Failure Analysis of Machined Component Using Statistical Control Tools

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Abstract

Statistical process control is generally accepted and essential tool to improve the quality of manufacturing processes. It not only provides customers consistency, high quality products/services, but also a driver for efficiency and effectiveness of all aspects of the organization. Indian industries need a study to explore the practices of SPC tools so that appropriate strategies may be formulated. This paper presentation is an attempt to explore the practice of statistical process control tools. For the case study break liner were selected as machined component. A liner consists asbestos material and cover press, grinding, drilling, chamfering and notching etc. operations. The thickness of the liner here consider as critical dimension as it need tight tolerance to ensure the liner for fitting on shoe and drum. Grinding operation were used for making thickness. To ensure the process is under control and reduce variations SPC methods are being used. To coverage the study on SPC application on liner manufacturing process, a visit to Hindustan Composite Ltd. Co. MIDC-Paithan Dist; Aurangabad has been made. This study explored the motives of implementing SPC tools, extent of applicability of SPC tools and the difficulties encountered during implementation of these tools. In Liner manufacturing process thickness is critical dimension and significant differences in dimension and deviation from the part tolerances will make the liner product rejected or rework. Statistical process control will monitor the processes and magnifies the small deviations of the process from the actual control limits and find out root causes of variations for better improvement and reduce rework, rejection and customer's satisfaction.

Keywords: *Statistical process control (SPC), quality tools, dissertation brake liner.*

1 Introduction

Statistical process control (SPC) involves using techniques to measure and analyze the variation in processes. Most often used for manufacturing processes, the intent of SPC is to monitor product quality and maintain processes to fix targets. Statistical quality control refer to using statistical techniques for measuring and improving the quality of the processes and includes SPC in addition to other techniques, such as sampling plans, experimental design, variation reduction, process capability analysis and process improvement plans.

The consistent, aggressive and committed use of SPC to bring all processes under control, recognize and eliminate special cause of variation and reduce rework, rejection and wastage in production. SPC is defined as prevention of defects by applying statistical methods to control the process.

In this paper the relevant SPC method applied to brake liner component manufactured at Hindustan Composite Ltd. Paithain, Aurangabad, Maharashtra, India. Here I select thickness as a critical dimension to which grinding operation used. The process analyzed using SPC methods and its effectiveness is studied.

1.1Statistical Process Control

Statistical process control (SPC) is the use of Statistical methods in the monitoring and control of a process by repeatedly sampling measurements, or counts to predict the results. Once a process has become stable and responds as predicted, then it is said to be in state of "statistical control". While SPC has been applied most frequently to controlling manufacturing lines, it applies equally well to any processes which has measurable factors. Key tools in SPC are control charts, a focus on continuous improvement and designed experiments.

Much of the power of SPC lies in the ability to examine a process, for the sources of variation in that process, by using tools which give weight to objective analysis over subjective opinions and which allow the strength of each source to be determined numerically. Variation in the process, which might affect the quality of the end product or service can be detected and corrected, thus reducing rework, rejection and waste as well as the like hood that problems will be passed on to the customer. Proper SPC starts with planning and data collection.

1.2 Control charts details

A control char consists of:

Points representing a statistic (e.g., a mean, range, proportion) of measurements of a quality characteristic in sample taken from the process at different times [the data]

- The mean of this statistic using all the samples is calculated (e.g. a mean of the mean of the proportions)
- A center line is drawn at the value of the mean of the statistic.
- The standard error (e.g. standard deviation/sqrt(n) for the mean) of the statistic is also calculated using all the samples.
- Upper and lower control limits that indicate the threshold at which the process output is considered statistically 'unlikely' are drawn typically at 3 standard errors from the center line.
- The charts may have other features, including: Upper and lower limits, drawn as separate lines, typically two standard error above and below the center line.

Chat usage

If the process is in control, all points will plot within the control limits. Any observations outside the limits, or systematic patterns within, suggest the introduction of a new (and likely unanticipated) source of variation, known as a special-cause variation. Since increased variation means increased quality costs, a control chart "signaling" the presence of a special-cause requires immediate investigation.

1.3 Objectives

The goal of the production is to produce output of consistent quality that meets technical specifications. When quality is consistent, both the producer and the consumer benefit. Producer benefit by having less need for inspection, less scrap and rework and higher productivity. The consumers are assured that all products have similar quality characteristics

The objective of this paper determined. There are two objectives have been defined to be focused on and to simplify the dissertation as stated below:

1- To perform a quality control technique for a selected manufacturing process of selected machined component as here used are brake liner using statistical process control method.
2- To propose method to improve the selected manufacturing process based on the case study.

1.4 Scope of the study

The objective of this paper is narrowed down by performing scopes of study. Firstly a comprehensive literature review has been conducted to determine the best quality statistical method. Second a case study has been conducted at Hindustan Composite Ltd. Company on thickness of brake liner production. Then processes of case study analyzed using SPC methods. Lastly the methods to improve the manufacturing processes further were proposed base on the analysis outcome.

2 Literature review

2.1 History Of SPC

Statistical process control was pioneered by Walter A. Shewhart in the early 1920s. W. Edwards Deming later applied SPC methods in the U.S. during World War II, thereby successfully improving quality in the manufacture of munitions and other strategically important products. Deming was also instrumental in introducing SPC methods to Japanese industry, after the war had ended. [1][2].

Dr. Shewhart concluded that while every process displays variation, some processes display controlled variation that is natural to the process (common causes of variation), while others display uncontrolled variation that is not present in the process causal system at all times (special causes of variation).[3]

2.2 SPC Background

Statistical Process Control (SPC) is a control mechanism whereby measurement of product quality are actively obtained and charted simultaneously as industrial products are produced. Control is obtained when a statistical measurement such as mean of a group of products are within certain control limits drawn on the statistical process charts. For these charts, there are certain set of rules to follow that will tell the technicians when the process may be out of control. When these conditions are observed, the technicians are expected to stop manufacturing process so that corrective actions can be taken.(Douglas .C.Montgomery, 2003)

2.3 Concluding Remark

Usage of quality research and estimation methods in piston-cylinder assembly permits to avoid occurrences of productive defects already in production stage, which helps in elimination of their source formation. Employment of suitable methods of estimation and forecasting enables us to foresee whether, and when quality feature is not situated in founded admissible area. Such activities permit to properly react in early stages of production, setting of devices. Most often used for manufacturing processes, the intent of SPC is to monitor product quality and maintain processes to a fixed target. Statistical quality control refers to usage of statistical techniques for measurement and improvement the quality of processes and include SPC in addition to other techniques, such as sampling plans, experimental design, variation reduction, process capability analysis and process improvement plans. The present idea of quality concentrates first of all on change of quality approach strategy. At present special pressure attention is paid to "prevention strategy" which replaces "detecting strategy". SPC is used to monitor the consistency of processes used to manufacture a designed product. Its aim is to get and keep process under control. Summing up, it was found that the aim of usage of control charts type X-R in above process is measurement and minimization of variations occurrence in process, and essential aspects is delimitation of coefficients of process correctness what in effect leads to improvement. Control charts and quality index of capability, in showed example, determine quality tools, enabling to decide about usage of suitable activities in case when we have some problems with our process. It means that alarming signals originating form process. Such statistical activities allow to prevention of defects instead their of defecting.

3. Experimental Setup

3.1 Problem identification and Company profile

Company Profile :

Hindustan Composite Ltd, established in 1859, is one of India's leading and well-diversified engineering companies. It manufactures a wide range of Brake Liners of two, four wheelers and railways to meet the requirement of core sectors in India and abroad. Component selected for the case study are brake liner, and thickness are critical dimension selected as it plays major role in fitting in drum of the wheels as company facing problems of rejection and rework.

Component selection: Brake liner- HC/TTS/2

Process: Grinding

Checking parameter: Thickness

Thickness dimension: 17.10mm

Tolerance: ±0.20

3.2 Methodology used for Failure analysis of component

1. Identify the critical dimension.

The critical dimension for brake liner here selected is thickness of liner. The Grinding operation used for thickness making.

2. Observe or study the obvious causes of variations.

This should be observe from the past data i.e. from previous records of variations of selected component in company. Than observe actual variations by on line inspection of the process and find the causes of variations.

3. Sample plan Preparation

Generally collect 20-25 groups of simples in one shift. Total no of sample in at list five shifts i.e. 100 should be collected before calculating the statistics and control limits. Consider historical data to established a performance baseline. In each shift samples of lot size n=5 are collected hourly basis.

4. Major Work Steps.

A) Data collection.

1) Set the process characteristics at the average of control limits for set up parameters.
2) Take the readings per the frequency of the characteristics by using measuring instrument. The continuous five liners reading to be taken.
3) Calculate the average of the reading by

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

4) Calculate the range by subtracting the
Range R= max ($X_1 \ldots X_n$) - min($X_1 \ldots X_n$)

B) Selecting control charts. Then analysis.

For n=5 Control charts here selected are X-bar and R-chart for variable data.
Plotting of data on control chart,
1) Mark the line of control limit in blue colour and line of upper and lower control with the red colour by taking the sufficient scale on control charts.
--For X-bar (Average) charts:-

$$\textit{Upper control limit} \quad UCL = \overline{\overline{X}} + A_2 \overline{R}$$

$$\textit{Lower control limit} \quad LCL = \overline{\overline{X}} - A_2 \overline{R}$$

$$Centerline(CL)\overline{\overline{X}} = \frac{\overline{X}_1 + \overline{X}_2 + \ldots + \overline{X}_N}{N}$$

-- For Range R-chart:-

$$CL = \overline{R}$$

$$UCL = D_4 \overline{R}$$

$$LCL = D_3 \overline{R}$$

$\overline{\overline{X}}$ – the average of the sample means
$\overline{X}$ - Average X
n –sample size (number of observation sper sample)
N – number of samples
A_2- factor for X-bar chart
D_3/D_4 – factors for R-chart

2) The value usually plotted on the vertical scale and horizontal scale is the sequence in time. The data values and the plot points for the control statistics should be aligned vertically.
3) Log observations (Events)—this section details such as tool change, operator change or other events which may affect the variability of process.

C) Interpret statistical control

The average will be used for the location control statistic and Range for variation control statistic. The process said to be statistically controlled unless both charts have no out-of-control condition indicating special causes of variation.
1) *Analyze the Data points on the Range chart*.
The range chart will be analyzed then the average chart to be analyzed. the data points are compared with the control limits for points out of control or for unusual pattern or trends. Analyze the process if any appearance of any point beyond control limit.
2) *Analyze the Data points on the Average charts.*
For each indication of the out-of-control condition in the average data determine reason for special cause, correct that condition and prevent it from recurring.
and apply the needed changes to reduce this with the help of statistical control tools

4. Results and Discussion-

4.1 X-bar and R- chart calculations

As per the case study requirement observations of thickness of liner are taken and calculation done as shown in table 1.0 for plotting X-bar and R-chart to find out the root causes in the process to reduce variations in the process.

Table 1.0: Calculation to plot X-bar and R-chart

Sr. No.	Observations n=5					Average X-bar	Range R
	X_1	X_2	X_3	X_4	X_5		
1	17.15	17.23	17.14	17.11	17.02	17.13	0.22
2	17.15	17.24	17.12	17.00	17.06	17.11	0.24
3	17.16	16.99	17.16	17.05	17.14	17.10	0.18
4	17.15	17.02	17.20	17.06	17.04	17.09	0.18
5	16.94	17.05	17.06	16.92	16.97	16.99	0.14
6	16.96	17.11	16.90	17.08	17.02	17.01	0.22
7	17.00	17.19	17.02	17.16	17.12	17.10	0.20
8	17.10	16.92	16.97	17.06	16.94	17.00	0.19
9	16.90	16.98	16.98	16.91	17.05	16.96	0.16
10	16.96	17.11	17.15	16.98	16.99	17.04	0.18
11	17.26	17.29	17.14	17.30	17.03	17.20	0.27
12	17.29	17.13	17.23	17.24	17.22	17.22	0.16
13	17.30	16.94	17.28	17.22	17.21	17.19	0.36
14	17.21	17.27	17.30	17.28	17.04	17.22	0.26
15	16.99	17.08	17.18	17.27	16.99	17.10	0.28
16	17.28	17.02	16.98	17.27	17.26	17.20	0.30
17	17.25	16.94	16.90	16.99	17.17	17.10	0.35
18	17.28	17.17	17.20	17.22	17.30	17.20	0.13
19	16.98	16.95	17.24	16.99	17.24	17.10	0.29
20	17.24	17.10	17.05	17.22	17.24	17.20	0.20
Total						**325.16**	**4.51**

Control Limits for Averages:

CL = 17.108, LCL = 16.978, UCL = 17.237

Control Limits for Ranges:

CL = 0.224, LCL = 0.000, UCL = 0.474

Table 1.1: Factors foe 3-sigma control limits

Sample	A_2 (for X-bar)	D_3 (for R-chart)	D_4 (for R-chart)
1	2.560	0	3.270
2	1.880	0	3.270
3	1.020	0	2.570
4	0.730	0	2.280
5	0.580	0	2.110

4.2 X-bar and R-Chart Plots

Graph shown below in X-bar chart shows variations in the process that process are out of control as it crosses upper and lower control limits .

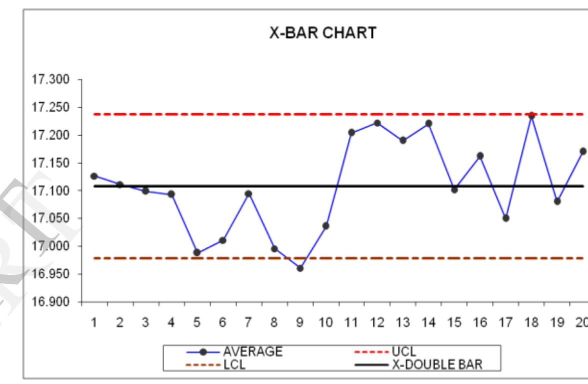

Figure 1.1: X-bar chart for thickness of liner.

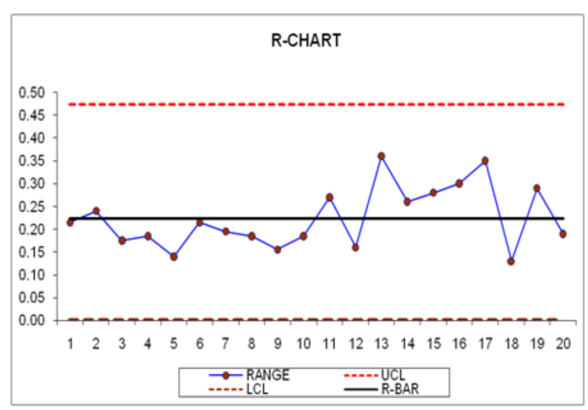

Figure 1.2: R- chart for thickness of liner.

4.3 Causes of Variations

To find the significant and non significant cause of variations the methods used are

1) 4M methods are used which is as shown in fig; 1.3 in Ishowvaka or fishbone diagram.
2) Why why analysis.

The root causes of the variations are find out by above methods and as shown in Fig.1.3 in fishbone diagram.

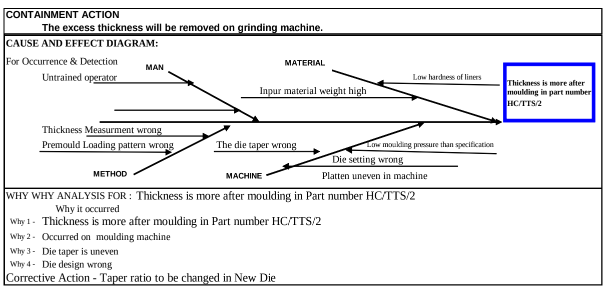

Figure 1.3. Fishbone diagram for root cause analysis

--Significant/Non (S/NS) significant analysis
Defect – Thickness is more after moulding in part number HC/TTS/@ of HC/TTS/2

Table 1.3 Causes of Defects find out in observations

Cause	Cause verification (observations) & requirement	S/NS	Current control	Corrective Action
Operator untrained	Trained person are deploying	NS	----	----
Measurement wrong	Thickness measuring with Mic.	NS	----	----
Premould loading pattern wrong	Thick & thin end are loading	NS	----	----
Low hardness of liners	Hardness is within specification	NS	----	----
Input material weight high	Weights are taking as per specification	NS	----	----
The die taper wrong	**Die taper not as per requirement**	**S**	1 mm excess thickness than final thickness	**The correct taper ratio maintained in new die design**
Die setting wrong	Setting are as per requirement	NS	----	----

4.4 Conformation Experiment

From the above study on thickness of brake liners the root cause of variations in thickness has been detected that the die taper in the press mould were not as per the specification due to which thickness was excess.

After giving instruction to make necessary changes and maintained correct taper ratio in die we took final observations and found that process are within control.

5 Conclusion and Future Scope

As the brake liner unit faces several problems like increase in the rate of rework as the required thickness of liner is crosses variation limits i.e. tolerance. So they allow to study and gives suggestion regarding study and prepare report of failure analysis of components by implementation of SPC tools so as to control these variations and reduce the rework and rejection rate and also control and monitor the process.

This study aims to reduce rejection and rework with the help of implementation of SPC tools in the industry. The data is obtain from Hindustan Composite manufacturing company on thickness parameter and identifies motives for implementation of SPC tools and difficulties encountering during implementation of SPC tools. The SPC tools are beneficial for overall improvement of industry. Industries are also making efforts to match with competitors by using these quality tools. The most important benefit of implementing SPC is reduction in rejection rate or defectives and rework.

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