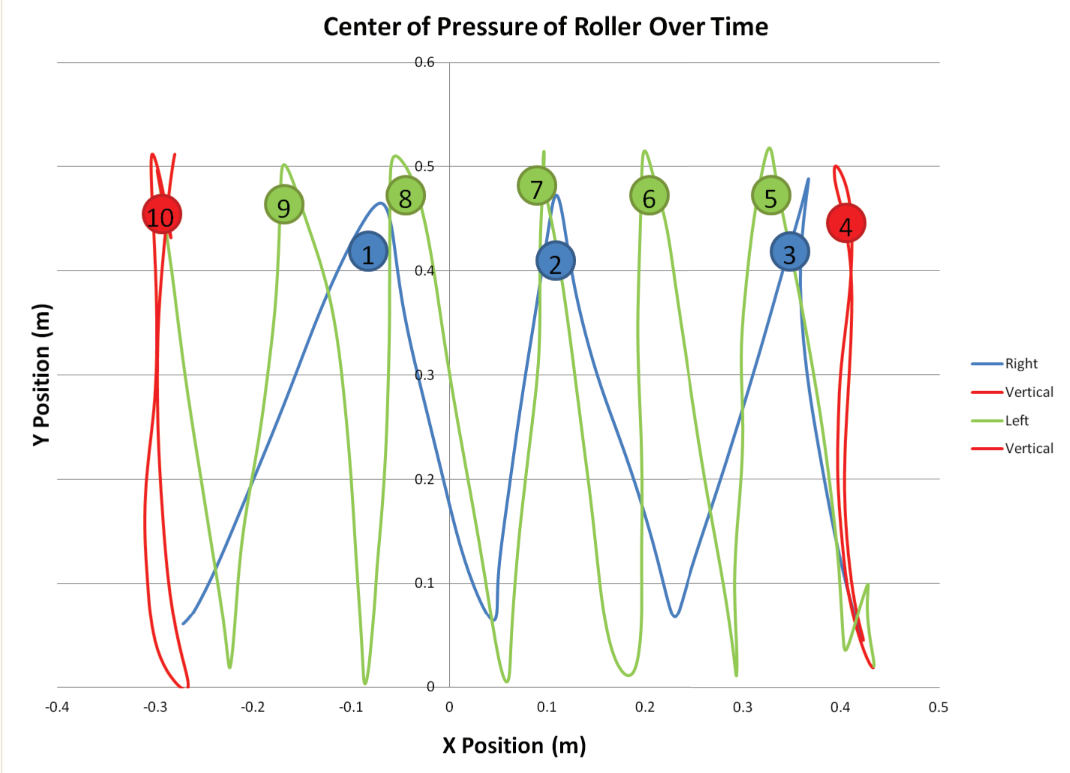


**Figure 3**—A snapshot of the portion of the roll-out experiment: 1–3—rolling cycles in the right direction, 4 and 10 vertical cycles tracing left and right border of the chart, and 5–9 rolling cycles in the left direction.

is then reversed and the roller travels in the left direction (5–9, green). The leftward motion ends in the top left corner with a final upward half cycle, shown in green. The timeframe snapshot is then completed by a vertical cycle (10, red) tracing the left border of the chart.

The collected data is automatically processed yielding a number of parameters characterizing the application process. Some key parameters are summarized in *Table* 2.

The weight of the applied paint, shown in the second column of *Table* 1, is calculated from the difference in $F_y$ at the end and the beginning of the roll-out process. The total painting time is defined as the time at which the roll-out began to the point at which the experiment was concluded. The actual painting time is the sum of the time that the roller was in motion and excludes pauses between the strokes. The distance rolled represents the distance traveled by the roller, while the average speed and the normal force are self-explanatory. The total work of rolling is calculated using the following expression: $W = \sum F_x \Delta X + F_y \Delta Y$.

The data in *Table* 2 explains the observed empirical paint application feel results. The combination of shorter painting time and the shorter rolling distance of Paint 1 reflects the better spreading of the paint. The highest work recorded with Paint 1 agrees with the observed highest resistance during roll-out. The work also confirms the observation that Paint 2 had the least resistance when rolled out. We did not observe slowing of rolling in Paint 2. The differences in average compressive forces are significant, and the work directed at understanding these values is ongoing.

## RHEOLOGY

The rheology of Paints 1 to 3 were characterized with a TA Instruments AR G2 stress controlled rheometer using 60 mm parallel plate at 100 μm gap. The temperature was kept at 25°C with the Peltier heat pump incorporated into the bottom fixture of the rheometer. *Figure* 4 shows the results of steady shear sweep carried out with the paints.

Paint 2 exhibits the highest low-shear viscosity, whereas Paint 3 exhibits a low-shear Newtonian plateau. Clearly, Paint 2 shows the strongest shear thinning behavior (based on the rate of viscosity decrease with the increasing shear rate).

**Table 2**—Summary of Sensorial Evaluation Device Results

| | Weight Applied (gm) | Total Painting Time (sec) | Actual Painting Time (sec) | Distance Rolled (m) | Average Speed (m/sec) | Average Normal Force (N) | Total Work of Rolling (J) |
|---|---|---|---|---|---|---|---|
| Paint 1 | 29.2 | 45.2 | 37.1 | 21.6 | 0.48 | 11.9 | 93.9 |
| Paint 2 | 21.7 | 47.2 | 42.3 | 23.4 | 0.51 | 6.9 | 54.7 |
| Paint 3 | 38.9 | 60.0 | 43.1 | 23.7 | 0.49 | 8.2 | 72.1 |

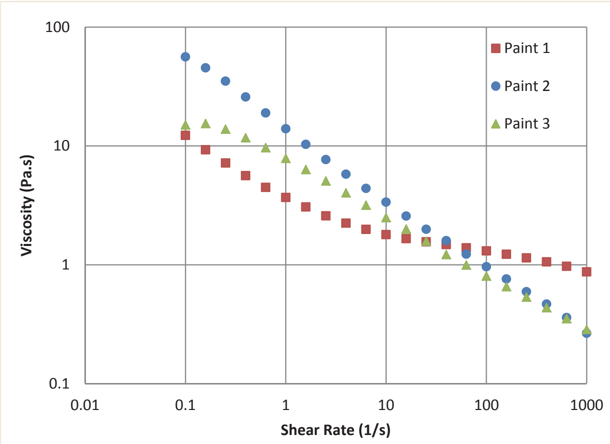


**Figure 4**—Steady rate shear sweep of Paints 1, 2, and 3.

The viscosity values reverse order at higher shear rates at and above 100 $s^{-1}$. At high shear, Paint 1 assumes the highest viscosity. The ordering of high shear rate viscosities of the paints is in agreement with the values of ICI viscosities measured. ICI viscosity is the viscosity at a shear rate of 10,000 $s^{-1}$. By visual extrapolation, the data in *Figure* 4 suggests that Paint 1 has the highest ICI viscosity, followed by Paint 3, and finally Paint 2. This is in full agreement with ICI viscosity values shown in *Table* 1.

Contrary to common expectation, the amount of deposited paint did not correlate with ICI viscosity. The highest applied paint amount of 39 g by Paint 3 corresponds to the intermediate ICI viscosity of 1.37P.

## CONCLUSIONS

We demonstrated how the Sensorial Evaluation Device can capture subtle details of the conventional roll-out experiment. These are characteristics of each paint stroke, speed of roller movement, the work of rolling, and the normal and shear forces. By capturing the consumer's painting experience, the device will assist paint formulators in removing the subjective from paint application feel characterizations. CT


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