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Overcoming challenges in coating application using simulators

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ABSTRACT

Coating a substrate with an objective to protecting it from corrosive influences of aggressive environments is as important as the coating research, formulation, specification, and installation. Technology developments are reported in all fields to protecting the infrastructure be it in process up gradation of the materials used or to its installing in the desired service. It is often stated that mimicking the service condition in controlled study at the laboratory is the most difficult, as conditions in actual service are quite different and the foremost of difference starts with the varying application standards adopted by the painters.

The industry has adequate knowledge and experienced personnel in all spheres of activity and do deploy competent professionals when it installs a project or while maintaining it during service; but when it comes to the crucial work in execution of a coating system, the worker who actually paints is the weakest link, with little or poor knowledge of the process or its requirements and it is at this phase of surface preparation and application, many a case study emanates to highlight premature failures.

This paper shall elaborate on the simulator tool developed for airless spray painter skill development training using a software supported spray gun that prepares a painter to learning it right, till one does not get it wrong.

Keywords: coating; airless spray painter; simulator; training; skill development

INTRODUCTION

Painting is one among the processes in coating application and the other aspects within the same arena, which gains equal importance is the requirement of surface preparation, environmental conditions and coating inspection that are construed as various challenges when we look at the challenges in coating application installation.

While we discuss on painting, the painter is ideally expected to have fundamental knowledge in his domain apart from the skill he needs to perfect for delivering his task. Since there is no recognized course offered in the institutions to graduate for being an industrial paint applicator, the onus of responsibility is shouldered by the coating contractor, coating manufacturers, and the client field engineer to developing the workmen to said requirements. The training imparted is at the cost of actual job and the need to train them and to develop proficiency is always in the agenda of the industrial corporates.

The various methods used in industrial paint application include mitt, brush, roller, conventional air spray, airless spray, as primary methods which are in common practice. In this paper we will look at the challenges in execution of an airless painting job and to address the solution offered by this experiment of introducing airless painting simulators to impart training and development of skilled manpower.

CHALLENGES OF AIRLESS PAINTING

Airless spray is a boon technology to the industrial segment for it has brought in the ability to apply coatings at various thicknesses uniformly and at high speed without compromising on the safety issues of handling high pressures. The first challenge is to address the knowledge level gap in understanding the fundamentals of airless spray to limitations the equipment can offer, based on the atomization requirements of the various types of paints.

With lack of complete understanding of the technology of paints and spray machine, the task of coating application has suffered leading to different pre-mature failures. The most common of application time failures is mud cracking (typical to inorganic zinc coatings), over spray, dry spray, sagging, pin holing, uneven thickness; leading to costly rework and poor finishes. The coating failure due to application error is estimated at 68% of instances.
To the coating applicator it means loss of manpower time, increased cost due to high paint consumption and loss of coating job opportunities and profits. To the client it is extended down time, production losses and increased maintenance painting cycles.

The most common of the statements given by contractors to justify the higher application cost when the requirements are for airless spray; the primary explanation is higher transfer efficiency loss. This is actually not true theoretically when compared to conventional air-spray methods, but considering the poor knowledge and practicing methods of airless spray application we have found that the transfer efficiency is as low as 20-30% in many job sites as against the targeted value of 60-70%. This is primarily due to wrong use of output pressures, use of limited tip sizes irrespective of the substrate design complexities or the type of paint. Most importantly lack of painter skill and lack of understanding the proper time to replace the worn out spray tip has contributed to the claimed loss in transfer efficiency.

Targeted area of airless painter skill development

Painters need to be tutored for systematic educational class room session on the spray equipment working methodology, the safety aspects and practical session for training on airless spray skill. The following is the list that has been considered for development program through use of paint simulator and then exposing them to actual liquid paints to master the techniques.

The airless painting involves certain fundamental understanding for implementation.

Knowledge aspect- The spray painter basic requirement in understanding the paint

1. Paint type and thickness per coat
2. Volume Solids
3. Mixing ratio and pot life in two pack paints
4. Permitted thinner and quantum
5. Orifice size
6. Spray pattern (fan size)
7. Output pressure

Skill aspect- The airless spray painter basic skill in handling equipment during application process

1. Spray gun distance from the substrate
2. Hand movement in parallel to substrate while spraying without tilting the gun in vertical, horizontal and rotational angles
3. Trigger on/off mechanism as per the targeted spray line width
4. Speed of pass during application
5. Proper overlapping to the first pass of spray
6. Ensuring no sagging, run-down, holidays while covering the targeted surface
7. Ensuring proper wet film thickness as targeted for the respective coating specification

Proposed role of airless spray painting simulator in training needs

The objective of Simulator shall be to impart training on spraying skill and also evaluate by grading the scores to reflect the practical needs and demands of the industry. The advantage of training using simulator will help the trainer to systematically develop the painter and ensure;

- Uniformity- maintaining even paint thickness
- Optimality- economize consumption
- Flexibility- expertise to maintain skill

The architecture of simulator applies a psycho-physics approach by mapping stimuli to the response through audio visual clues. This is to mimic the actual painting experience by providing a feel of the spray over an LED screen by exhibiting a colour of paint, while the pass of spray gun is moved in parallel. The time lapse effect between the actual hand movement and the eye capture of paint colour in screen is very close to the actual liquid paint application. The hand movement of the painter with respect the substrate, and trigger on/off timing, position and orientation of the spray gun are tracked accurately using a three dimensional position tracking camera, and other electronic sensors. The sensors of trigger and the sound effects of spray add to more sensation as that of field training.

EXPERIMENTAL PROCEDURE

The aim of the experiment carried is to evaluate the performance of simulator over conventional painter training and record the grade of skill required.

1. Time required to train a painter
2. Space and material constraints for practical class
3. Grading efficiency of skill development

Methodology- controlled study

Materials used for conventional training on airless spray: covered shed area with wind stoppers, paint 40 ltrs, 30 panels of 4sqmt each, video recording equipment, and airless painting equipment.

Facility and equipment used for paint simulator based airless spray training: closed room of 100sqft size, table for mounting equipment, simulator with overhead tri-focus video camera and sensor, typical airless spray gun with sensors attached, monitor and computer.

Methodology adopted was to facilitate the target group of painters to have exclusive training either by the conventional method or by painting simulator and on completion of training, evaluate their skill learning by grading under certain fundamental parameters. The most important parameters that shall be measured; distance of gun from substrate, movement of gun in parallel passes to the substrate, tilting angle (vertical, rotational, horizontal) by hand movements with the spray gun, trigger on/off controls to be operational within the substrate, fifty percent overlap to previous spray passes, holidays, sagging and rundown.

The groups to be named as Group-A for conventional method of airless spray training and Group-B for paint simulator based airless spray training.
Group-A will get trained only with liquid paints and Group- B by the paint simulator to learn the fundamentals of the identified skills in handling the paint spray gun.

Table-1: Photograph of training groups

Group- A Conventional Training on airless spray	Group- B Paint Simulator Training on airless spray
	

Group- A shall use potable water to practice with actual airless spray equipment (a decision taken to minimize the paint costs during hand movement practice sessions); and this group requires external video recording to explain and help practice on acquiring the defined skill of handling the spray gun. The expert painter would correct their hand movements whenever the painter's hand movement went wrong. Each painter to undergo this process of repeated failure and correction until the expert painter feels that the trainee has reached certain level of skill.

Group-B shall use no paints and only work on paint simulator to fine tune their spray gun handling skills. There is no requirement of external video for simulator based training as there is an inbuilt tool provided for the trainer to simultaneously observe in lap top as a graphical representation of the hand movements.

In the simulator based airless spray training each user underwent a structured method of skill acquisition. The learning was divided into six lessons. Each user has to score above 85 for three consecutive times. Until the painter scores for three consecutive times, the trainee will not be allowed to progress for the next lesson.

Lesson-1: The trainee painter has to master the distance (D) skill.

Lesson-2: The trainee painter has to steady his hand against tilting it to angles of yaw, the horizontal arching angle (H), pitch, the vertical movement (V) and rotationally.

Lesson-3: The trainee painter now works on the speed of passing one hand stroke to a defined length and practice to have a steady pass of hand for each stroke.

Lesson-4: The trainee painter now works on moving the hand on the line of spray and trigger control as on/off during the pass and this triggering should be within the target surface width.

Lesson-5: The trainee painter has to ensure a correct overlap of 50% on the previous pass.

Lesson-6: After mastering the first three important subs skill sets, the trainee undergoes combined lesson on all the above skills put together.

The hand movement, body movement, and head movement of the painter with respect the substrate, and trigger on/off timings, position and orientation of the spray gun are tracked accurately using a 3-dimensional position tracking camera, and other electronic sensors. With these measurements, it becomes possible to record the skillful movements of an expert, map it digitally, and provide corrective feedback when a novice is training. This digital feed and track of hand movements facilitates faster training and helps in getting a more perfect skilled painter.

The trainer for Group- B has computer aided controls from the simulator to replay the strokes by graphic support and help in teaching the trainee to correct the strokes. There are quantitative scores for each lesson and the trainee is able to perfect with the support of the trainer and masters the skill and hand movement as required for airless painting. The three angles of vertical, horizontal and rotational movement of the spray gun is considered as one parameter of score giving due weightage considering the importance in actual skill requirement.

Both the Groups would be given actual paint and their learning efficiency is then evaluated for the defined skill set. The painting application shall be video recorded and an expert painter would comment and grade with a qualitative score on the observations. The quantitative score system has been drawn to assist in evaluation of each painters performance and their hand skills are noted based on comparable skills as measured by the IOT-sensor-kit. (IOT- Internet-of-things).

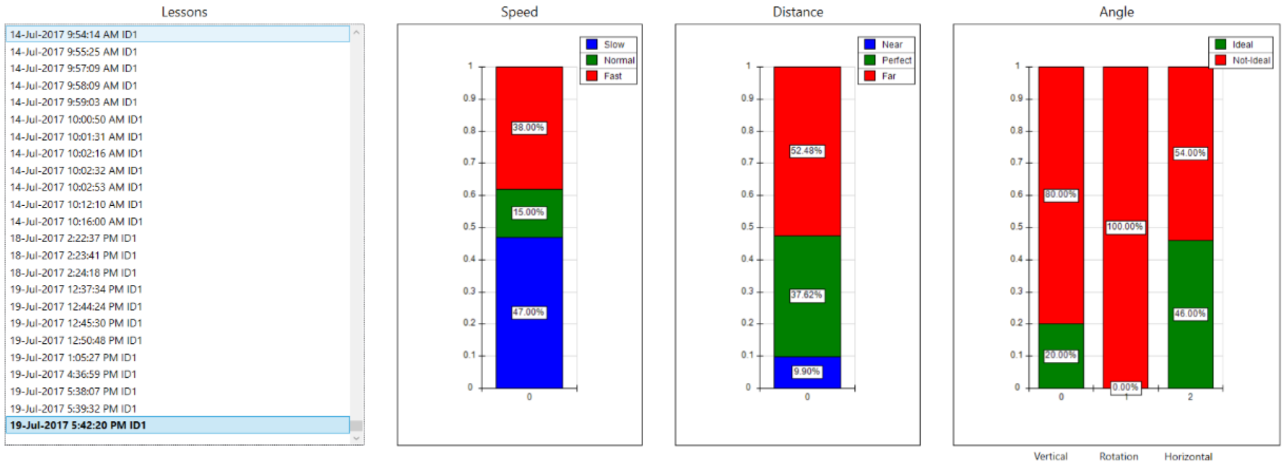
OBSERVED RESULTS

The results of a scientific study done at a training centre with over 30 students, by splitting them into two control groups with one group following the conventional method, and the other group following a simulator integrated training method, have been highly encouraging. The effect of training on their hand technique was measured using a IOT based sensor kit which was fit into the actual gun to capture the distance and angle of the gun, relative to the substrate.

Sample report from simulator during training exercise is given under figure 1&2.

As shown in Fig-1, the graph shows the variations in speed, distance and angle of operating with the spray gun. Speed is monitored to ensure practice of movement with a steady hand stroke. The green in first bar graph shows good hand movement in the area of speed monitoring, the blue portion in bar graph indicates the slow movement in speed and the red shows the faster movements of hand during a paint pass. The distance from substrate (D), and on the angle of holding the spray gun with respect to vertical (V), rotational and horizontal tilting (H) during a spray pass is shown in the following bars charts.
At the second graph on distance monitoring of the gun to substrate; the blue portion indicates the percentage time spent by the trainee holding his spray gun too near to substrate and the red portion indicates far away as distance of spray gun to substrate; both these conditions are considered as negative score. Here again the green indicates correct distance.
Most of the trainee painters have difficulty in holding the gun at proper distance to substrate, and in pitching / arching which is reflected in the scores of vertical, rotational and horizontal angles. Here red stands for not-ideal and green for ideal.

Fig-1: trainee performance monitored in a paint simulator



In figure-2 which is also a report from the paint simulator training operation, it shows the by a score of performance of the trainee painter on the parameters of distance, angle and speed. There are more details to explore on uniformity that will reflect in field as even film thickness; wastage- to reflect the pass of spray gun outside the targeted surface; holidays- where paint application was missed; overlap- by the successive pass of a coat; and a combination score based on weightage of the parameters are considered in the performance chart. The result in performance chart has more inputs for analysis of skill set and gradation of score is possible to rank the efficiency of painter trainee.

Fig-2: Scores as reflected in the monitor of the paint simulator

For the purpose of this study we have considered four important parameters and its weightage in performance evaluation is given in the following table.

Table-2 weightage for performance evaluation on select parameters

Parameter	Weightage	Requirements for ideal skill set
Distance (D)	40	To maintain ideal distance of 12-15" from substrate
Pitch (V-vertical angle)	10	Permissible deviation is restricted to 3 degree tilt
Yaw (H- horizontal angle)	30	Permissible deviation is restricted to 3 degree tilt
Sagging	20	No sagging is allowed but up to 2 spot is tolerated

The paint simulator Group-B showed over 50% reduction in mistakes and undesirable hand-movement variations, when measured using an internet-of-things sensor and data-capture kit retro-fitted on the spray gun during actual painting and measuring the values of "D, V, H", before and after training for 4 hours. The conventional training Group- A also showed a 15% improvement in their skill development.

Table-3: Standard deviation (SD) from ideal values of the controlled group of 30 painter trainees

Team	Before Training				After Training			
15 trainees/ group	Distance (D) from substrate	Pitch (V) (vertical angle)	Yaw (H) (arching angle)	Sag Count	Distance (D) from substrate	Pitch (V) (vertical angle)	Yaw (H) (arching angle)	Sag Count
SD (Gr-A)	56.89	19.74	44.72	5	46.21	12.029	39.92	4
Group-A score	51.9				60.3			
SD (Gr-B)	44.68	13.87	56.78	7	26.72	9.06	22.72	3
Group-B score	49.7				75.6			

Additionally the measure of actual defects as a count, in terms of uniformity of thickness, holiday spots, sagging was lesser by 40%. Further work is on the IOT based field data kits which not only have benefits to validating the simulator effectiveness but can also work on estimating quantum of paint consumption and relate the loss factors with the skill defects of the painters.

CONCLUSION

The objective of this paper was to approach; in design and development of a training simulator built to overcome the challenges in spray application for want of skilled manpower. The solution involved an architecture involving psycho-physics approach, which modeled the stimuli as seen by a painting applicator and the responses the applicator would give on seeing the stimuli sensed by his/her sense organs.
The results of this study summarize as less time required to train using paint simulator, very less paint required probably during test application and that too after mastering the hand skills with simulator, and the quantitative grading efficiency that marks the proficiency skill of painter makes this study more meaningful. The authors confidently recommend training using paint simulator to address the industry requirement, providing with faster and effective training to the trainee painter who can be deployed in job site soon thereafter.
Based on the positive results of this study, the value of a training simulator for spray painting has been demonstrated successfully, and training the painters all over the world would become more economical and quicker from such technology supported intervention.

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