Quality improvement in manufacturing processes using SQC tools

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ABSTRACT

The aim of this paper is to apply the quality tools to find out the root causes of the quality problems related to manufacturing of mechanical seal. The modes of defects on production line are investigated through direct observation on the production line and statistical tools like Check sheets, Histogram, Pareto analysis, Cause and Effect diagram etc are used in enhancing the process by continuous monitoring through inspection of the samples. The work shows utility of quality tools to find the root causes of the problems and eliminate them. A case study has been carried out in 'EKK Eagle Products India Pvt. Ltd' company that specializes in manufacturing of mechanical seal.

Keywords- *Control Charts, Cause and effect diagram, Histogram, Pareto Analysis, Mechanical Seal, Statistical Quality control.*

1. INTRODUCTION

Quality concepts have changed over time. Quality of product means the product must be within the acceptable limits. Edwards Deming, explained chain reaction in his book "out of the crisis" published in 1986. The benefits from quality and process improvements to organization are:

a. Improved Quality
b. Less rework, fewer mistakes and hence cost decreased
c. Capture the market with better quality and lower price
d. Improved Business
e. Improved productivity [1]

The most common process of continuous improvement is the PDCA Cycle shown in "Fig.1" which was first developed by Walter Shewhart in the 1920s and promoted by quality preceptors Dr Edwards Deming. *PDCA*-cycle consists of four consecutive steps, as follows:

• Plan – Perception for improvement
• Do – Implementation of the changes that is decided in the Plan.
• Check – a) Control and measurement of processes and products in accordance with changes in previous steps
b) Policy, goals and requirements
c) Report on results
d) Decision making
• Act – a) Adoption of the changes or run through *PDCA*-cycle again
b) Repetition of cycle for continuous improvement.

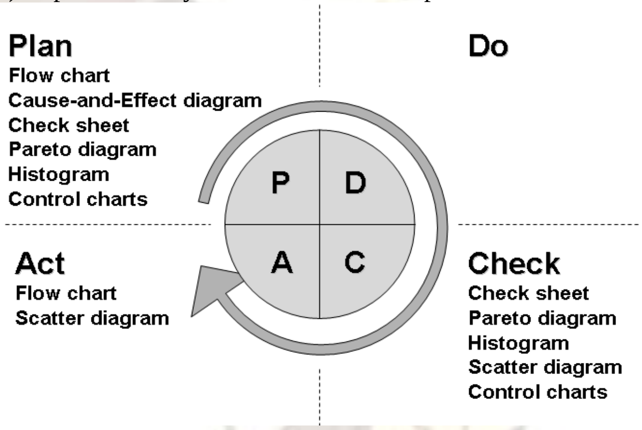


Figure 1. PDCA cycle

PDCA-cycle is required in process improvement. When the process improvement starts with careful planning results in corrective and preventive actions supported by appropriate quality assurance tools. Application of seven basic quality tools in correlation with four steps of PDCA-cycle is shown in Table 1. [2]

As shown in Table 1, for problem identification Flow chart, Cause-and-Effect diagram, Check sheet, Pareto diagram, Histogram and Control charts can be used. For problem analysis Cause-and-Effect diagram, Check sheet, Pareto diagram, Scatter plot and Control charts tools can be used. When the team is developing a solution for analyzed problem Flow chart and Scatter plot can be useful. For evaluation of results, Check sheet, Pareto diagram, Histogram, Scatter plot and Control charts can be used.

Table 1. Seven basic quality tools (7QC tools) in correlation with PDCA-cycle steps

Seven basic quality tools (7QC tools)	Steps of PDCA-cycle			
	Plan	Plan, Check	Plan, Act	Check
	Problem identification	Process analysis	Solutions development	Result evaluation
Flow chart	√		√	
Cause-and-effect diagram	√	√		
Check sheet	√	√		√
Pareto diagram	√	√		√
Histogram	√			√
Scatter plot		√	√	√
Control charts	√	√		√

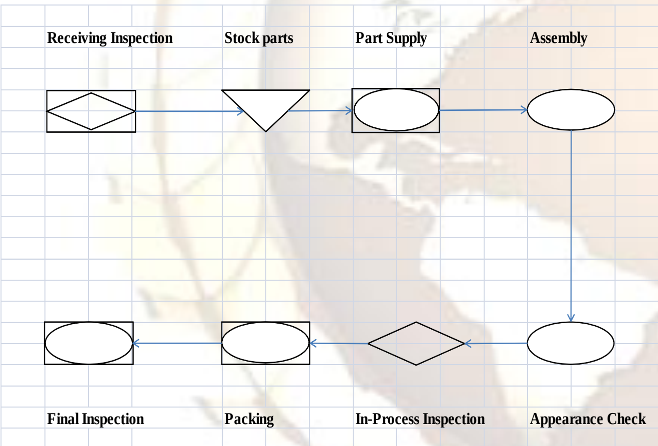


Figure 2. Process flow chart

A case study has been carried out at EKK Eagle Products India Pvt. Ltd to monitor the process of manufacturing mechanical seals. Process flow chart at EKK Eagle Products India Pvt. Ltd producing mechanical seals is as shown in “Fig 2.” The data was collected for improving the quality of mechanical seals and reducing the defects

2. THE SQC TOOLS

Quality tools can be used in all phases of production process, from the start of product development up to product marketing and customer support. The 7 QC Tools are simple statistical tools used for problem solving. These tools were developed by the Quality preceptors such as Deming and Juran. Ishikawa has stated that these 7 tools can be used to solve 95 percent of all problems. The following are the 7 QC Tools:

1) Histogram
2) Check Sheet
3) Pareto Diagram
4) Brainstorming
5) Cause & Effect Diagram
6) Control Charts
7) Scatter Diagram

2.1. Histogram

A histogram is one of the basic quality tools. It is used to graphically summarize and display the distribution and variation of a process data set. A frequency distribution shows how often each different value in a set of data occurs. The main purpose of a histogram is to determine the shape of data set. We can present the same information in a table; but the graphic presentation shows relationship. Based on the frequency of distributed values, one can come to a conclusion whether the values falls within the specified values and gives a normal distribution curve out of it. [3] This can be achieved by Histogram. It is a useful tool for breaking out process data into regions for determining frequencies of certain events or categories of data.

Typical applications of histograms in root cause analysis include:

1) Presenting data to determine which causes dominate
2) Understanding the distribution of occurrences of different problems, causes, consequences, etc.

Table 2 Shows Seal Ring height data of mechanical seal. It shows the cell boundaries of Seal Ring height and frequency of them. “Fig.3” shows histogram for Seal Ring height data of mechanical seal

Table 2. Cell boundaries of Seal Ring height data

Class	**Cell Boundaries (mm)**		**Frequency**
1	1.00	1.05	0
2	1.05	1.10	0
3	1.10	1.15	0
4	1.15	1.20	0
5	1.20	1.25	5
6	1.25	1.30	26
7	1.30	1.35	18
8	1.35	1.40	1

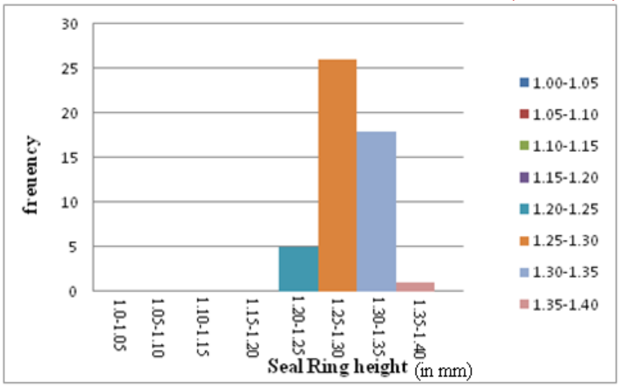


Figure 3. Histogram of seal ring height data.

2.2. Check Sheet.

Data collection is important because it is the starting point for statistical analysis. The function of a check sheet is to present information in an efficient, graphical format. Check sheets help to organize data by category. They show frequency of each particular value and their information. Check sheets are tools that make the data collection process easier. Their power is greatly enhanced when they are used in conjunction with other quality tools such as histograms and Pareto analysis. The check sheet shown in Table 3 was created by tallying each type of mode of defect of mechanical seal during a specified time. It shows the type of defects and how many of each type occurred during that period.

2.3. Pareto analysis

It can be described as the 80/20 rule applied to quality-control. The 80/20 rule was formalized by economist Pareto after studying the distribution of wealth. He observed that about 80% of wealth was held by about 20% of the population. Joseph Juran applied this principle to quality-control. Pareto Analysis states that 80% of quality problems in the end product or service are caused by 20% of the problems in the production or service processes. In practice it is beneficial to separate "the vital few" problems from "the trivial many".

2.3.1 Pareto Chart

A Pareto Chart is simply a frequency distribution (or Histogram) of attribute data. The Pareto Chart is named after Italian economist Pareto; A Pareto Chart is a series of bars whose heights reflect the frequency or impact of problems. The bars are arranged in descending order of height from left to right. This means the categories represented by the tall bars on the left are relatively more significant than those on the right. This bar chart is used to separate the "vital few" from the "trivial many". These charts are based on the Pareto analysis which are useful for the user to focus attention on a few important factors in a process.

Pareto chart shown in "Fig.4" was constructed based upon the data collected by check sheet shown in Table 3 for various modes of defects with their respective frequency and percentage of mechanical seal. The figure reveals that the mechanical seal has vital few modes of defects and represents around 80 % of total cumulative percentage of non-conformities.

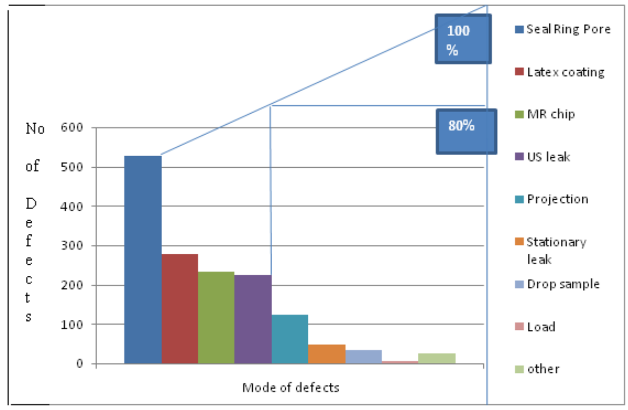


Figure 4. Pareto chart for mode of defects

Table 3. Check sheet for various modes of defects with their respective frequency and percentage

Sr. no.	Mode of defect	Production volume (No.s)	No. of defective components (No.s)	% of defect	Cumulative qty (No.s)	Cumulative %
1	Seal Ring pore		528	35.22	528	35.22
2	latex coating		277	18.48	805	53.70
3	MR chipping		232	15.48	1037	69.18
4	US leak	93823	225	15.01	1262	84.19
5	Projection		122	8.14	1384	92.32
6	stationary leak		48	3.20	1432	95.53
7	Drop sample		35	2.33	1467	97.86
8	load		7	0.47	1474	98.33
9	other		25	1.67	1499	100.00
Total		93823	1499	100.00	1499	100.00

2.4 Brainstorming

Brainstorming is a tool used by teams to bring out the ideas of each individual and present them in an orderly fashion to the rest of the team. The key ingredient is to provide an environment free of criticism for creative and unrestricted exploration of options or solutions.

Some of the specific benefits of Brainstorming are that it

1. Encourages creativity. It expands thinking to include all aspects of a problem or a solution with wide range of options.
2. Rapidly produces a large number of ideas by encouraging people to offer creative and justified ideas.
3. Equalizes involvement by all team members. It provides a nonjudgmental environment that encourages everyone to offer ideas. All ideas are recorded.

The recommended sequence for conducting Brainstorming and some suggestions for conducting the session effectively are provided below:

- Review the rules: describe how the session will be conducted.
- Set a time limit: assign a timekeeper and data recorder.
- State the topic: Write down and publicize it. Ensure that everyone understands it.
- Collect everyone's ideas: After allowing a few minutes for the participants to think about the question, ask them to give their ideas.
- Record ideas: Display the ideas where everyone can see them. Having the words visible to everyone at the same time avoids misinterpretation and duplication.
- Clarify each idea: After all ideas have been presented, to ensure that all members have the same understanding of it.
- Eliminate duplications: Repeated ideas are to be eliminated.

2.5 Cause & Effect Diagram

Process improvement involves taking action on the causes of variation. A team typically uses Cause-and-Effect (C&E) diagrams to identify and isolate causes of a problem. The late Dr. Kauro Ishikawa, Japanese quality expert, developed the technique and hence it is called as Ishikawa diagram. [4] The Diagram is a tool to show systematic relationship between a result or a symptom or an effect and its possible causes. It is an effective tool to systematically generate ideas about causes for problems and to present them in a structured form.

2.5.1 Structure

The symptom or result or effect for which one wants to find causes is put in the dark box on the right. The lighter boxes at the end of the large bones are main groups in which the ideas are classified. Usually four to six such groups are identified.

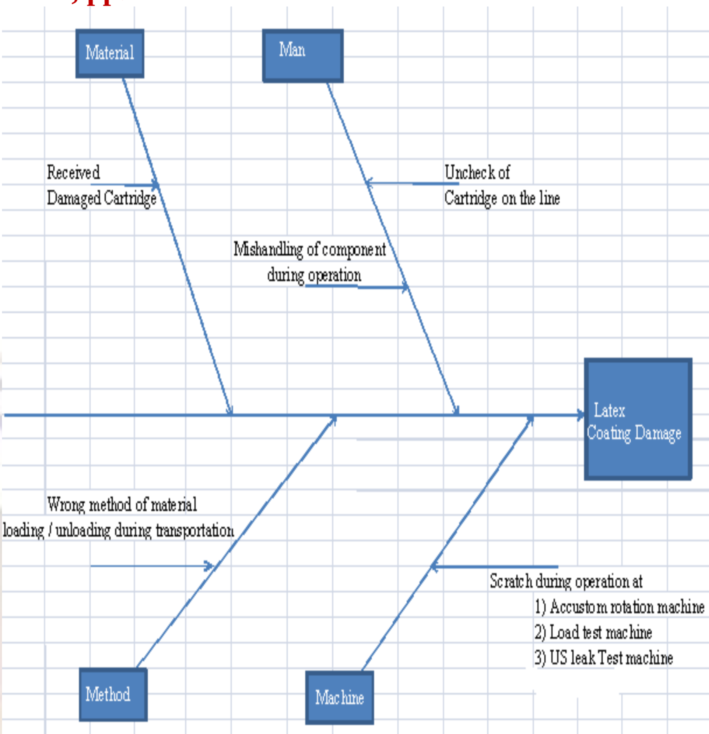


Figure 5. Cause & effect diagram

In a typical manufacturing problem, the groups may consist of five Ms - Men, Machines, Materials, Method and Measurement. The six M Money may be added if it is relevant. In some cases Environment is one of the main groups. Important subgroups in each of these main groups are represented on the middle bones and these branch off further into subsidiary causes represented as small bones. The arrows indicate the direction of the path from the cause to the effect. [5]

Brainstorming technique is therefore very useful in identifying maximum number of causes. The cause & effect diagrams shown in "Fig.5" were constructed by quality team and through brainstorming sessions involving all employees taking part in the related production and test activities

Cause and effect diagram shown in Figure 5 shows major factors that can cause latex coating damage of cartridge of mechanical seal. The diagram was constructed by quality improvement team through brainstorming sessions involving all operators taking part in the related production and test activities.

2.6 Control Chart

Control charts are the one of the most important and effective statistical tools for determining the process stability and variability. [4] These charts contain the upper control limit and lower control limit .Control charts are statistical tools used to analyze and understand process variables, to determine a process's capability to perform with respect to those variables and to monitor the effect of those variables on the difference between customer needs and process performance.

Every process has variation that can be classified as the result of either common causes or special causes. Common causes of variation are inherent in a process while variation created by special causes is not normally present in the process. Control charts are used to identify and distinguish between those two different causes of variation. One goal of using a Control Chart is to achieve and maintain process stability.

We get benefit from using a Control Chart when we

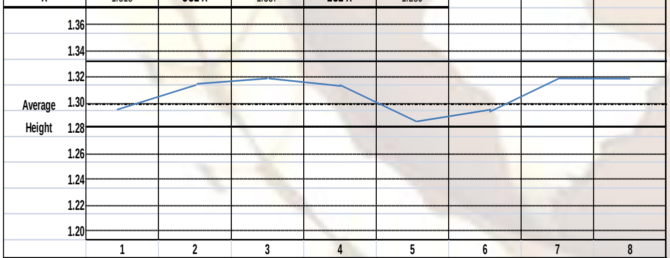
1. Monitor process variation over time.
2. Distinguish between special cause and common cause variation.
3. Assess the effectiveness of changes to improve a process.
4. Communicate how a process performed during a specific period.

"Fig.6" shows $\bar{X}$ and R chart for Seal ring height of mechanical seal. The figure illustrates natural process limits controlled within specification limits (1.00 to 1.40 mm)

Machine Name	Finish Grinding M/c	$\bar{X}$ & R Control Chart
Operation	Seal Ring Grinding	
Characteristic	Seal Ring Height	
Specification/ Tolerance	1.2 ± 0.2	

Hour / Sample	1	2	3	4	5	6	7	8
X1	1.31	1.32	1.32	1.31	1.32	1.28	1.34	1.35
X2	1.32	1.35	1.34	1.33	1.27	1.30	1.32	1.32
X3	1.30	1.32	1.35	1.32	1.3	1.32	1.34	1.34
X4	1.29	1.31	1.34	1.32	1.28	1.29	1.31	1.30
X5	1.31	1.34	1.33	1.32	1.28	1.3	1.34	1.36
$\bar{X}$	1.306	1.328	1.336	1.320	1.290	1.298	1.330	1.334
R	0.03	0.04	0.03	0.02	0.05	0.04	0.03	0.05

$\bar{\bar{X}}$	1.318	UCL $\bar{X}$	1.337	LCL $\bar{X}$	1.289



$\bar{R}$	0.036	UCL (R)	0.0766	LCL (R)	0

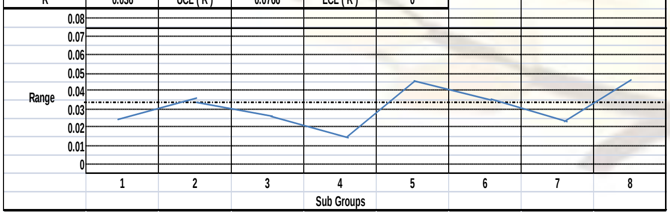


Figure 6. Control Chart

2.7 Scatter Diagram

It is also called as scatter plot or X–Y graph. A scatter diagram is a tool for analyzing relationships between two variables. One variable is plotted on the horizontal axis and called independent variable; the other is plotted on the vertical axis and called as dependent variable. The pattern of their intersecting points can graphically show relationship patterns. Scatter diagrams are used to evaluate cause and effect relationships. The assumption is that the independent variable is causing a change in the dependent variable.

3. RESULTS AND DISCUSSION

Before implementation of SPC tools, production process at EKK Eagle products India Pvt. Ltd. was not in normal condition. After the techniques were built into the process, the management and operators had understood the cost wastage due to rejection of work piece.

As seen from these studies, statistical process control and statistical quality control were effective in improving a process, irrespective of its application, and are key success factors to stay in business and the achievement of customer satisfaction and business excellence.

1. A histogram is a picture of the data distribution that includes its spread and shape. This can provide clues about the variation that exists in the work performed. Histogram for Seal Ring height is normal and bell shaped. It shows Cp is greater than 1.
2. Check sheets help to organize rejection data by category.
3. Pareto analysis states that 80% of rejection is due to a) Seal Ring pore
   b) Latex coating damage
   c) Mating Ring Chip
   d) US leak
4. Cause and effect diagram identify and isolate causes of problems.
5. Using control charts and by making changes in processes, we can make processes stable.

4. CONCLUSION

It has been shown that with use of basic quality tools, organization can monitor, control and improve their processes. The seven basic quality tools in general have demonstrated a great capacity in the improvement of manufacturing and service industries across the world. There are basically five reasons behind this:

1. They are proven techniques for improving productivity;
2. They are effective in minimization of defects;
3. They prevent unnecessary process adjustments;
4. They provide diagnostic information;
5. They provide information about process capability to meet customer requirements.

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