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Elimination of Viscosity Defect Rate of Acrylic White Flat Latex Paint Production Using Six Sigma Method

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Abstract:- This paper discusses the importance of specifications in defining product quality. Viscosity, which is a major property of paint, is critical to painters; therefore, it is essential that the manufacturing company knows how to control it in such a way that there is no need for additional investments or extra time spent in production. The key to a defect-free product is knowing the process capability (machine, process, raw materials, etc.), data gathering, and the application of Six Sigma.

Keywords:- *Paint; Coatings; Viscosity; Manufacturing; Six Sigma; Acrylic; Latex; Process Capabiliy (CPK).*

I. INTRODUCTION

When we hear about paint, what is the first thing that comes to mind: Color, viscosity, covering? On one occasion, a painter returned a gallon of paint to the hardware store where he purchased it, complaining to the paint salesperson, “I don’t want this brand of paint, this is too thin; it has less ingredients. I like my old brand; it is thick, and it contains more ingredients.”

Is the customer’s complaint correct? Technically speaking, for a product line like acrylic flat latex, the nonvolatile content is almost the same for all brands. Nonvolatile content refers to total solid content of a paint, which is a measure of the combined polymer and pigment content in a paint.[1] Viscosity is defined as resistance to flow,[2] and can be measured quantitatively. Viscosity can be adjusted depending on customer requirements. The scenario above gives a better understanding of how critical viscosity is. A painter will notice any changes in the flow consistency of paint. Clearly, viscosity defines the customer’s standard of quality, and that justifies why it should be kept within an acceptable range.

XYZ Paint is one of the leading paint companies in United Arab Emirates, in operation for 10 years. Its white acrylic flat latex is the best-seller among the products, representing 70% of the market demand. Because of this, no major formulations or changes have been made to the product since it was launched to the market.

However, over time, many changes occurred in the production process, raw material compositions, machinery, and metrology which affected the product significantly. For many years, it was observed that the acrylic white flat latex had a 70% defect rate in terms of viscosity. This means that upon completion of the batch and submission of sample to Quality Control, the viscosity did not conform to the required specification. This gave inconsistent product quality because of adjustments in the formulation: either addition of cellulosic thickener when viscosity is low, or addition of water if viscosity is high. In addition, the adjustment increased the process time of the product by 15-30 minutes, which meant decreased productivity and additional operating cost.

This practice was alarming to the Quality Control Team, so they began exploring ways to improve the quality of the said product in order to remain competitive in the market and boost customer satisfaction. The key to high quality paint is delivering a consistent viscosity through systematic and continuous improvement; thus, post adjustment in the process is eliminated. Six Sigma, the data-driven approach centered around statistical analysis, is what the team came up with because it focuses on quality output by minimizing the number of defects or disabilities in a consistent manner.[3]

Despite the existing quality, the management was stuck in old routines and old patterns because of the continuous sales growth of the product. They wanted to know why it was crucial to unlearn an old practice to make way for a new experiment. It was indeed a huge challenge for the team to sell the idea of Six Sigma. In the end, Six Sigma was an innovation and method of continuous improvement, correcting poor outcome and ultimately exchanging a weak for a consistent process. The product was a higher quality of finished acrylic white flat latex, which maintained expected sales. At the same time, this innovation avoided considerable investment in new equipment and human resources.[4]

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II. LITERATURE REVIEW

For most customers, Quality is defined as the measure of excellence; however, it may be viewed on a wide spectrum. Most of the time it is subjective, depending upon the customer's need. For example, a customer may prefer higher viscosity paint than low viscosity because of his different method of application. In a narrower perception, Quality is consistently meeting standards appropriate for specific product or service.[5]

In achieving consistent quality, several tools are applied to the study of eliminating defects. One important tool is data assessment using Statistical Quality Control as defined below[6]:

- Flowchart

  Diagram of the stages and flow of a certain process. It is presented using different symbols, i.e. oval for start and end, diamond for the stage that needs decision, and rectangles. It is drawn from top to bottom. Although not formally considered a statistical graphic, this is useful in identifying bottlenecks and the sources of variability.

- Mean - It is the average of a given set of data.

- Standard Deviation- It is a measurement of data variation. Standard deviation will show how far the values are from the mean. Low standard deviation means data are close to the mean and vice versa

- Control Chart - It is a graph where plotted data reflects the variation in the process. A control chart displays the average line, upper control limit line and lower control limit line.

- Process Capability (cpk) - It is a measurement of the performance of the process to produce a product that will meet customers' requirement.

- Six Sigma – It is a tool improving product quality by eliminating defect rate.

- Upper Control Limit – It is the upper limit horizontal line in the control chart, based on historical data. It represents variation and indicates if the process is stable or out-of-control.

- Lower Control Limit – It is the lower limit horizontal line in the control chart, based on historical data. It represents variation and indicates if the process is stable or out-of-control.

- Upper Specification Limit – the highest viscosity the customer would consider during the paint application

- Lower Specification Limit – the lowest viscosity the customer would consider during the paint application

III. METHODS

The quality control team decided to work on product consistency, the backbone of Six Sigma,[7] to reduce the defect rate of acrylic white flat latex. The methodology includes variation identification, market research, implementation, and validation of results.

- *Identify Variation*
  - Data Gathering – process mapping to pinpoint weaknesses that cause variability and recognize the area of control.

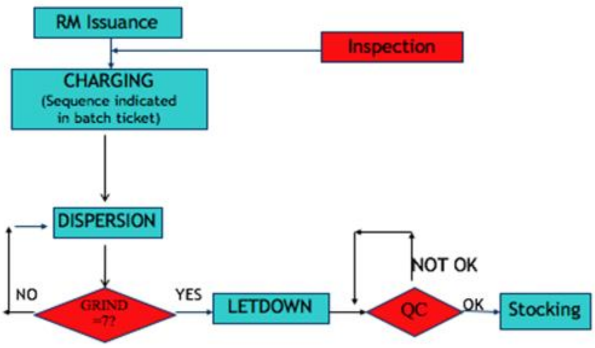

Fig 1:- Process Flow of Acrylic White Flat Latex

The process flow shows the areas that would possibly cause variability of result. With this, it is important to standardize the activities of each process. Below is the standard process that was defined.

PROCESS	CRITICAL TO FUNCTION	STANDARD
RM Issuance	Quantity	100% inspection
	Quality	100% inspection (No Contamination)
Charging	Mixing of Thickener	10 minutes at High speed (500rpm)
	Order of Addition	Refer to batch ticket
	Charging Rate	Average of 30 seconds per bag
	Quantity of Water	Refer to batch ticket
Dispersion	RPM	Max 900 rpm
	MB Temperature	less than 40°C
Letdown	Quantity	100% inspection
	Quality	No Contamination
	Order of Addition	Refer to Batch ticket
	Rheology Modifier Handling/Preparation	No foul odor, drum should be mixed thoroughly before using
	Quantity of Water	Refer to batch ticket
	Mixing time	20 minutes agitation prior sampling to Quality Control
	Machine to be used	Paddle type or agitator
QC	Sample Temperature	29 degrees Celsius
	Drying of drawdown	Air dry
	QC Standard	Keep in 1L plastic container

Table 1

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It is important that the above parameters are followed as in-process control.

The Six Sigma technique adapted to this project does not demand radical changes like purchase of new equipment, changing process, or others. It simply analyzed the current process flow, standardized work procedure, and aligned product specification based on process capability to reduce defect rate.

The process flow was recognized to be able to define the standard operating procedure on critical areas to eliminate product deviation. No new practice was introduced. It was found that the process was not consistent, and activities like charging and mixing time, machine setting, batch temperature, raw materials and others affect the quality of the product. Through this project, the production team consolidated all the practices and agreed on one standard practice.

For the raw materials, quality control data sheets from suppliers were reviewed and acceptable parameters were discussed with suppliers

RAW MATERIAL	CRITICAL TO FUNCTION	STANDARD
Emulsion	Viscosity, secs	1000 to 3000
	%NV	49 - 51
	pH	4 -5
Thickener	Quality	Free of lumps
Titanium Dioxide	Oil Absorption	21-26.8
Calcium Carbonate	Oil Absorption	26

Finished Goods Specification

Properties	Range
Viscosity, Krebs Unit	90-95
Density	1.21-1.31
pH Grind	8.5-9.0 5-6 NS
Compatibility	Match to qc std

Table 2

- Data Analysis using Statistical Process Control[8] – interpreting data to concise language like average (ave), standard deviation (stdev), process capability index (cpk), upper and lower control limit (UCL, LCL), Gauge of Repeatability and Reliability (GRR) of QC technicians, unit per hour of the process, man-hour consumption

Below is the breakdown of process time in unit per hour (UPH) and Efficiency of Acrylic Flat Latex gathered in the year 2012.

Process	Acrylic Flat Latex White (120 gals)	
	time (minutes)	Manhour Consumed
Charging Dispersion	15 15	30 15
Letdown Cleaning	30 5	60 5
Mixing QC	30 30	30 60
Total time	125	3.33
UPH **Efficiency**	**0.48**	 **36.03**

Acrylic White Flat Latex Viscosity 2012		
Batches	Average Initial Viscosity, ku	Adjustment Made
Jan	89.1	0.5 kilogram thickener
Feb	88.7	1 kilogram thickener
Mar	94.0	No adjustment
Apr	96.5	2 kilograms water
May	96.7	2 kilograms water
Jun	98.0	3 kilograms water
July	91.5	No adjustment
Aug	89.3	0.5 kilogram thickener
Sept	89.3	0.5 kilogram thickener
Oct	91.8	No adjustment
Nov	88.0	1.5 kilogram thickener
Dec	90.3	No adjustment
Average	91.9	
Standard Deviation	3.51	
Process capability based on upper limit (cpu)	0.29	
Process capability based on upper limit (cpl)	0.18	
Upper Viscosity Specification, ku	95.0	
Lower Viscosity Specification, ku	90.0	

Table 3

Acrylic White Flat Latex Viscosity Chart

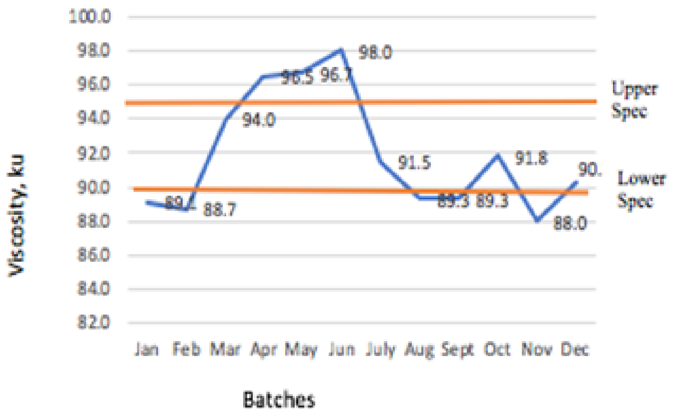

Fig 2

Gauge of Repeatability and Reliability		
	Results	Samples
Laboratory Technician 1	100%	10 samples, 10 times each
Laboratory Technician 2	100%	10 samples, 10 times each
Laboratory Technician 3	100%	10 samples, 10 times each
Laboratory Technician 4	100%	10 samples, 10 times each

Table 4

Result of Gauge of Repeatability and Reliability performed by 4 Laboratory Technicians increases the confidence of accurate testing and eliminates the probability of false viscosity reading of Acrylic White Flat Latex batch samples.

- *Market Research – performs blind test application with painters using paint of different viscosity to determine the minimum and maximum acceptable viscosity*

Market Research was conducted through the feedback of 40 painters with varying painting experience upon application of four different viscosities of Acrylic White Flat Latex.

Two comments were noted for paint with 102 ku viscosity.

The rest of the painters found the four paints within the tolerance workability.

Blind Test	Viscosity of Paint, krebs unit				
	Years of experience	90	92	95	102
Painter 1	0-1	ok	ok	ok	ok
Painter 2	0-1	ok	ok	ok	ok
Painter 3	0-1	ok	ok	ok	ok
Painter 4	0-1	ok	ok	ok	ok
Painter 5	0-1	ok	ok	ok	ok
Painter 6	0-1	ok	ok	ok	ok
Painter 7	0-1	ok	ok	ok	ok
Painter 8	0-1	ok	ok	ok	ok
Painter 9	0-1	ok	ok	ok	ok
Painter 10	0-1	ok	ok	ok	ok
Painter 11	2-5	ok	ok	ok	ok
Painter 12	2-5	ok	ok	ok	ok
Painter 13	2-5	ok	ok	ok	ok
Painter 14	2-5	ok	ok	ok	ok
Painter 15	2-5	ok	ok	ok	ok
Painter 16	2-5	ok	ok	ok	ok
Painter 17	2-5	ok	ok	ok	ok
Painter 18	2-5	ok	ok	ok	ok
Painter 19	2-5	ok	ok	ok	ok
Painter 20	2-5	ok	ok	ok	ok
Painter 21	6-10	ok	ok	ok	ok
Painter 22	6-10	ok	ok	ok	ok
Painter 23	6-10	ok	ok	ok	ok
Painter 24	6-10	ok	ok	ok	ok
Painter 25	6-10	ok	ok	ok	ok
Painter 26	6-10	ok	ok	ok	ok
Painter 27	6-10	ok	ok	ok	ok
Painter 28	6-10	ok	ok	ok	thicker but workable
Painter 29	6-10	ok	ok	ok	ok
Painter 30	6-10	ok	ok	ok	ok
Painter 31	11 +	ok	ok	ok	ok
Painter 32	11+	ok	ok	ok	ok
Painter 33	11+	ok	ok	ok	ok
Painter 34	11+	ok	ok	ok	ok
Painter 35	11+	ok	ok	ok	ok
Painter 36	11+	ok	ok	ok	ok
Painter 37	11+	ok	ok	ok	a little thick but ok
Painter 38	11+	ok	ok	ok	ok
Painter 39	11+	ok	ok	ok	ok
Painter 40	11+	ok	ok	ok	ok

Table 5

- ➢ *Implementation – change of viscosity specification of acrylic flat latex based on process capability, addition of 0.5 kg of cellulosic thickener in the formulation (based on minimum adjustment made).*

The new viscosity specification implemented for Acrylic White Flat Latex is 92-102 ku with addition of thickener on the formulation.

- ➢ *Validation – monitoring new viscosity ave, stdev, cpk, UCL/LCL, customer complaint, productivity, and manhour consumption*

IV. RESULTS

Computation for New Viscosity Specification Limits:[8]

Upper Viscosity Specification Limit = average + (3 x stdev) = 91.9 + (3x3.51) = 102 ku
Lower Viscosity Specification Limit = average – (3 x stdev) = 91.9 – (3x3.51) = 92 ku

Acrylic White Flat Latex	
Batches	Viscosity, ku
3120850	96.7
3120851	99.7
3120945	97.2
3120946	95.6
3120947	96.1
3120950	95.6
3129053	96.5
3129054	97.7
5121546	96.0
7120237	96.4
Ave	96.8
stdev	1.23
cpk	1.29

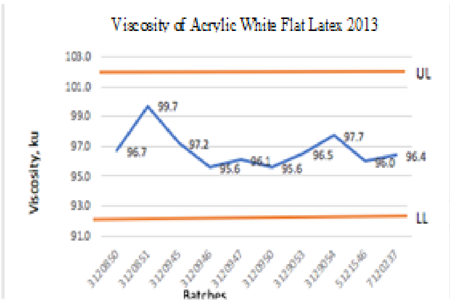

Fig 3

Comparison of Viscosity Specification: Old versus New		
Parameter	Old Specification (90-95 ku)	New Specification (92-102 ku)
Average, ku	91.9	96.8
Standard Deviation	3.51	1.23
Process Capability (cpk)	0.18	1.29
Process Time, unit per hour	0.48	0.3636
Labor consumption, man-hour	3.33	4.5
Defect rate, %	70	0

Table 6

The results show that it is important to know the process capability when setting up a certain specification.

It is also essential to monitor deviation and figure at once when it occurs.

V. CONCLUSION

The application of the Six Sigma Technique was vital in tracking the area of improvements in the production process of acrylic white flat latex. With this new knowledge in place, a key solution was found, defining a new specification of viscosity limits based on process capability, yielding a higher quality finished product. This

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meant a zero-defect rate of the product, eliminating post adjustment in the formulation. In addition, this increased production efficiency by reducing process time (increased units per hour) and reducing man-hour consumption.

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