FAILURE ANALYSIS OF MACHINED COMPONENT BY USING SPC TECHNIQUE

Shilpa Chumbale
Assistant Professor
Department of Mechanical Engineering,
New Horizon Institute of Technology & Management, Thane, India

Abstract: The aim of this work is to study the variation in manufacturing processes and to monitor product quality and maintain processes to fixed targets using Statistical process control (SPC). In this project, the relevant SPC method is applied to machined component. The process is analyzed by using SPC method and its effectiveness is studied. For this purpose, the component 'Fuse body' is selected for SPC analysis and remedies are drawn to reduce the total manufacturing cost reducing scrap, rework and inspection costs by controlling the process. To keep the production of the fuse body components in control to its dimension an accurate and effective process control method is required. While analyzing the component we had made certain discussion that production is not reaching to expected rate and process is not capable to meet specification limit.

Index term: Statistical process control, Rework and Reuse analysis, process capability index, parts per million count.

I. INTRODUCTION

It has been the aim of engineers to strive at higher and higher accuracy, but absolute accuracy is unattainable. Every process and its output are subject to variation. No two things are exactly made alike. In mass-production therefore no attempts are made to attain absolute perfection but to control the degree of variability so that the parts lie within prescribed tolerances. Statistics acts as practical tool in this direction. Statistics refers to the collection, organisation, analysis, interpretation, and presentation of data. Statistical quality control involves analysis of characteristics of a production output by inference from sampling the output. The analysis in turn is used to make some corrections to ensure that no defectives are produced, and process remains in control. So statistical process control is a part of quality control in addition to that it uses some tools to form uniform products with low waste.

II. BACKGROUND

The modern quality control is defined as the combination of all the devices and techniques that are used to control product quality at the most economical cost which yield adequate customer satisfaction; whereas the statistical quality control is that part of means for establishing and achieving a quality specification, which requires use of tools of statistics. The aim of statistical methods of quality control is to provide a rapid and objective way of deciding when measurable quality variations should be investigated and when they should be dismissed as chance variations which probably would not be profitable to investigate. In this project, the relevant SPC method is applied to machined component at Jadhao Icon (Amravati). The process is analysed by using SPC method and its effectiveness is studied.

III. PURPOSE OF STUDY

Fuse body is the component to be selected for SPC analysis. There are several reasons why this project focuses on Statistical Process Control applications at the Jadhav Icon Company. The problems observed are a) Production is not reached up to expect rate b) Process is not capable to meet specification limit. To keep the production of the fuse body components in control to its dimension an accurate and effective process control method is required. A case study has been conducted at Jadhao Icon (Amravati). Then the processes of the case study analysed using statistical process control method. Lastly the ways to improve the manufacturing processes further were proposed base on the analysis outcome.

IV. METHODOLOGY

- Select Critical Parameters

Critical parameters are usually correlated to product fit and/ or functions.

- Collect Data

It is preferable to collect at least 60 data values for each critical parameter. If this is not possible, corrections can be made to adjust for the error that is introduced when less than 60 data values are collected.

- Establish Control over the process

The product is end result from the process. Calculation of predictable process capability indices is dependent on the statistical control of the process. If the process is not in statistical control, then the results of the study are subject to fluctuate unpredictably. The statistical control of the process can be studied using control charts.

- Analyze Process Data

To calculate the process capability indices, estimates of the process average and dispersion must be obtained from the process data. In addition, the formulas for process capability indices assume that the process data

- Analyze Sources of Variation

Analyzing sources of variation involves determining what process factors affect the natural process spread and the process centering.

- Establish Process Monitoring System

Once the process capability indices indicate a capable process, a routine process control technique should be employed to assure that the process remains stable. This may be done by a variety of methods such as establishing a statistical process program.

V. Development of Sample chart

- Using preselected sampling scheme and sample size record measurements of the selected quality characteristics on the appropriate forms.
- On each sample calculate mean and range using the same formula.
- Obtain and draw the center limit and trial control limits for each chart.
- Plot the values of the range on the control chart for range with the center limit and the control limits drawn. Determine whether the points are in statistical control. If not investigate the special causes associated with the out of control points and take appropriate remedial action to eliminate special causes.
- Delete the out of control points for which remedial actions have been taken to remove special causes and the use the remaining samples to determine the revised center line and control limits for the $\bar{x}$ and R chart.
- Implement the control chart.

VI. Analysis of patterns in control charts

Objective of using control charts is to determine when the process is out of control so that necessary actions to be taken. Criterion other than a plotted point falling outside the control limits are also used to determine whether the process is out of control.
Some rules for identifying an Out of Control process

1) A process is assumed to be out of control if a single point plots outside the control limits.
2) A process is assumed to be out of control if two out of three consecutive points fall outside the 2σ warning limits on the same side of the center line.
3) A process is assumed to be out of control if four or five consecutive points fall beyond the 1σ limit on the same side of the center line.
4) A process is out of control if nine or more consecutive points fall to one side of the center line.
5) A process is assumed to be out of control if there is a run of six or more consecutive points steadily increases or decreases

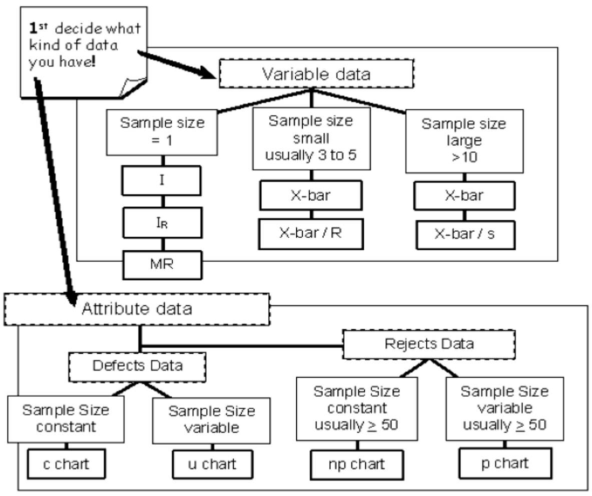


Figure 1: Data definition for proper chart selection

VII. Description of component

FUSE BODY is a machine component undergoes the 3 successive operations viz. external threading, internal threading, tapering on CNC machine. In the figure we can see the dimensions of the object. The component has dimension as shown in figure below. From these different dimensions we have selected internal diameter as critical dimension, having 30.00mm size. Tolerance limits 45.00 microns (+30microns -15 microns). Bilateral tolerance is given. Material used for component is Mild steel.

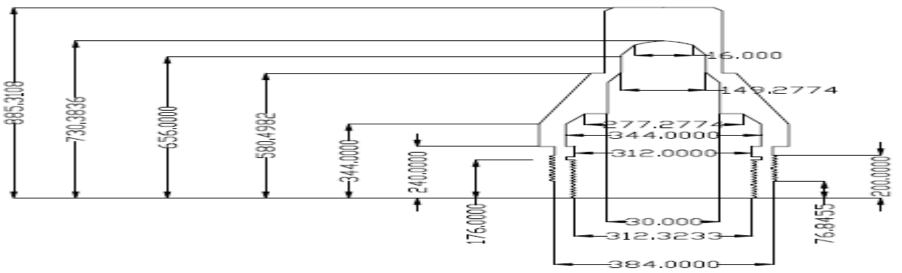


Figure 2: 2D drawing of a component

VIII. PROCEDURE OF PRELIMINARY DECISION

We have examined samples on all machines and one machine has been chosen. And samples chosen from the lot of that machine are homogeneous. Then we have selected the sample size as 5 because in industries normally sample size 5 is standardized. And according to central limit theorem sample size decides the accurate readings. The cycle time of the product is 6 minutes.

For measuring the critical dimension, we have selected the instrument as BORE DIAL GUAGE because it gives more precision and accuracy in measurement having least count 1 micron. As per the requirements needed for plotting the X bar and Rang Chart we have recorded the data in the way of time sample number and readings taken.

Sample chart with explanation

Here in X-bar chart, ordinate shows the average of sample measurements. And on abscissa sample numbers are plotted.

$$\bar{X} = \frac{\sum_{i=1}^{n} X_i}{n}$$

$$R = X_{max} - X_{min}$$

Obtain and draw the center limit and trial control limits for each chart-
For X-bar chart Center line is given by-

$$\bar{\bar{X}} = \frac{\sum_{i-1}^{N} \bar{X}_i}{N}$$

For R Chart Centre line is given by-

$$\bar{R} = \frac{\sum_{i=1}^{N} R_i}{N}$$

Control limits are given by-
For X-bar chart-

$$UCL = \bar{\bar{X}} + A_2\bar{R} = 33.5092$$

$$LCL = \bar{\bar{X}} - A_2\bar{R} = 9.2067$$

The X-bar chart shows all the data with a sample size of 5 lies within the given upper and lower control limits. Before eliminating the erroneous data, the UPPER SPECIFICATION LIMIT (UCL) is 33.51mm and LOWER SPECIFICATION LIMIT (LCL) is 9.21mm. And X-bar value is 21.4167.
For R chart-

$$UCL = \bar{R}D_4 = 44.7322$$

$$LCL = \bar{R}D_3 = 12.2093$$

In range chart, we have plotted range chart between range values (the difference between maximum and minimum values) and sample numbers. In this UPPER SPECIFICATION LIMIT IS 44.73 and LOWER SPECIFICATION LIMIT is 12.21mm

Plotting these values, we get following chart-

$$LCL_X = \bar{X} - 3\sigma = -6.2041$$

$$UCL_X = \bar{X} + 3\sigma = 49.04$$

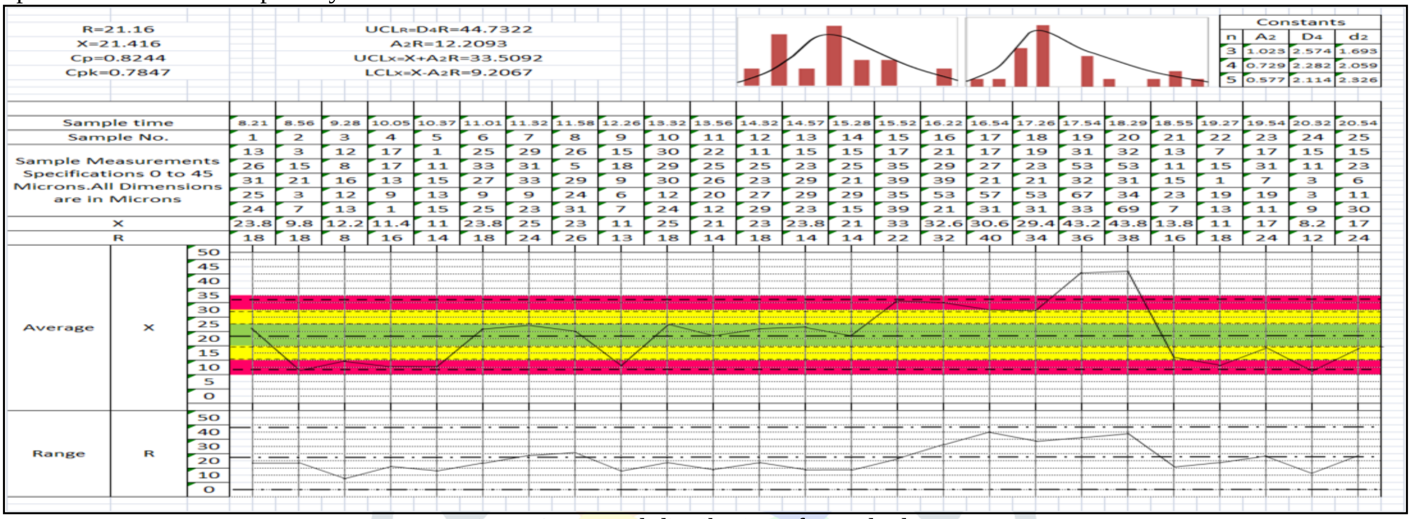
From the normal distribution curve, the maximum value, the mean value and the minimum value are 49.04, 21.416, and -6.2041 respectively. The value for standard deviation is 9.2067 mm and the skewness value is 2.47.and process capability values are Cp as 0.8244 and Cpk as 0.7847. Calculate the Z-score

Z-Score = 3Cp

The Z-Score is the Z percentage point from the standard normal distribution tables. In fact, Cp and Cpk assumes that the process data follows a normal distribution. Use the Z-Score to find out the Z-Score curve area value in the standard normal table. Since the Z-Score is the Z percentage point the area under the normal distribution curve can be looked up directly in the normal tables. Convert the Z-Score curve area to the process percent nonconforming and process yield.

Process Percent Nonconforming = (1.0- Z-Score Curve Area) (2) (100) = 6750*2 =13500

The process percent nonconforming is the long-term percent nonconforming that can be expected from the process if it can operate at the current capability.



Sample time	8.21	8.56	9.28	10.05	10.37	11.01	11.32	11.58	12.26	13.32	13.56	14.32
Sample No.	1	2	3	4	5	6	7	8	9	10	11	12
Sample Measurements Specifications 0 to 45 Microns.All Dimensions are in Microns	13	3	12	17	1	25	29	26	15	30	22	11
	26	15	8	17	11	33	31	5	18	29	25	25
	31	21	16	13	15	27	33	29	9	30	26	23
	25	3	12	9	13	9	9	24	6	12	20	27
	24	7	13	1	15	25	23	31	7	24	12	29
X	23.8	9.8	12.2	11.4	11	23.8	25	23	11	25	21	23
R	18	18	8	16	14	18	24	26	13	18	14	18

Sample time	14.57	15.28	15.52	16.22	16.54	17.26	17.54	18.29	18.55	19.27	19.54	20.32	20.54
Sample No.	13	14	15	16	17	18	19	20	21	22	23	24	25
Sample Measurements Specifications 0 to 45 Microns.All Dimensions are in Microns	15	15	17	21	17	19	31	32	13	7	17	15	15
	23	25	35	29	27	23	53	53	11	15	31	11	23
	29	21	39	39	21	21	32	31	15	1	7	3	6
	29	29	35	53	57	53	67	34	23	19	19	3	11
	23	15	39	21	31	31	33	69	7	13	11	9	30
X	23.8	21	33	32.6	30.6	29.4	43.2	43.8	13.8	11	17	8.2	17
R	14	14	22	32	40	34	36	38	16	18	24	12	24

Figure 3: Normal distribution of sample data

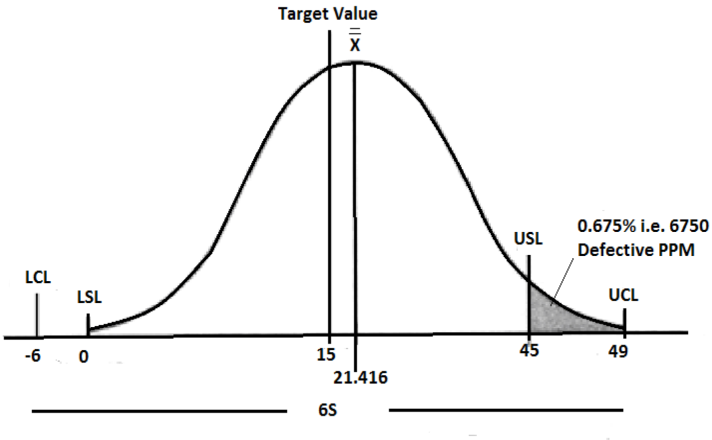


Figure 4: Normal Distribution Curve

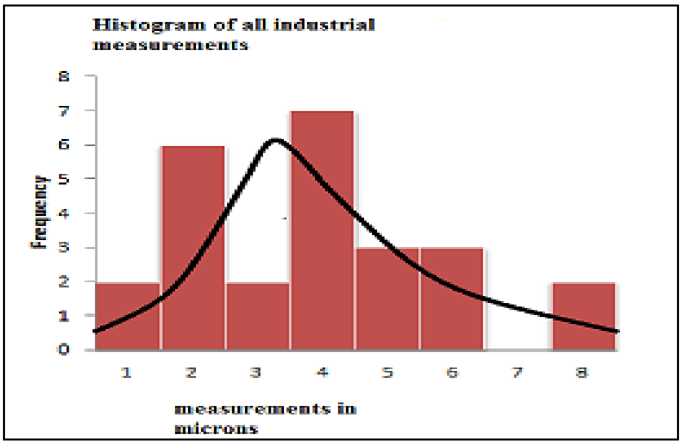


Figure 5: Histogram of all Individual Measurements

Conclusion drawn after studying the sample plan

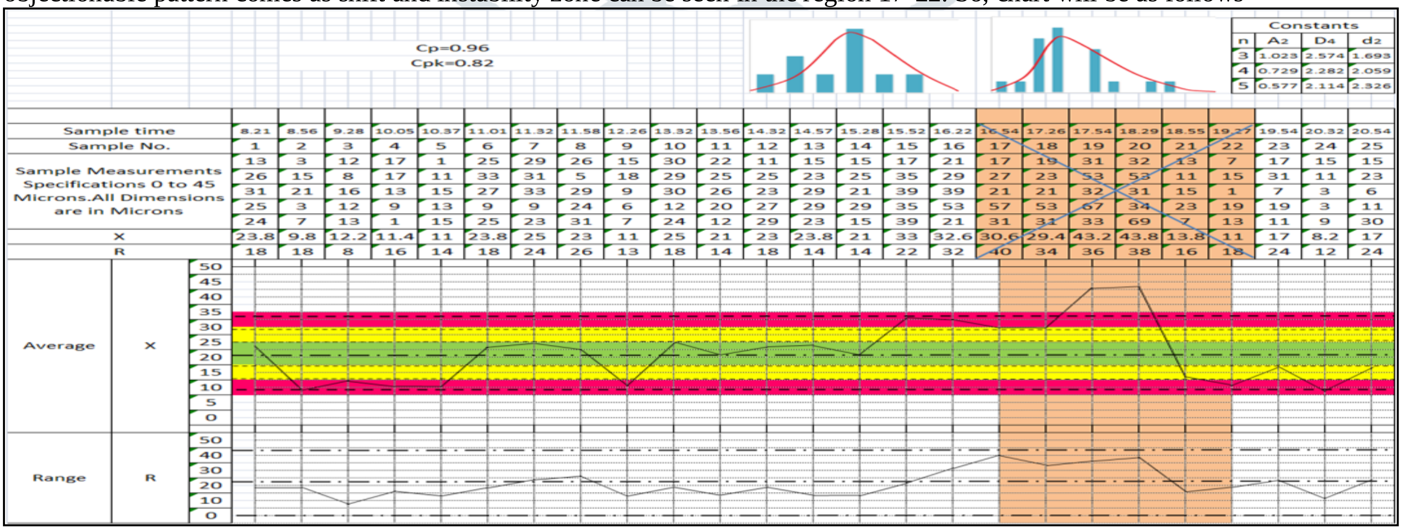
The case study conducted in Jadhao icon had showed that the importance of statistical process control for monitoring and ensuring the products produced are able to satisfy customer needs and requirements. All the studies used SPC as equality control and improvement tool in their products manufacturing process. In this study SPC technique was used to evaluate machines capability (Cp) and process centering (Cpk) of the process involved in manufacturing and fabricating products.

However, the results from the case study shows that the Fuse Body manufacturing process is out of control because the mean percentage of two subgroups samples for positioning error data lies outside the upper and lower control limits. To overcome this problem, we have suggested to company top management to carry out further investigation on the fuse body manufacturing process to find out the root causes and take necessary actions to solve and rectify the problem. Application of SPC in product manufacturing process is very important because it must provide engineers and company management on the quality status of the product manufactured, whether it meets customer specification or not.

- Tool insert changed or checked before indication of tool wear in graph due to lack of SPC application so idle time increases
- In sample No.10-16 all points are above central line expected to set the machine or check for tool wear
- 2 out of 3 points in a row in zone A (15,16,17) indicates early warning of process shift but no SPC technique is used so process go out of control
- Points in a row (15-25) in zone B, A or beyond on either side of central line without any point in zone c indicates instability pattern, so process goes out of control. This is because change of operators within a shift with some internal causes.
- 1-5 four samples fall in red zone, this is because absence of supervisor from 7:30 to 10:15am.

Sample plan after eliminating erroneous data

After eliminating erroneous data, the result comes in the form of following chart. In this chart we can observe that the objectionable pattern comes as shift and instability zone can be seen in the region 17-22. So, chart will be as follows-



Constants			
n	A_2	D_4	d_2
3	1.023	2.574	1.693
4	0.729	2.282	2.059
5	0.577	2.114	2.326

Sample time	8.21	8.56	9.28	10.05	10.37	11.01	11.32	11.58	12.26	13.32	13.56	14.32	14.57	15.28	15.52	16.22	16.54	17.26	17.54	18.29	18.55	19.27	19.54	20.32	20.54
Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Sample Measurements Specifications 0 to 45 Microns.All Dimensions are in Microns	13	3	12	17	1	25	29	26	15	30	22	11	15	15	17	21	17	19	31	32	13	7	17	15	15
	26	15	8	17	11	33	31	5	18	29	25	25	23	25	35	29	27	23	53	53	11	15	31	11	23
	31	21	16	13	15	27	33	29	9	30	26	23	29	21	39	39	21	21	32	31	15	1	7	3	6
	25	3	12	9	13	9	9	24	6	12	20	27	29	29	35	53	57	53	67	34	23	19	19	3	11
	24	7	13	1	15	25	23	31	7	24	12	29	23	15	39	21	31	31	33	69	7	13	11	9	30
X	23.8	9.8	12.2	11.4	11	23.8	25	23	11	25	21	23	23.8	21	33	32.6	30.6	29.4	43.2	43.8	13.8	11	17	8.2	17
R	18	18	8	16	14	18	24	26	13	18	14	18	14	14	22	32	40	34	36	38	16	18	24	12	24

Figure 6: Normal distribution after eliminating erroneous data

When normal distribution curve is plotted, the maximum minimum value comes as 42.6919, -4.4183 respectively. The standard deviation comes as 7.8517.

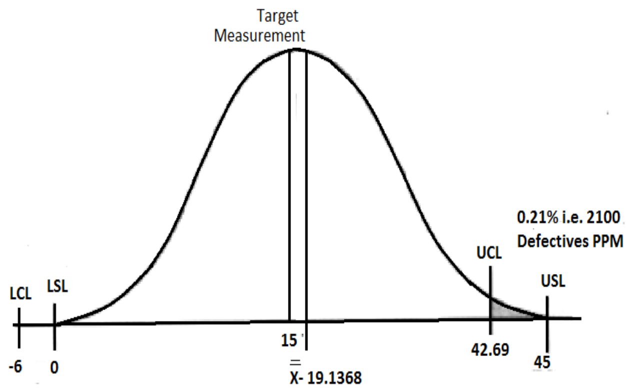


Figure 7: Specification limits on the normal curve after neglecting bad data

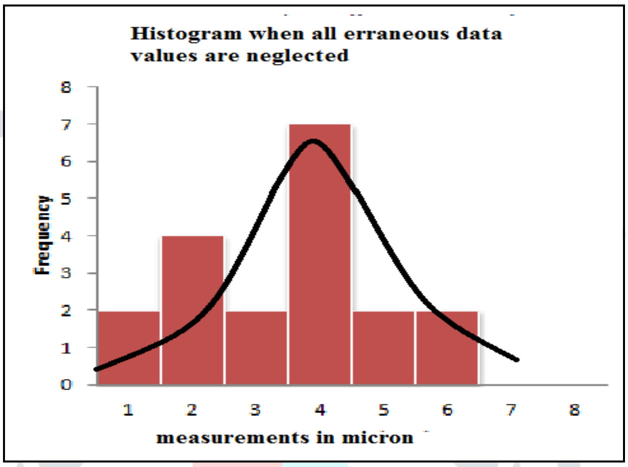


Figure 8: Histogram after neglecting erroneous data values

$$\sigma = \frac{\bar{R}}{d_2} = 7.8517$$

$$UCL_X = \bar{X} + 3\sigma = 42.6919$$

$$LCL_X = \bar{X} - 3\sigma = -4.4183$$

Table 1: Comparative of sample data

Eliminating erroneous data values	Cp	Cpk	Z	Defective PPM
Before	0.82	0.78	2.47	6750
After	0.96	0.82	2.86	2100

IX. Result and Conclusion

The machine capability value comes as 0.82 and after eliminating erroneous data it comes as 0.96. Then the process capability value changes from 0.78 to 0.82. Also, the Z-Score has changed from 2.47 to 2.86. Because of eliminating erroneous data defectives parts per million decreased from 6750 in first sample plan to 2100 after eliminating the erroneous data

Common Causes of getting failure data

(A) ENVIRONMENTAL CAUSES

- Temperature changes. (1 degree rise in temp causes a deflection of 1 micron in the measuring instrument BORE DIAL GUAGE).
- Humidity changes.

- Dust.

(B) MATERIALS CAUSES

- Changes in supplier.
- Changes in material.
- Inhomogeneous materials.
- Accumulation of waste.
- Mixing of batches, parts, etc.

(C) MACHINES

- Lack of maintenance.
- Badly designed equipment.
- Changes to equipment.
- Worn tools.
- Clogged tools.
- Gradual deterioration.
- Over-adjustment.
- Preventative maintenance.

(D) MEN

- Fatigue.
- Lack of training.
- Supervision.
- Attitudes.
- Shift rotation.
- Skill improvements.
- Awareness.
- Fudging.

(E) METHODS

- Poor production methods.
- New production methods.
- Changes in production.
- Undocumented production
- Constant re-adjustment of
- Machinery.

(F) MEASURES

- Unsuitable test methods.
- Different test methods.
- Different test devices.
- Changes in test methods.

(I) Assignable causes

- No inward inspection of semi finished work
- Drawing of rough finished work is not available by the vendors
- Operator is fully responsible for dimension control
- Statistical quality tools are not being used
- There is no need to set the machine or tool after completion of every job
- Maximum raw material with corrosion due to improper inventory storage

REFERENCES

[1] Muhammad M Hossain “development of statistical quality control Evolution or revolution” University of North Texas USA.
[2] Michael Stuart, Emanon, Mullins, Eileen drew, “statistical quality control and improvement” Department of statistics, Trinity College, Dublin 2, Ireland.Feb.1995.88 (1996) 203-201.
[3] M. Suozzi, “Process capability Studies” Member of Technical Staff, Hughes aircraft company, Tucson, Arizona, 27Nov.90
[4] A. Zaidi “SPC Concepts methodologies and tools” Prentice – Hall of India Pvt. Ltd. New Delhi 2003.
[5] Western electric company (1956) “statistical quality control Hand book” ATT Technologies, Commercial sales clerk, IN 46219 1-800-432-6600.
[6] R.G.D. and Jhtorrie “Principles and Procedures of Statistics” New York Mc-Graw Hill 1980.
[7] M. Mahajan, “Statistical Quality Control” Dhanpat ray Publication, 2003.
[8] Nelson, Loyd S. “Interpreting Shewart X control charts” Jornal of quality Technology, 17; 114-16.