QUALITY CONTROL STUDY IN THE PAINT INDUSTRY

by

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ABSTRACT

Quality is an important aspect in every industry that exists in the world today. It is always the priority of the industry, irrespective of domain, to always put out the best quality produce for the public or consumer to consume. It goes without saying that the same principle is followed in the paint industry as well, one of the largest chemical industry domains to ever exist.

This project acutely focuses on the production quality of the paints produced. This project is a study of how well the plant has been able to preserve the set quality of the automotive paint produced in one particular batch. Real time data from industry is procured and studied. Analysis of the process was done by utilizing the different quality control tools available to us. An analysis was done to determine the most commonly occurring defect, identify its causes and how they can be removed in the future batches. In the end, a cost calculation has been done to compare the profits when process regulations were followed vs not followed. The last part of the project focuses on corrective measures and suggestions that could be implemented in the industry.

It is always important to focus on the client/customer satisfaction in any industry, and this study is purely done to understand the good practices that must be taken up in an industrial scale to ensure the standard of the product produced.

INTRODUCTION

Paint is an entity containing pigments suspended in liquid or a semi-solid phase. It is one of the most widely used chemicals on walls of houses, automobiles and even industries. There are different types of paints manufactured in the industry, some are epoxy based while others are enamel based. Paints have played an important role in aesthetics, protective layer and even weathering protection on different kinds of surfaces for over a century now. Paint comprises four components: resin, pigment, solvent, extender (additives). Pigment is the component that offers the shade and colour to the paint while the resin binds these pigments and binds the paint to the surface it is painted on. Different types of paints use different binders. Additives contribute to the paint properties, such as improving smoothness, scuff resistance, drying time to name a few. Solvents act as carriers to bind the pigment and resin together. They are generally organic in nature or even water can be used in some cases.

The paint manufacturing process is quite complex in itself. The entire process begins with analysing the raw materials to be used and their respective quantities. The next step is pigment addition and dispersion. Resins are added at this to prevent the pigment particles sticking together and making a clump. After this, the let-down stage is in play. In this stage, resin, solvent and additives are added in a sand mill with good stirring due to blades and teeth on the inner surface. In this stage, all additional components are added if necessary. Once the mixing and processing has been done, the manufactured material is taken to the laboratory to test for various paint properties such as adhesion, colour, dry time, viscosity to name a few. If satisfactory results are obtained, then it's sent for canning. Once canned, it is sent through a final inspection before being sent to market.

In this entire process, the industry's main aim is to ensure quality products are manufactured. That is, paint samples must be within the tolerance limit of each paint film property standard. Since mixing is the main unit operation in this entire process, there could be faults or issues in this operation that could lead to a degraded quality of manufactured product. Using low quality raw materials, ineffective equipment, faulty control systems, improper mixing and even wrong chemistry and formulation can also lead to errors. Six sigma uses principles that will assess the quality of the manufactured products, so as to satisfy consumer needs. In such scenarios, using control tools to identify if a process is in control or not plays a very important role. Identifying the cause of the problem at each and every step of the manufacturing process can lead to better identification of process issues and thus reduce losses due to defects in industries.

Quality tools like X bar chart, R chart, NP chart determine if the process is well within the control region or not. Other quality tools such as check sheets observe the number of defects occurring in the samples sent in every week. This helps identify the most common issue in a small span of time thus making it an old fashioned yet efficient way of identifying defects. Pareto chart helps understand the distribution of these defects by understanding the frequency of the defects occurring. Apart from these tools, CUSUM charts exist to identify even a very small shift in the process even if X bar, R charts conclude a controlled process. Ishikawa or fishbone diagrams can be used to get to the root cause of the defects occurring, thus making it easy to implement immediate alterations in the process.

Thus with the help of various quality control tools, it is easy to understand if the process is under control or not. And if not, using six sigma principles it makes it easy to approach the problem and find effective solutions for the same.

PAINT TESTING

Paint is made of multiple components such as resin, pigment, solvent and extender. Each of these components contribute to the overall quality of paint manufactured. These components have multiple parameters such as appearance, viscosity, specific gravity that contribute to the parameters of the paint manufactured. Paint in its original state is a liquid which on drying gets converted to a solid coating. Understanding both of these states of paint is very important.

Paint in its liquid state known as wet film has multiple parameters such as viscosity, specific gravity, % volatile matter to name a few. While dry film of paint has other parameters such as dry film thickness, gloss, adhesion and colour. Each of these parameters are important when it comes to paint quality. There exists various methods in the industry that measure these properties. In this project, specific gravity, DFT, non volatile matter content, viscosity, gloss, colour and adhesion of the paint are main focus areas.

Liquid paint is measured using various sophisticated instruments. Such as, viscosity is measured by a stormer viscometer. Specific gravity is measured using a Wt/10 ltr cup. Oven is used to measure the solids content in the paint. Likewise for dry film properties, multiple mechanical tests are conducted to understand the range of the parameters. Gloss is measured using Glossometer, Adhesion using Cross-cut method, DFT using gauge and Colour based on visual appearance. All of these properties are measured during the testing process to make sure all of these process variables lie within the specific standard range. Data for the same has been collected as shown below.

DATA COLLECTED

Pareto chart

MONTHLY DEFECTS	Number of defects	Cumulative %	Cumulative	% defect
Adhesion	110	20.29	110	20.3
Colour	84	35.79	194	15.5
Corrosion	66	47.97	260	12.17
Opacity	56	58.3	316	10.33
Fineness of grind	52	67.89	368	9.59
Finish of dried film	42	75.64	410	7.75
Resistance to oil	39	82.84	449	7.2
Scratch hardness	36	89.48	485	6.64
Drying period	32	95.38	517	5.9
Composition	25	100	542	4.61
SUM	542			

CONTROL CHART DATA						ADHESION DATA					
S.No	Specific gravity	DFT (microns)	Non volatile matter(%)	Application viscosity (s)	Gloss at 20℃	Observation 1(% of squares)	Observation 2(% of squares)	Observation 3(% of squares)	Observation 4(% of squares)	Observation 5(% of squares)	No of defects
1	0.98	27	43.94	26	82	7	6	9	8	7	5
2	0.98	27	44.83	25	84	7	8	6	5	8	4
3	0.98	27.5	44.87	25	84	5	0	1	4	3	3
4	0.97	26	44.51	25	82	8	6	6	7	7	4
5	0.97	27	43.83	25	85	1	2	1	3	3	2
6	0.97	26.5	43.29	25	83	0	1	1	0	2	1
7	0.98	27	43.16	22	84	2	1	2	0	0	1
8	0.99	26.5	43.78	24	82	4	5	3	4	2	4
9	0.97	27	43.16	24	84	2	0	1	1	0	2
10	0.97	26.5	43.83	26	81	5	5	4	5	2	3
11	0.97	27	43.91	24	82	1	1	0	0	1	1
12	0.99	26	44.21	25	80	5	4	4	5	5	5
13	0.96	28	43.97	23	83	8	6	5	5	10	3
14	0.97	27	44.56	27	85	5	5	3	1	1	2
15	0.98	27.5	43.38	26	82	3	3	2	0	1	1
16	0.98	26.5	43.89	24	81	9	8	5	5	7	4
17	0.97	28	44.76	25	80	5	6	5	5	6	5
18	0.97	26	44.88	23	84	9	5	5	8	7	3
19	0.98	27	43.23	26	81	4	4	3	2	2	2
20	0.97	27	44.12	22	85	0	1	1	0	0	1

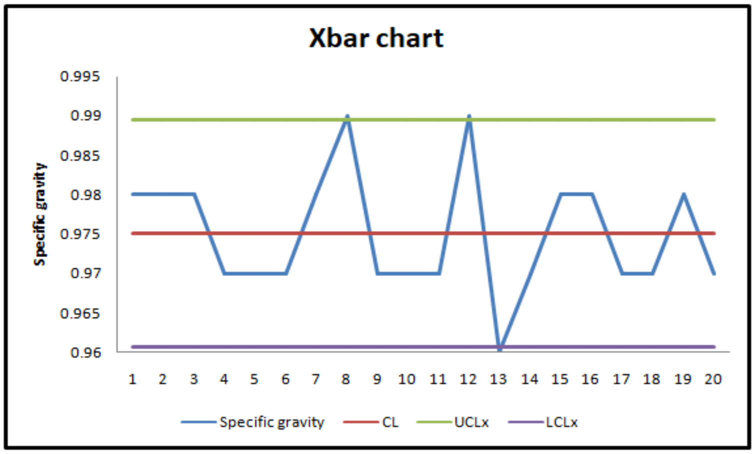
ANALYSIS

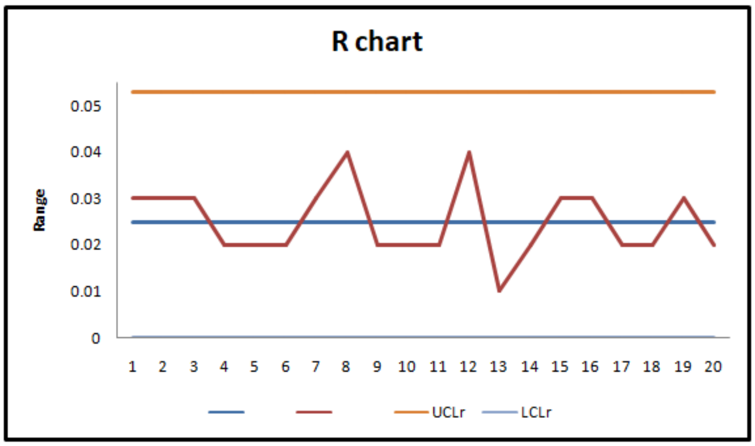
In this section, control tools will be implemented to understand if the process to manufacture paint was in control or not. This section also focuses on finding out the most frequently occurring defect and the causes for the same.

PART I - Paint Film Properties

Five properties of the paint film have been chosen and their control charts have been drawn to understand if the process with respect to these properties were under control or not. For each of these properties, 20 lots with 5 samples were observed.

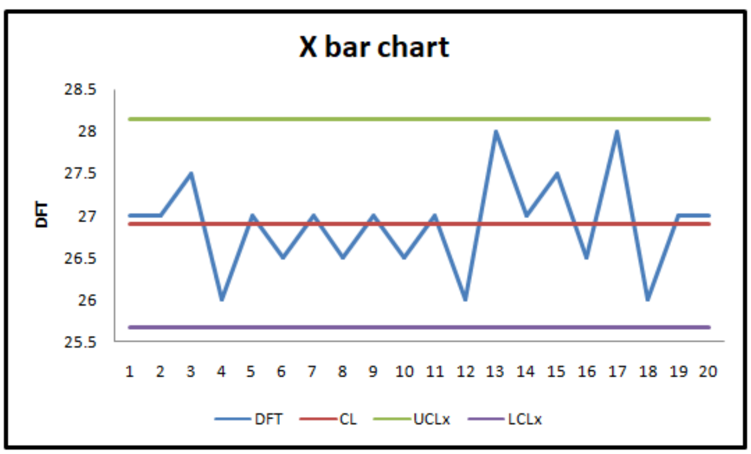
I. Specific gravity



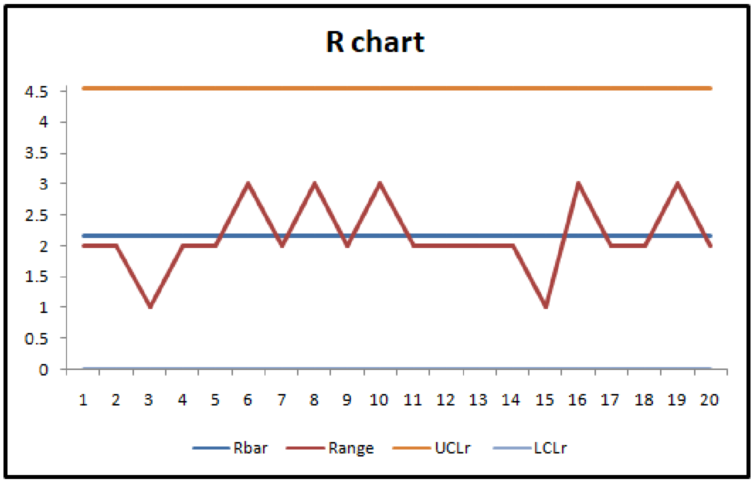


Using the data in the above section, Excel was used to plot the X bar and R charts. We can see that 3 lots out of 20 lots have their mean just a little above or below the control limits. However, in the R chart that is not the case. All points in the R chart lie well within range. So we can say that the process with respect to specific gravity is fairly under control because such small deviations can be removed easily.

II. Dry Film Thickness

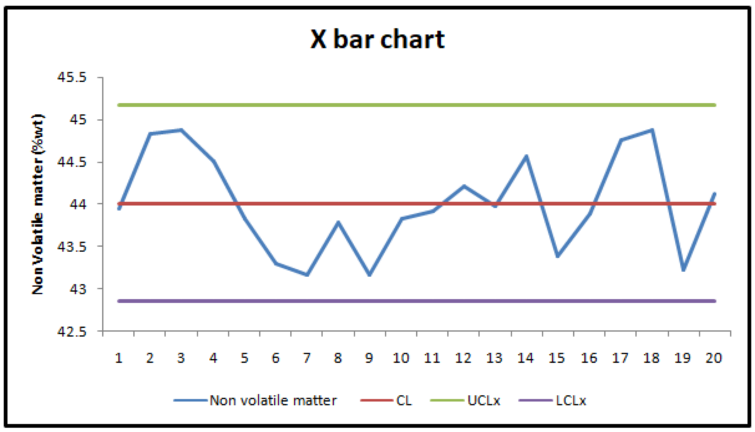


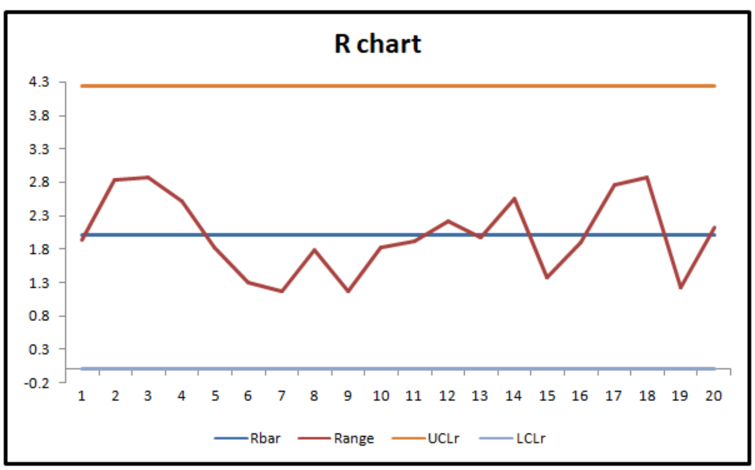
Using the above data and plotting the X bar chart and R chart using excel, following are the results. We can observe that all the lots have DFT well within the control limits.



Likewise, from the R chart, we see that all lots lie well within the control range. Overall, we can say that the process was in control with respect to DFT.

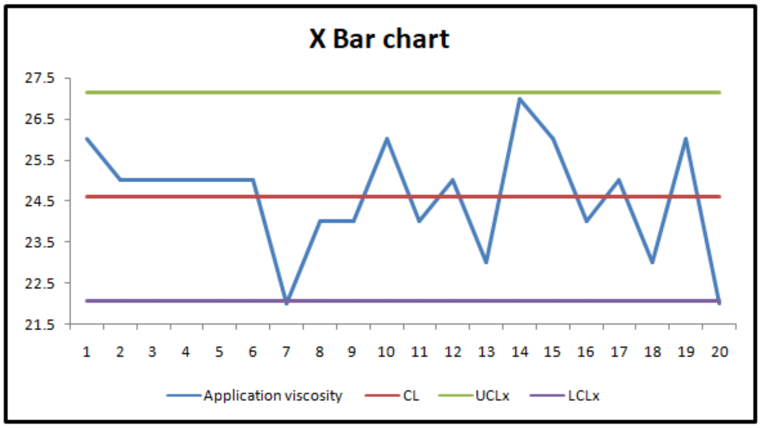
III. Non Volatile Matter

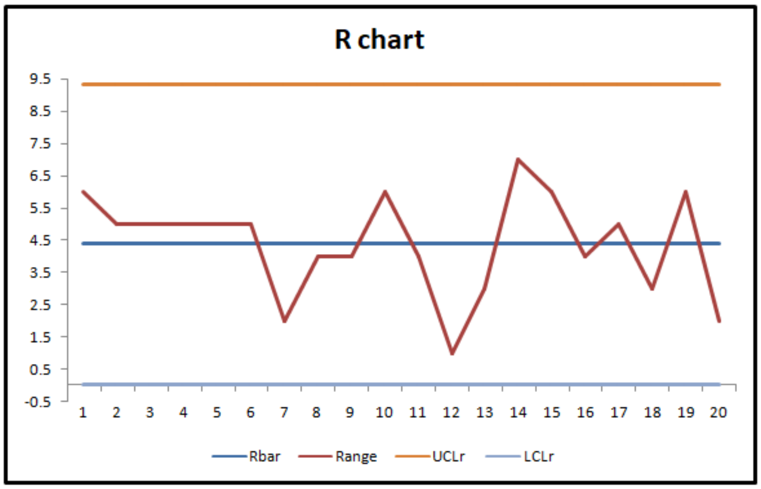




Using the above data and plotting the X bar chart and R chart using excel, following are the results. We can observe that all the lots have Non Volatile matter % well within the control limits. Likewise, from the R chart, we see that all lots lie well within the control range. Overall, we can say that the process was in control with respect to non volatile matter content.

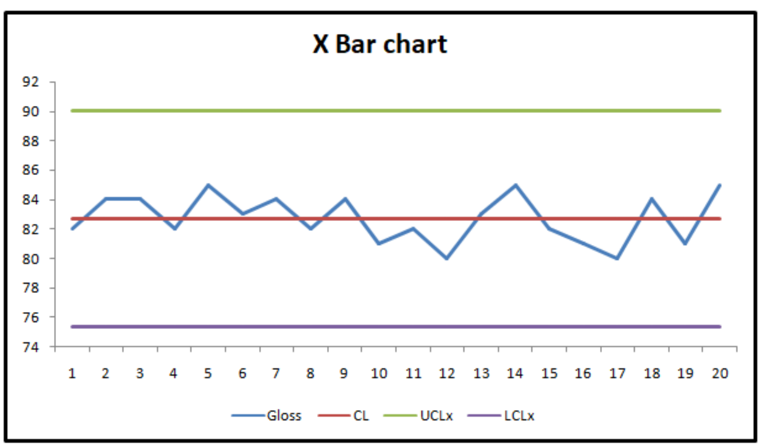
IV. Viscosity



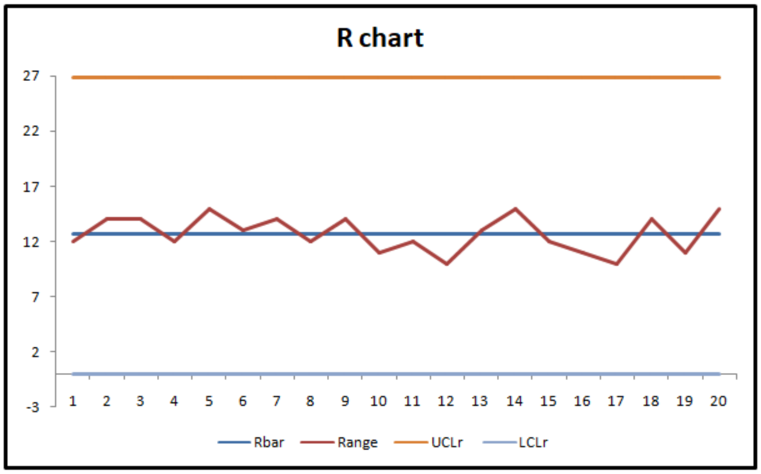


Using the data in the above section, Excel was used to plot the X bar and R charts. We can see that 2 lots out of 20 lots have their mean just a little above or below the control limits. However, in the R chart that is not the case. All points in the R chart lie well within range. So we can say that the process with respect to paint viscosity is fairly under control because such small deviations can be removed easily.

V. Gloss



Using the above data and plotting the X bar chart and R chart using excel, following are the results. We can observe that all the lots have Gloss well within the control limits.



Likewise, from the R chart, we see that all lots lie well within the control range. Overall, we can say that the process was in control with respect to Gloss of the paint.

PART II - Defects

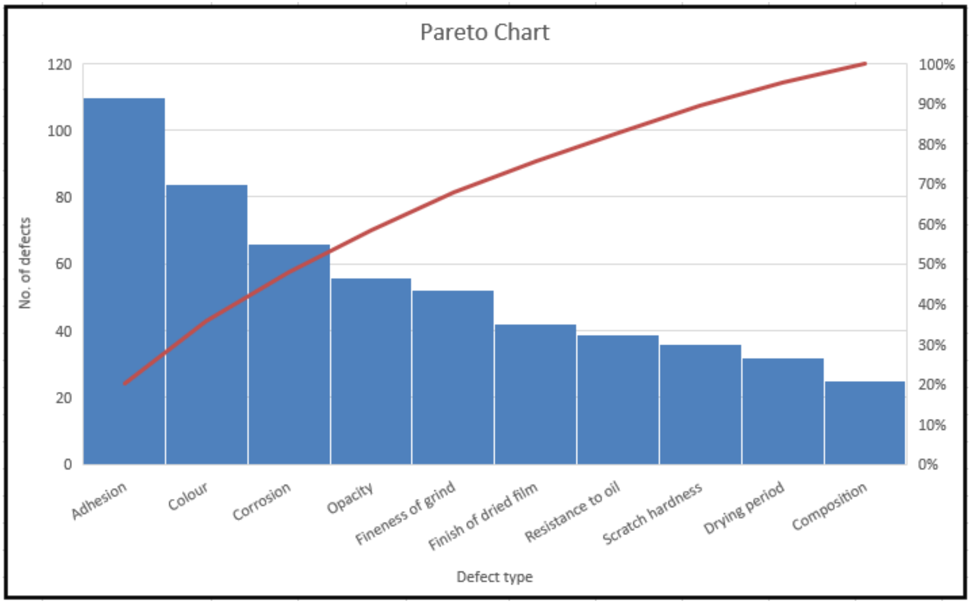
This section focuses on using Control tools such as Check sheet and Pareto chart to identify the commonly occurring defects and how frequent they are. For the Pareto chart, data given in the previous section has been used as reference.

I. Check Sheet

DEFECT/DAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY		SUM
Composition	x	3	2	x	x	x	x		5
Fineness of grind	2	x	1	x	3	2	1		9
Opacity	4	2	2	1	x	x	x		9
Finish of dried film	1	x	x	2	3	1	x		7
Scratch hardness	3	2	1	x	x	x	x		6
Colour	x	1	1	2	5	3	2		14
Adhesion	7	4	3	4	2	1	1		22
Resistance to oil	1	x	2	3	1	x	x		7
Corrosion	2	x	5	3	x	1	x		11
Drying period	4	1	x	x	x	1	x		6
Total number of defects	24	10	15	15	14	9	4		

This is a weekly checksheet of 20 lots with 300 samples each. From above, we can see that Adhesion is the most frequently occurring defect, followed by colour and then lack of corrosion resistance. To understand the trend and frequency of the defects, a Pareto chart was constructed.

II. Pareto Chart

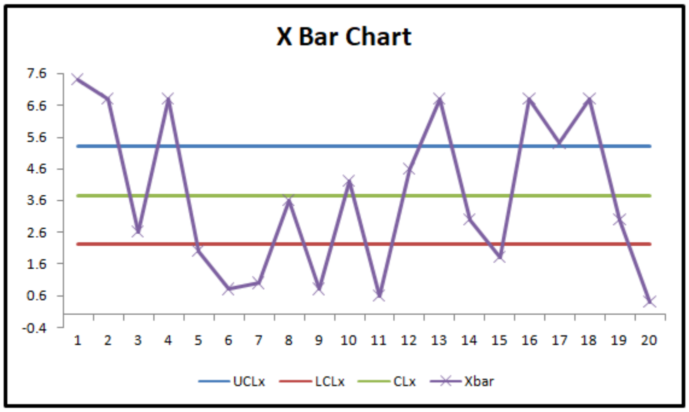


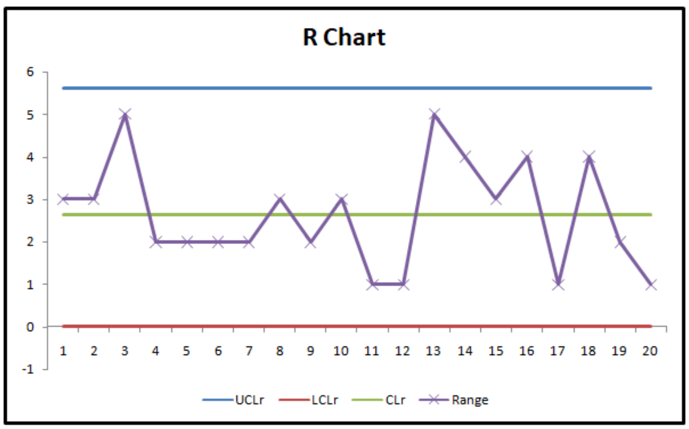
This is an observation for 80-85 lots with 300 samples coming in at a particular month. From the chart, we see that Adhesion happens to be the most commonly occurring defect with around 110 samples being defective each month. Using the 80-20 rule of the Pareto chart, we can say that the reasons contributing to the adhesion defect (80% of the total defects) also affect the occurrence of other defects.

PART III - Adhesion

Now that the most frequently occurring issue has been identified, it is now important to get to understanding the process with respect to adhesion and identify if it is in control or not. In this section, using the Adhesion data in the previous sections some control charts such as X bar chart, R chart, CUSUM chart and Np chart will be plotted.

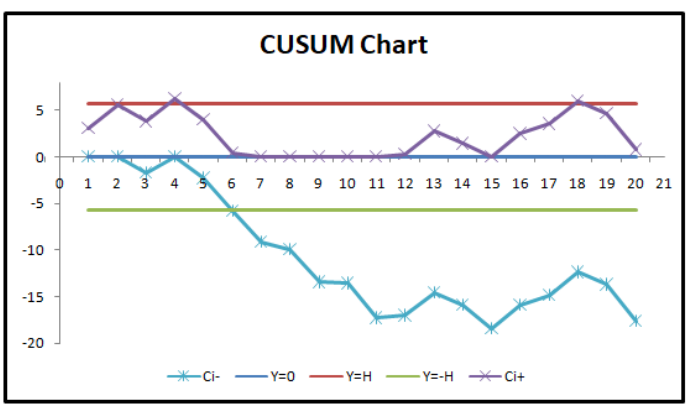
I. X bar chart, R chart





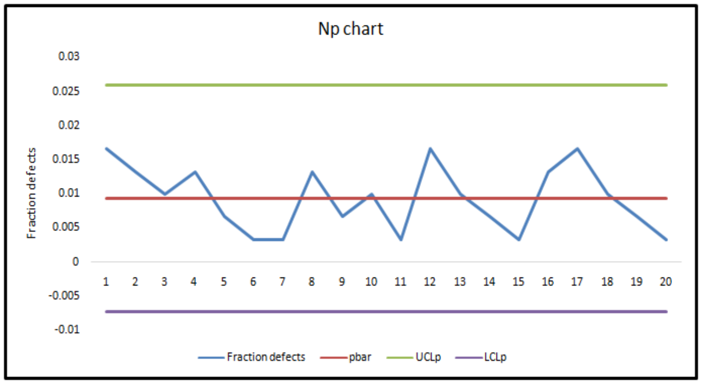
From the charts plotted, we can see the X bar chart has a lot of points way out of the limit region. Only 7 out of 20 lots have the adhesion measurements within range. This is a very small percentage in comparison to the total observations thus explaining the high number of defects. From the R chart, we can see that the points are well within range but huge deviations.

II. CUSUM chart



Since adhesion contributes to most of the defects from above, we wish to observe the effect of a small sigma shift in the process mean value. We observe that the Ci- values are way out of the limit/range. Thus we can say that the process with respect to adhesion is quite unstable due to such a high shift in the process mean variable. Thus we can confidently conclude that the adhesion process is not monitored thus leading to high defects.

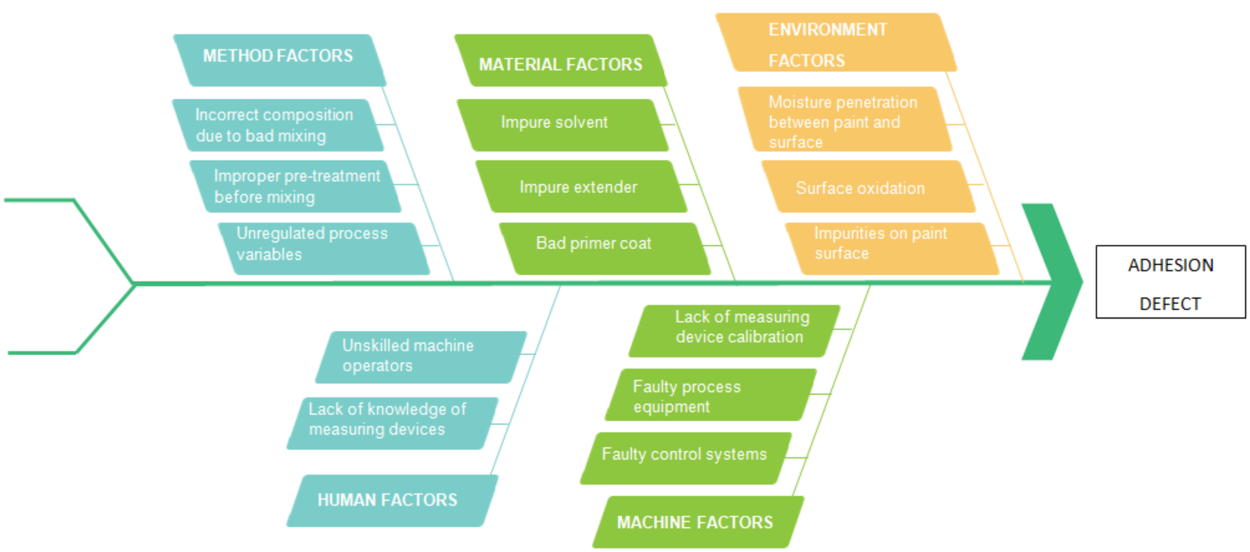
III. NP chart



Out of 20 lots with 300 samples (6000 samples), the number of defects for each lot were noted and an NP chart was plotted for the same. We can see that the observations lie well within the limits. Process capability for the same was calculated to be 2.498239. The index is way too high. For the process to be capable the Cpk index must lie between 0.5 and 1.3 to give 83% and 99.9% yield respectively.

PART IV - Cause and Effect

In this section, the main focus is to understand the root causes for such defects to appear. This was studied by taking help of the Ishikawa or Fishbone diagram. Every process is a result of multiple components and aspects involved. It is important to analyse the reasons for the occurence of the defect by grouping into five main categories namely Method factors, machine factors, human factors, material factors and environmental factors.



Even though environmental factors contribute to defects, this category is not controllable in terms of the process. Changes in the process can be made by providing solutions for each factor under the other subcategories.

PART V - Cost analysis

This section focuses on the cost analysis. The main purpose of this analysis is to calculate the approximate loss that would occur due to defective samples in the paint batches. Consider the Pareto chart data table, where 542 cumulative defects were observed in the paint samples coming in during a particular month due to multiple types of defects, we proceed with the calculation.

Assuming each can of paint contains 1 litres of paint. According to market price, each litre of automotive paint costs INR 300. In one month 80-85 lots (4 weeks + 2 days) with 300 samples each come in, which is around 25500 samples. If every single sample passed the quality tests, the estimated profits would've been 25500x300, which is INR 76,50,000. Considering the worst case scenario where 542 samples are defective, the industry will discard these samples and send the perfect samples only for further sale. This is around 2 entire lots of paint manufactured. The loss will be around 600x300 which is INR 1,80,000. The fraction of loss to estimated profits is not as big, but any industry wouldn't want to compromise on the quality of the final product, so they will take steps to reduce the occurrence of defects.

PART VI - Corrective Measures

This section focuses on the corrective actions that should be taken to avoid defects from showing up again in the future. Some of the corrective or preventive measures that can be taken are as follows:

- Depending on the base of the paint, for example enamel based or water based, the appropriate additive must be chosen. For enamel paints, the proper additive must be chosen so that the adhesion effect is much more effective. Some of the suggested additives are vinylic silane, methacrylic silane.
- Raw material quality should be checked before proceeding to the processing. The purity and other properties must be checked for so as to get maximum effect. Purity largely affects the paint quality post processing. Using chromatographic or other laboratory

methods that guarantee accuracy can be used to check for the purity of the raw materials. This must be done for the solvent, extender and resin without fail so as to reduce the number of defects showing up.

- Checking for process equipment. Generally in the paint industry, an industrial mixer or sand mill is used to blend all components together in the let down stage. It is important to check for the equipment's functionalities regularly by scheduling services and check-ups. This not only prevents health and safety hazards from happening, but also cuts down on costs incurred due to poor quality of the manufactured material.
- Examining the control loops involved in the process. Each process has a designated control loop which considers any disturbance in the process and rectifies it to make the final product of perfect finish. Oftentimes, control loops become faulty due to prolonged use and they might not be giving the feedback that they're designed for. Fixing the control loop ensures that the process is under control by regulating the process variables such as optimum temperature, pressure etc.
- Material handling in the industry must be done with great care by the personnel responsible for the same. Being knowledgeable and aware of appropriate regulations and techniques will save the industry from a lot of losses and also ensure safety.
- Composition of the paint matters a lot. The amount of resin, solvent and additives can affect the paint performance by a huge degree. Thus it is important to check for the ratio of each component to make the blend efficient.

CONCLUSION

This section will summarise the different things that have been done in the project. Through this project we understood what paint is, its components, how it is made and what is quality control. The different testing methods available for each paint characteristic was also discussed. Later part of the project, data was collected from an individual directly involved with the paint industry. This data was used to study the process and the quality of paint manufactured by making use of control tools such as X bar charts, R charts, Check sheet, Pareto chart, CUSUM chart, NP chart and Fishbone diagram. These quality tools helped understand if the process is within control limits, most frequently occurring defects and root causes for such problems. Some of the conclusions are -

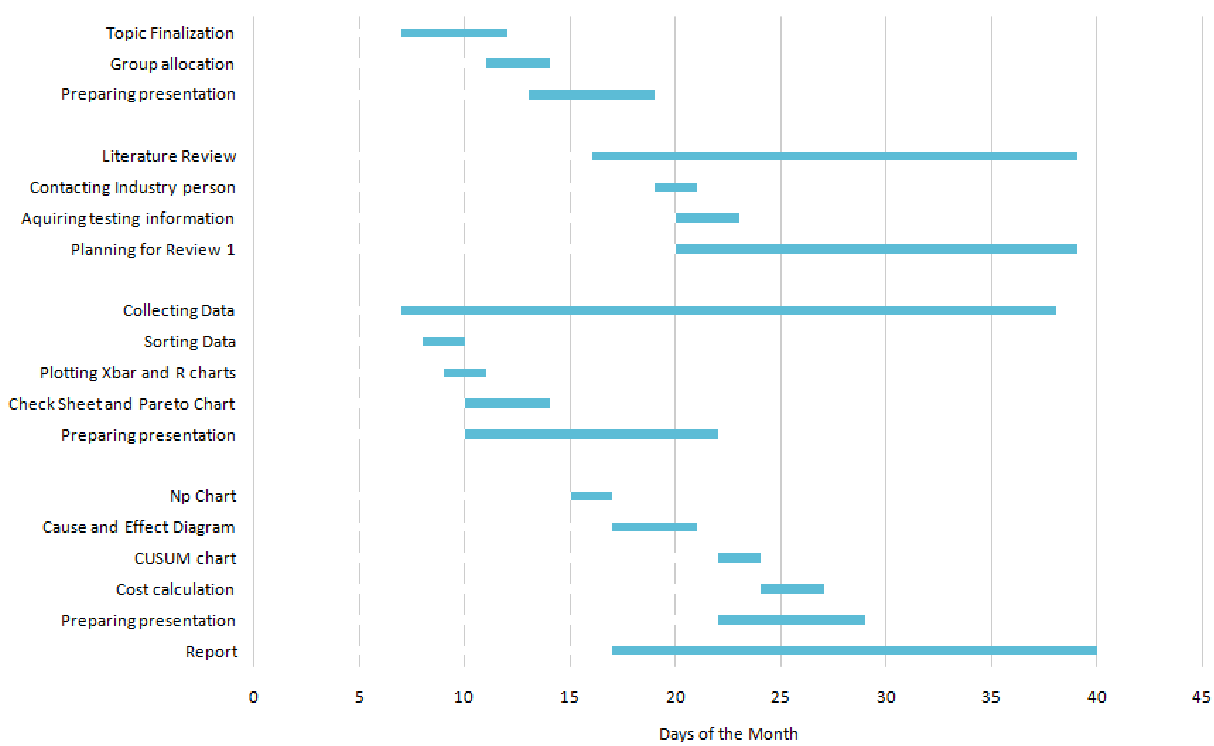
- The process is in control with respect to paint properties such as specific gravity, DFT, non volatile matter content, Gloss, Viscosity.
- The most commonly occurring defect was adhesion and that contributed to the other defects showing up from the 80-20 rule of Pareto chart.
- Process was not in control with respect to adhesion which is why more adhesion defects were occurring.
- Causes for the adhesion defect were understood through the ishikawa diagram.
- Losses are incurred due to the defects in the sample and the industry's focus should be on minimizing these losses by implementing corrective actions.
- Some corrective actions were discussed from the industry standpoint and if they're implemented, they can yield impressive results.

Further scope of this project would be to understand the reduction in losses due to such defects after implementing the corrective measures.

GANTT CHART

	TASK NAME	START DATE	DAY OF MONTH	END DATE	DURATION	DAYS COMPLETE	DAYS REMAINING	PERCENT COMPLETE
Review 0								
	Topic Finalization	2/7	7	2/11	5	5	0	100%
	Group allocation	2/11	11	2/13	3	3	0	100%
	Preparing presentation	2/13	13	2/18	6	6	0	100%
Review 1								
	Literature Review	2/16	16	3/10	23	23	0	100%
	Contacting Industry person	3/19	19	3/20	2	2	0	100%
	Acquiring testing information	3/20	20	3/22	3	3	0	100%
	Planning for Review 1	3/20	20	4/7	19	19	0	100%
Review 2								
	Collecting Data	4/7	7	5/7	31	31	0	100%

	Sorting Data	5/8	8	5/9	2	2	0	100%
	Plotting Xbar and R charts	5/9	9	5/10	2	2	0	100%
	Check Sheet and Pareto Chart	5/10	10	5/13	4	4	0	100%
	Preparing presentation	5/10	10	5/21	12	12	0	100%
Review 3								
	Np Chart	5/15	15	5/16	2	2	0	100%
	Cause and Effect Diagram	5/17	17	5/20	4	4	0	100%
	CUSUM chart	5/22	22	5/23	2	2	0	100%
	Cost calculation	5/24	24	5/26	3	3	0	100%
	Preparing presentation	5/22	22	5/28	7	7	0	100%
	Report	5/17	17	6/8	23	23	0	100%



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