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PROCESS VARIABILITY REDUCTION THROUGH STATISTICAL PROCESS CONTROL FOR QUALITY IMPROVEMENT

B.P. Mahesh [1)]
M.S. Prabhuswamy [2)]

1) Department of Industrial Engineering and Management M.S.Ramaiah Institute of Technology, Bangalore-, India
2) Department of Mechanical Engineering S.J. College of Engineering, Mysore, India

Abstract: *Quality has become one of the most important customer decision factors in the selection among the competing product and services. Consequently, understanding and improving quality is a key factor leading to business success, growth and an enhanced competitive position. Hence quality improvement program should be an integral part of the overall business strategy. According to TQM, the effective way to improve the Quality of the product or service is to improve the process used to build the product. Hence, TQM focuses on process, rather than results as the results are driven by the processes. Many techniques are available for quality improvement. Statistical Process Control (SPC) is one such TQM technique which is widely accepted for analyzing quality problems and improving the performance of the production process. This article illustrates the step by step procedure adopted at a soap manufacturing company to improve the Quality by reducing process variability using Statistical Process Control.*
Keywords: *Statistical Process Control; Process Capability Indices; Six Sigma; Variable control chart; Attribute control chart; Cause and effect diagram.*

1. LITERATURE REVIEW

1.1 Quality Control

Quality may be defined as that characteristic which renders a product or service as having "fitness for purpose or use". There are different reasons why a product may have unsatisfactory quality. Statistical methods play a central role in Quality improvement efforts and recognized as an efficient and powerful tool in dealing with the process control aspects (Montgomery 2003).

1.2 Concept of Variation

Variation is part and parcel of life. The concept of variation states that no two products will be perfectly identical even if extreme care is taken to make them identical in some aspect. The variation in the quality of product in any manufacturing process results because of two reasons namely, Chance cause and Assignable cause.A process that is operating with only chance causes of variation is said to be in a state of statistical control.

This means, chance causes results in only minor variation in the process. The major objective of SPC is to quickly detect the occurrence of assignable causes so that investigation of process and corrective action may be taken before many non-conforming units are manufactured.

Finally, the eventual goal of SPC is the elimination of variability in the processes.

1.3 Process Capability

The process capability studies are helpful in analyzing the quality and efficiency of the process. The process capability analysis has been widely adopted as the ultimate measure of performance to evaluate the ability of a process to satisfy the customers in the form of specifications (English et al 1993).

Process capability acts as a TQM tool and is described as a strategic management technique that plays a vital role in the company's operations management. The process capability study helps in designing the product, deciding the acceptance norms, process and operators selections in the operations management (Feigenbaum 1994). The evaluation of process capability is an important step in process quality improvement (Juran 1991).

It is customary to take the six sigma prime spread in the distribution of the product quality characteristic as a measure of process capability. In process capability study of particular process, six sigma prime spread is compared with the difference of Upper Specification Limit (USL) and the Lower Specification Limit (LSL).

The following are the three possible cases.

1. $6\sigma` > (USL – LSL)$: In this case, the process spread is greater than the tolerance. So the process is incapable of meeting the specification.
2. $6\sigma` = (USL – LSL)$: In this case, the process spread is exactly equal to the tolerance. So

the process is exactly capable of meeting the specifications.

3. 6σ ` < (USL – LSL) : In this case, the process spread is less than the tolerance. So the process is capable of meeting the specifications.

1.4 Process Capability Indices

It is frequently convenient way to have a simple, quantitative way to express process capability. One way to do so is through process capability indices. Process capability indices (PCI) are powerful means of studying the process ability for manufacturing a product that meets specifications (Chen et al 2001).

PCI is defined as the ratio of tolerances to the process spread.

i.e. PCI = (USL – LSL) /6σ

If the PCI is greater than or equal to one, then the process is capable of meeting the specification limits. If the PCI is less than one, then the process is incapable of meeting the specification limits.

A Multistage process capability analysis algorithm is developed to prioritize process improvement process (Richard Linn, et al 2002-03). The application of this algorithm is demonstrated with 2 stage and 4 stage examples for its expandability.

There exists no standard calculation for process capability in the case of non-normal data (Edwin R. Van den Heuvel and Roxana Ion 2003). The authors have evaluated two adaptive capability indices and have used log-normal and Weibull distribution functions to illustrate the adaptiveness of their capability indices in relation to standard capability indices.

The most common and earliest forms of process capability indices assume that the process under examination is normally distributed and violation of this assumption often leads to inappropriate results (Mc Cormack et al 2000). The authors have performed Monte Carlo simulation to investigate the characteristics of process capability indices when samples were drawn from distributions with varying degrees of non-normality. The process capability studies should be carried out at the vendors end in order to reduce the burden of inspection cost and time at the manufacturing end (Jaju S B et al 2002).

Cp simply measures the spread of the specification relative to the six sigma spread in the process. Cpk will come into picture if the process is off centered. Cpk is an index (a simple number) which measures how close a process is running to its specification limits, relative to the natural variability of the process.

Cpk = min (Cpu, Cpl)

Cpk = Min (Cpu = (USL - μ) / 3σ, Cpl = (μ - LSL) / 3σ)Generally if Cp = Cpk, the process is centered at the midpoint of the specifications, and when Cpk is less than Cp, the process is off centered.

The manufacturers and suppliers use quality measures calculated from dimensional data to make informed decisions regarding measurements system and product quality (Karl Majestic and Richard Andrews 2002-03). The authors have recommended the manufacturers to consider all three quality measures namely, Precision-To-tolerate ratio, Cp and correlation factors.

A statistical rationale for adjusting estimates of process capability by including a shift in the average was provided by some researchers (Davis R Bothe 2002). A method to detect all types of Shifts (large, moderate and small) by taking both large and small samples under suitable framework of sampling was given (Shivaswamy R.et al 2000). The authors have concluded that shift in the mean value of X are more sensitively detected by the $\overline{X}$ chart based on Markov Dependent Sampling.

If the performance improvement objective is changed from minimizing the non-conformity to making the process less sensitive to variation i.e. a more robust process, then a metric is required to measure the robustness of the process and that metric is Net Sensitivity. The shift value which makes NS=0 will also minimize the non conformity (John Flaig 2002-03).

To achieve optimal outcomes in continuous process, non linear and complex relationships among process factors must be managed (Cherly Hild, Doug Sanders and Tony Copper 2000-01). The data from continuous processes are often plentiful in terms of processing variables and limited with regard to product characteristics. With continuous processes, the variation in the main product stream does not necessarily reflect the true level of variation exhibited by the process.

The desirability function do not explicitly account for the combined effect of the mean and dispersion of quality (Charles Ribardo and Theodore T Allen 2003). The authors have used an Arc welding application to illustrate how the proposed desirability function can yield a substantially higher level of quality.

The decisions made during the design stage of a product and process development profoundly affect product quality and process productivity (Nam P Suh 1995). The author has presented several criteria that govern the design and manufacture of quality products. These criteria provide the bounds for the validity of some of SPC techniques being used.

The multi-vari chart graphically displays the behaviour of the quality characteristic in the running process (Jeroen De Mast et al 2001). The authors have presented an introductory example to describe the composition of multi-vari chart. This chart allows for more additional variance components to be part of analysis.

The process capability analysis has been applied in the textile industry to assess the variation in the ability of the process (Saravanan 2002). The author has opined

that while conducting a process capability study, one should ensure stable process identifiable samples, notes on process factors and conditions avoid making changes in the process during study and allotting an experienced person to conduct the study.

The cause and effect analysis is one of the simplest and cheapest measurement tools for improving the production system quality efficiency which gives tangible benefits in the shortest possible time for any organization (Gopala Raju et al 2005). The authors have carried out a case study in paper machine department of a paper mill. Using the cause and effect diagrams, they identified problems and possible recommendations because of which productivity was increased by 13%.

In a company producing 3000 units of compressors per month, almost 8-10% defective compressors were identified (Santosh Garbayl et al 2006). The authors have conducted root cause failure analysis and corrective action was taken which reduced the defectives by 3-4%.

2. OBJECTIVE OF THE STUDY

At the outset, it was observed that the Quality of the soaps were not up to the mark as per the company manual. Then the detailed study of flow process and steps involved in manufacturing the soaps was carried out and it resulted in the identification of the following defects.

1. Poor surface finish
2. Color variation
3. Grits: appearance of black dots on soap
4. Specks: cluster of brown / white spots on soap
5. Blisters: band like appearance on soap

These defects indicated that there might be some assignable causes in the manufacturing process. These causes are responsible for the poor Quality of soap. So, the objective of the study has been set to improve the Quality by reducing the variability in the process through Online Quality Control Techniques.

3. ROAD MAP TO ACHIEVE THE OBJECTIVE

The road map to achieve the objective of the study is listed below.

- To set up control charts for monitoring and diagnosing the process.
- To trace out the root causes for each and every defect identified, i.e. to determine the assignable causes.
- To suggest remedies for the root causes.
- To implement the solution and measure the improvement of Quality.

4. TOOLS AND TECHNIQUES USED IN THE STUDY

A detailed analysis was done for each production line. Data was collected at various stages of the manufacturing process, keeping in mind the principles of rational sub grouping and the following tools and techniques were used.

- Variable control chart ($\overline{X}$ – R charts)
- Attribute control chart (u chart)
- Pareto chart
- Cause and effect diagram

5. PROCEDURE FOR $\overline{X}$ AND U CHART

5.1 Procedure for $\overline{X}$ and r chart

The steps followed for constructing $\overline{X}$ and R - chart in the study are given below.

Step 1 - Determine the data to be collected: The data was collected for weight of the soaps for 20 subgroups of size 5. (Table 2)

Step 2 - Calculate the range for each subgroup: The range is calculated by taking the difference between the Largest Value and the Smallest Value in each Subgroup and tabulated. (Table 2)

Step 3 - Calculate the average of the subgroup ranges: The average of all subgroups becomes the centerline for the lower plotting area.

$$\overline{R} = \frac{R_1 + R_2 + R_3 \ldots\ldots\ldots + R_K}{k}$$

Where, R_i = the individual range of each subgroup

$\overline{R}$ = the average of the ranges for all subgroups

K = the number of subgroups

Step 4 - Calculate the control limit for the ranges: The control limits are calculated using the formula.

$$UCL_{\overline{R}} = D_4\overline{R} \qquad LCL_{\overline{R}} = D_3\overline{R}$$

Then range chart (R chart) is plotted for line 6 (Figure 1). Since two points were falling out of the control limits, the revised Range was calculated excluding those points which are falling outside the control limits. As all points fall within control limits, it was proceeded to the next step 5.

Step 5 - Calculate the average for each subgroup: The average (mean) for each subgroup is calculated using the following formula and tabulated. (Table 2)

$$\overline{X} = \frac{X_1 + X_2 + X_3 + \ldots\ldots\ldots + X_n}{n}$$

Where, $\overline{X}$ = the average of the measurements within each subgroup.

X_i = the individual measurements within a subgroup.

n = the number of measurements within a subgroup.

Step 6- Calculate the *grand mean* of the subgroup's average: The *grand mean* of the subgroup's average ($\overline{\overline{X}}$) was calculated and it becomes the centerline for the $\overline{X}$chart.

$$\overline{\overline{X}} = \frac{\overline{X}_1 + \overline{X}_2 + \overline{X}_3 + \ldots\ldots\ldots + \overline{X}_K}{k}$$

Where, $\overline{\overline{X}}$= the grand mean of all the individual subgroup averages

$\overline{X}$= the average for each subgroup

k= the number of subgroups

Step 7 - Calculate the Upper Control Limit (UCL) and Lower Control Limit (LCL) for the averages of the subgroups: The control limits for $\overline{X}$ chart are found out using the formula,

$$UCL_{\overline{X}} = \overline{\overline{X}} + A_2\overline{R} \qquad LCL_{\overline{X}} = \overline{\overline{X}} - A_2\overline{R}$$

Step 8 – Draw the $\overline{X}$chart: Since all the points are falling within the control limits for line 6, the $\overline{X}$Chart is plotted (Figure 2). If any point is falling outside the prescribed control limits, then the revised control limits have to be calculated excluding those points falling outside and then draw the $\overline{X}$ chart.Similarly, $\overline{X}$and R chart were drawn for the lines 7, 8 and 9 of the production unit.

5.2 Procedure for u chart

The procedure followed to construct the u-chart for line 6 is illustrated below.

1. 20 samples of varying sample sizes were collected for line 6 and tabulated. (Table 3)
2. The numbers of defects in each of the samples were noted. (Table 3)
3. The defects per unit (u) are calculated (Table 3) for each of the samples using the formula, u = c/n
   Where, c = total number of nonconformities.
   n = total number of items inspected.
4. Average number of non-conformities per unit is calculated.
5. The trial control limits for each subgroup is calculated using the following formula and tabulated. (Table 3)
   $UCL = \overline{u} + \sqrt[3]{(u/n_i)}$ $LCL = \overline{u} - \sqrt[3]{(u/n_i)}$
6. u chart for line 6 is plotted (Figure 3), and it can be seen that all the points fall within the control limits.

Similar procedure was followed and u chart was drawn for the lines 7, 8 and 9 of the production unit.

6. DATA COLLECTION AND CALULATIONS

A data collection sheet has been designed to collect data for various characteristics for all the four lines and a sample sheet is shown in the Table 1.

Table 1 *Sample Data Collection Sheet*

SL NO	CHARACTERISTICS	LINE 6	LINE 7	LINE 8	LINE 9
1	Weight in gms.	√	√	√	√
2	Color	√√	√√	√√	√√
3	Perfume	√	√	√√	√
4	Poor surface finish	√√	√√	√√	√√
5	Specks	√	√√	√√	√√
6	Blisters	√√	√	√√	√√
7	Grits	√√	√√	√	√
8	Stamping	√	√	√	√√

√√ = **Defect present needs immediate rectification before further production** √ = OK

6.1 Variable Control Chart

The data is collected for $\overline{X}$and R chart (Table 2).

The associated calculations were done and the R and $\overline{X}$charts are drawn for line 6. (Figure 1 & 2)

Table 2 Data for $\overline{X}$ and R chart line 6

SUB-GROUP NUMBER	OBSERVATION 1	2	3	4	5	$\overline{X}$	R
1	75.3	75.2	75	75.8	76	75.46	1
2	75.2	75.8	75.5	75.3	75	75.36	0.8
3	74.8	75.2	75.4	76	75	75.28	1.2
4	76	76	75	74	75	75.2	2
5	75	76	75	74	76	75.2	2
6	75.2	75.2	75	75.3	75.3	75.2	0.3
7	75.2	75.4	75.2	75.3	76	75.42	0.8
8	75.3	75.2	76	75	75	75.3	1
9	75.2	75	75.4	75.2	75	75.16	0.4
10	74.8	76	75.2	75.2	75.3	75.3	1.2
11	75	75.8	75.2	75.3	75.4	75.22	0.4
12	75.3	75.2	75.4	75.2	74	75.02	1.4
13	75.3	75.5	75.2	75	75.5	75.3	0.5
14	76	75	75.2	75	75.6	75.3	1
15	75.1	75	75.2	75.3	75.2	75.16	0.3
16	75.1	75	75.4	75.2	75.3	75.2	0.3
17	75.2	75.1	75	75.3	75.6	75.24	0.6
18	75.2	75.2	75.4	75.1	75	75.18	0.4
19	75.1	75.6	76	75	75.2	75.38	1
20	75	76	74.6	75.1	75.3	75.2	1.4

❖ **CALCULATIONS FOR LINE 6**

For subgroup size n=5

$D_4 = 2.115$, $D_3 = 0$, $A_2 = 0.577$, $d_2 = 2.326$ (From SQC tables)

- **R CHART**

$\overline{R} = \sum R / N$

Where N = Total number of subgroups

$\overline{R} = 18/20 = 0.9$

$CL_R = \overline{R} = 0.9$

$UCL_R = D_4 * \overline{R} = 2.115 * 0.9 = 1.9035$

$LCL_R = D_3 * \overline{R} = 0 * 0.9 = 0$

From the data, it seen that 2 subgroup i.e. sub group number 4 & 5 are crossing upper control limit which indicate the presence of assignable cause. So homogenization is necessary.

Revised $\overline{R}1 = \frac{18-2-2}{20-2} = 0.778$

Revised control limits:

$UCL_{R1} = D_4 * \overline{R}_1 = 2.115 * 0.778 = 1.645$

$LCL_{R1} = D_4 * \overline{R}_1 = 2.115 * 0 = 0$

Hence now from the data it is seen that all points fall within control limits.

- **FOR $\overline{X}$ CHART**

$\overline{\overline{X}} = \sum \overline{X} / N = 1505.08 / 20 = 75.254$

CONTROL LIMITS:

$CL_X = \overline{\overline{X}} = 75.254$

$UCLx = \overline{\overline{X}} + A2 * \overline{R}_1 = 75.254 + 0.577 * 0.778 = 75.703.$

$LCLx = \overline{\overline{X}} - A2 * \overline{R}_1 = 75.254 - 0.577 * 0.778 = 74.805.$

Since all data are falling with in control limit, the process is under control.

- **PROCESS CAPABILITY CALCULATION**

USL = 77.25 LSL = 75

$\sigma^1 = R_1 / d_2 = 0.778 / 2.326 = 0.3345$

$6\sigma^1 = 6 * 0.3345 = 2.007$

$6\sigma^1$ (2.007) < USL - LSL

Hence the process is capable of meeting the specification limits.

Process capability ratio = $C_P = \frac{USL - LSL}{6\sigma^1} = \frac{77.25 - 75}{6 * 0.3345} = 1.12107$

C_{pk} = Min (Cpu, Cpl)

= Min (Cpu = (USL - μ) / 3σ, Cpl = (μ - LSL) / 3σ) = Min (1.98, 0.25) = 0.25.

The percentage of soaps not meeting the specification

limits

p = P (x < 75) + P (x > 77.25).

= P (75 – 75.254/ 0.3345) + P (77.25 – 75.254/ 0.3345) = 0.2236 + 0 = 0.2236 i.e 22.36% .

The percentage of the specification band that the process uses up

$\tilde{P}$= (1/ Cp) * 100 = (1/ 1.12107) * 100 = 89.207%

The process is using about 90% of the specification band.

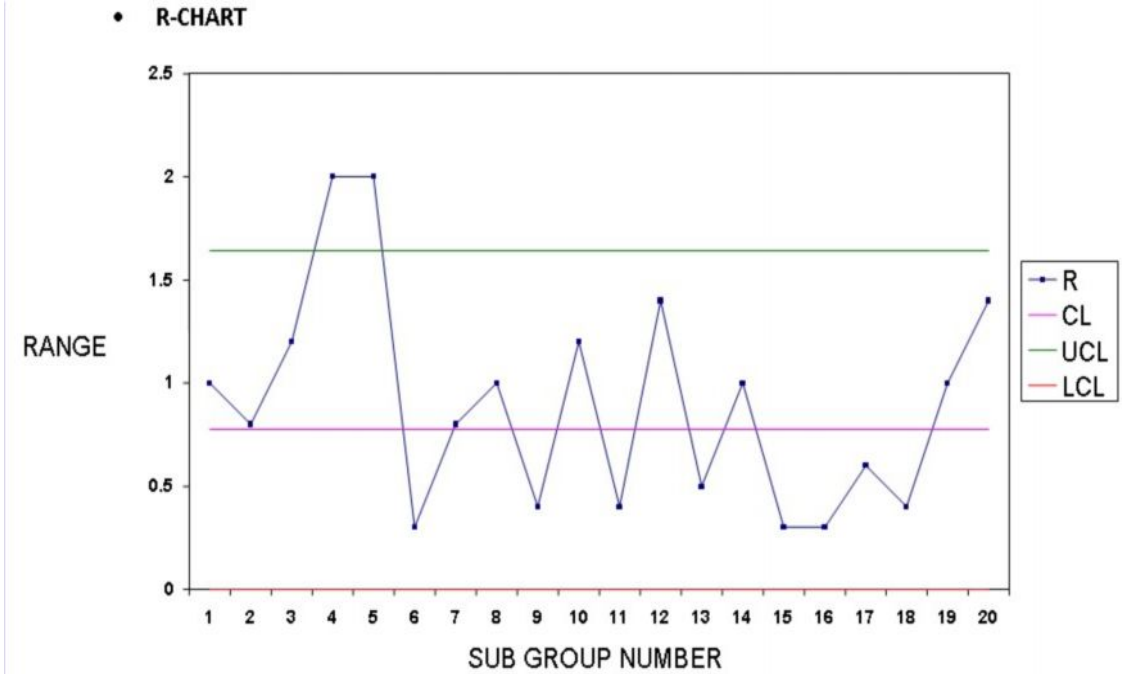

Fig 1 *R Chart for Line 6*

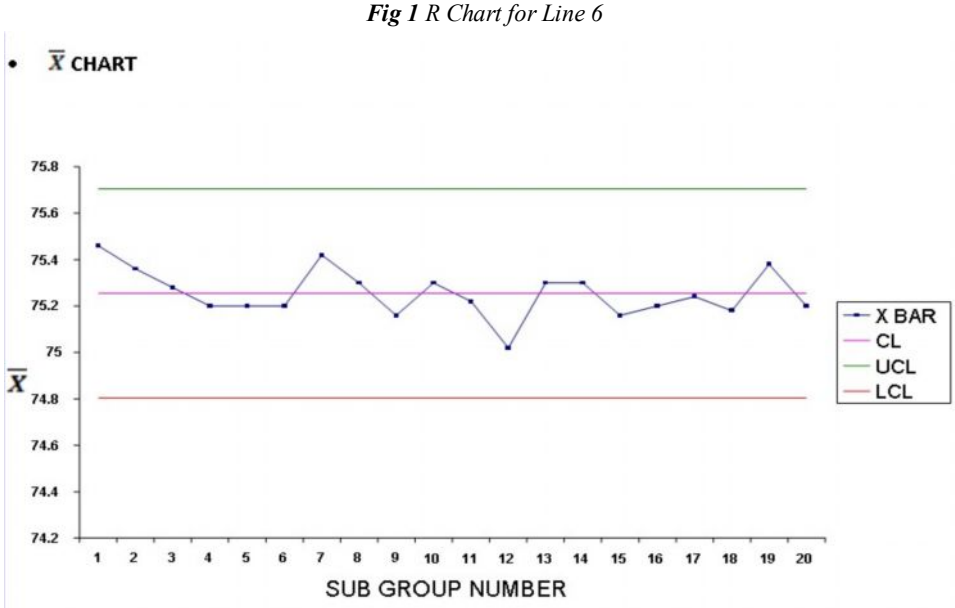

Fig 2 $\overline{X}$ *Chart for Line 6*

6.2 Attribute Control Chart

The data is collected for u chart (Table 3). The associated calculations were done and the u chart is drawn for line 6. (Figure 3)

Table3 Data for u Chart for line 6

SUB-GROUP NUMBER	NUMBER OF INSPECTED 'n'	NUMBER OF DEFECTS c	u=c/n	UCL	LCL
1	8	16	2	3.445	0.475
2	10	10	1	3.288	0.631
3	7	21	3	3.547	0.372
4	10	12	1.2	3.288	0.631
5	12	15	1.25	3.172	0.747
6	11	22	2	3.226	0.694
7	12	36	3	3.172	0.747
8	10	15	1.5	3.288	0.631
9	10	20	2	3.288	0.631
10	9	17	1.9	3.362	0.561
11	7	15	2.14	3.547	0.372
12	8	19	2.375	3.445	0.475
13	10	20	2	3.288	0.631
14	10	19	1.9	3.288	0.631
15	12	25	2.08	3.172	0.747
16	9	15	1.67	3.362	0.561
17	10	20	2	3.288	0.631
18	11	25	2.27	3.226	0.694
19	12	26	2.16	3.172	0.747
20	12	24	2	3.172	0.747

- **CALCULATION**

$\bar{u} = \sum c / \sum n = (392 / 200) = 1.96$

Specimen calculation for sample number 2

$UCL = \bar{u} + 3*\sqrt{(\bar{u} / n_i)} = 1.96 + 3*\sqrt{(1.96/10)} = 3.288$

$LCL = \bar{u} - 3*\sqrt{(\bar{u} / n_i)} = 1.96 - 3*\sqrt{(1.96/10)} = 0.631$

From the data, it is observed that all the points are falling with in control limit. So, the process is under control.

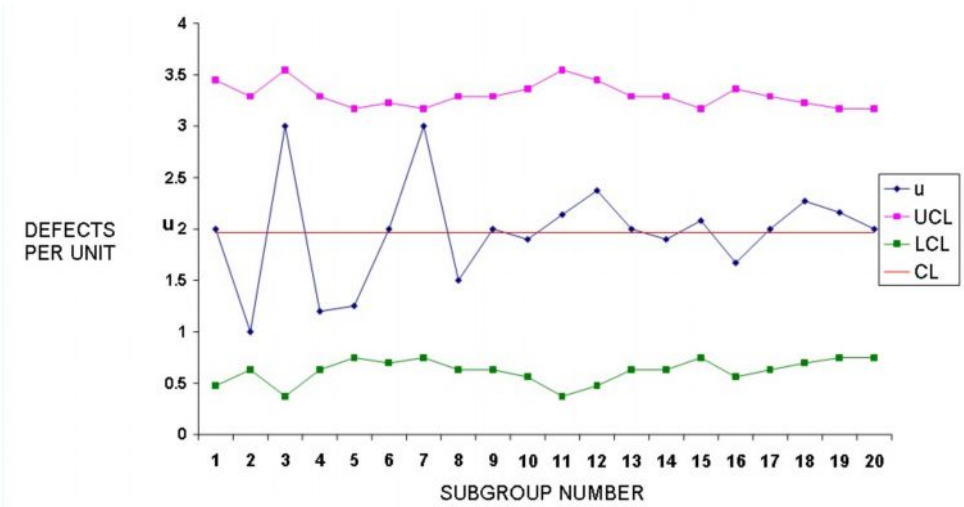

***Fig 3** u Chart for Line 6*

6.3 Prioritizing The Problems

In order to prioritize the problems, data is analyzed (Table 4) and pareto chart is drawn. (Figure 4)

Table 4 *Data for pareto chart for line 6*

SL NO	DEFECT	FREQUENCY	CUMULATIVE FREQUENCY	% FREQUENCY	% CUMULATIVE FREQUENCY
1	Finishing	196	196	50	50
2	Color	98	294	25	75
3	Brown/black Specks	39	333	10	85
4	Grits	30	363	7.7	92.7
5	Blister	29	392	7.3	100

6.4 Finding the Root Causes for the Problems

To find out the root causes, cause and effect diagrams were drawn for all defects. As an example, the cause and effect diagram for poor surface finish is shown in figure 5.

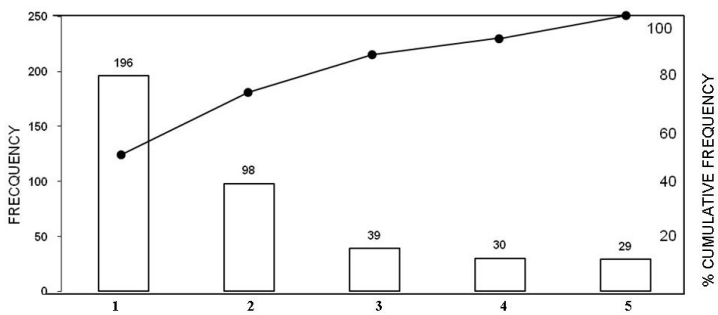

Fig 4 *Pareto chart for line 6*

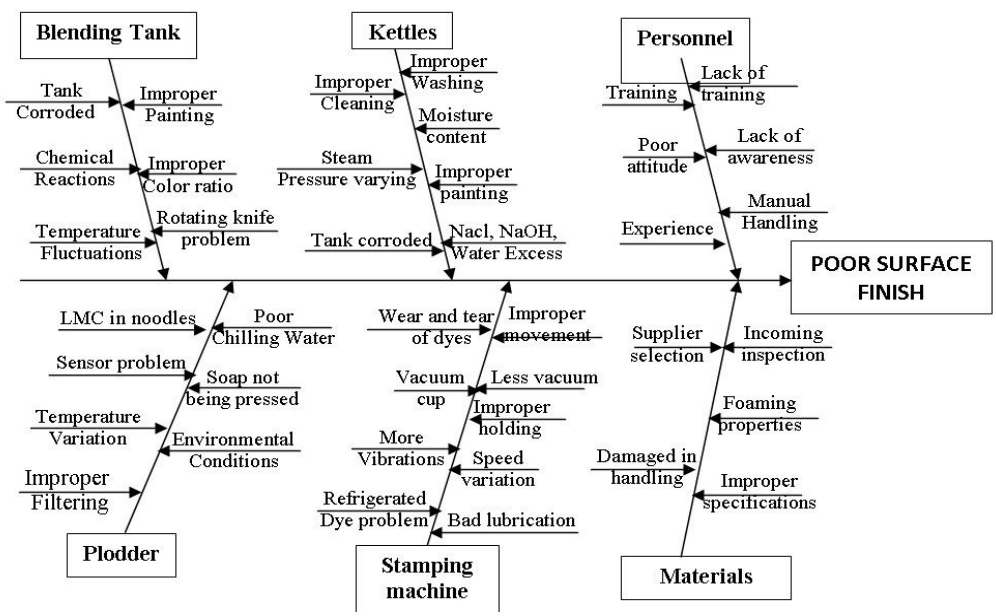

Fig 5 Cause and effect diagram for poor surface finish

7. RESULTS AND ANALYSIS

The process capability analysis for all the four lines is shown below.

For line 6,

Mean = 75.254 – estimated from the process.

$\sigma^1 = 0.3345$, Cp = 1.1207, Cpk = 0.25.

Since Cpk < Cp, the process is off-centered and is towards the Lower specification limit.

We find that around 22.36% of the soaps produced fall outside the specification limits.

P = (1/Cp) * 100 = 90% of the specification band is used by the process.

For line 7,

Mean = 75.18 – estimated from the process.

$\sigma^1 = 0.365$, Cp = 1.0273, Cpk = 0.164.

Since Cpk < Cp, the process is off–centered and is towards the lower specification limit.

We find that 31.21% of the soaps produced fall outside the specification limits.

P = (1/Cp) * 100 = 97.34% of the specification band is used by the process.

For line 8,

Mean = 75.263 – estimated from the process.

$\sigma^1 = 0.3326$, Cp = 1.1274, Cpk = 0.263.

Since Cpk < Cp, the process is off–centered and is towards the lower specification limit.

We find that 21.48% of the soaps produced fall outside the specification limits.

P = (1/Cp) * 100 = 88.69% of the specification band is used by the process.

For line 9,

Mean = 75.28 – estimated from the process.

$\sigma^1 = 0.324$, Cp = 1.1574, Cpk = 0.288.

Since Cpk < Cp, the process is off–centered and is towards the lower specification limit.

We find that 19.49% of the soaps produced fall outside the specification limits.

P = (1/Cp) * 100 = 86.4% of the specification band is used by the process.

After aggregating all the data obtained, it can be found that the system is operating under 1.5 – 1.6 sigma level. Around 23-28 % of the soaps produced are falling outside the specification limits and 85 – 90 % of the specification band is being used. And also since Cpk < Cp for all the four lines, the process is off-centered and is towards the lower specification limit. No point is falling outside the upper specification limit. It clearly indicates that the variability in the process is very high.

Now, to reduce the number of soaps falling outside the specification band, there are two types of strategies available. The first one is to reduce the variability in the system. The second one is to shift the target (process mean) towards the center. But, the first strategy of reducing the variability is preferred because the weight of the soap bar is to be kept just around 75g. Shifting the target (process mean) will lead to increase in weight of the soap, which is not profitable for the organization. Finally, remedies were given to reduce the number of defects being produced, so that the system can attain the state of statistical control.

8. REMEDIES FOR DEFECTS

After a thorough analysis of the actual root causes for the defects, the following remedies were suggested.

1. The frequency of painting the Blending tank and Kettles should be increased to twice a year from the present level of once a year to prevent corrosion.
2. For a better saponification process, excess time (more than 2 hours) should not be given for the mixtures (raw materials in blending tank) to settle down.
3. Temperature should be controlled around 50 – 60 degree Celsius in blending tank to get good *neat soap*.
4. Steam pressure should be kept constant in the kettles for the manufacture of *base soap*.
5. *Spent lye (waste)* formed at the bottom of kettles should be removed completely so that they do not react with the next batch of raw materials.
6. Circulation of cooling water should be done at regular intervals (once in three hours) of time in the plodder to maintain the required moisture content in soaps.
7. Thermostat should be installed permanently to monitor the required temperature continuously in the plodder. Even sensors can be used for checking the temperature.
8. A better mechanism can be used to create vacuum in duplex plodder-which facilitates pressing action of soap.
9. In amalgamator, pumps should be used for dosing viscous liquids like silicate, perfumes, etc at required rates.
10. Amalgamator blades should rotate with varying speed for better homogenization, texture and color of the soap.
11. Regular coating of stainless steel inside the amalgamator is required (at least once a year).
12. Milling rollers should be kept cool during operation to remove the heat generated during the milling process. They should be fabricated in mild steel with special alloy chilled rolls for better grinding.
13. All the three milling rollers should rotate at varying speed to get fine ribbons of soaps.
14. There should be provision to adjust the gap between rollers to give required thickness to the soap film.

15. Refrigerated dies should be cleaned regularly (every month) and there should be proper cooling water circulation for better finish of the soap in the stamping machine.
16. Workers should be properly trained and motivated.
17. Preventive maintenance system can be followed in the place of present Breakdown maintenance system.

9. CONCLUSIONS

In a span of one year, many easily executable remedies(remedy number's 1,2,3,4,5,6,7,10,13,15,16,17 as shown in section 5.13) were implemented. Then the entire study was repeated again for the same production lines 6, 7, 8 & 9 and the following improvements in Cp and Cpk values were obtained.

Post implementation study revealed that defects rate drastically came down thus reducing the process variability.

Table 5 *Improvements after solution implementation*

LINE NUMBER	Cp		PERCENTAGE IMPROVEMENT IN Cp VALUE	Cpk		PERCENTAGE IMPROVEMENT IN Cpk VALUE
	BEFORE	AFTER		BEFORE	AFTER	
6	1.1207	1.1546	3.02	0.250	0.261	4.4
7	1.0273	1.0712	4.27	0.164	0.170	3.6
8	1.1274	1.1803	4.69	0.263	0.272	3.4
9	1.1574	1.1785	1.82	0.288	0.295	2.4

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