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Application of Six Sigma Tool for Quality Improvement - A Case Study in Manufacturing Industry

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Abstract: ***Six Sigma and Total Quality Management are methods that help organizations improve product and service quality throughout their respective workplaces. Six Sigma and Total Quality Management each have their own venue that best suits their methods. When applied in the correct manner, both Six Sigma and total quality management provide a thorough check of the organizations quality assurance. This paper includes Six sigma define phase in problem solving of cylinder head valve guide surface finish out of specification. The specification of surface finish of valve guide is 8Rz. Problem definition, Pareto analysis used for problem selection, cost of poor quality calculation, process flow diagram with the generating and inspecting stage , physical phenomenon leading to the problem are carried out in this paper in the define phase.***

Keywords: Six Sigma, Process improvement, DMAIC, continual improvement, M&A , COPQ, SSV's , R&R

1. Introduction

Six-Sigma at many organizations simply means a measure of quality that strives for near perfection. But the statistical implications of a Six Sigma program go well beyond the qualitative eradication of customer perceptible defects. It's a methodology that is well rooted in mathematics and statistics. Six Sigma is a project-driven business systems improvement method [2]. Successful implementation and growing organizational interest in the Six Sigma method have been exploding in recent years. It is rapidly becoming a major force driving the strategy of numerous successful organizations. [1] The objective of Six Sigma Quality is to reduce process output variation so that +six standard deviations lie between the mean and the nearest specification limit. This will allow no more than 3,4 defect Parts Per Million (PPM) opportunities, also known as

Defects Per Million Opportunities (DPMO) [3], to be produced. As the process sigma value increase from zero to six, the variation of the process around the mean value decreases [5]. With a high enough value of process sigma, the process approaches zero variation and is known as "zero defects."

The roots of Six Sigma as a measurement standard can be traced back to Carl Frederick Gauss (1777-1855) who introduced the concept of the normal curve. Six Sigma as a Measurement standard in product variation can be traced back to the 1920′s when Walter Stewart showed that three sigma from the mean is the point where a process requires correction. Many measurement standards (Cpk, Zero Defects, etc.) later came on the scene but credit for coining the term "Six Sigma" goes to a Motorola engineer named Bill Smith. [6]. Six Sigma helped Motorola realize powerful bottom-line results in their organization – in fact, they documented more than $16 Billion in savings as a result of our Six Sigma efforts [4].

Six Sigma has evolved over time. Six Sigma can be seen as: a vision; a philosophy; a symbol; a metric; a goal; a methodology." Anbari (2002) pointed out that six sigma is more comprehensive than prior quality initiatives such as Total Quality Management (TQM) and Continuous Quality Improvement (CQI) [7] . The six sigma method includes measured and reported financial results, uses additional, more advanced data analysis tools, focuses on customer concerns, and uses project management tools and methodology. He summarized the six sigma management method as follows: Six Sigma = TQM + Stronger Customer Focus + Additional Data Analysis Tools + Financial Results + Project Management [8]

2. Theoretical analysis of Six Sigma Concept

Six-Sigma has at least three different meanings depending upon the context; there is not one answer to what is Six-Sigma. The first answer to what is Six-Sigma is that it is a management philosophy. Six-Sigma is a customer based approach realizing that defects are expensive.[6] Fewer defects mean lower costs and improved customer loyalty. The lowest cost, high value producer is the most competitive provider of goods and services [6].

Another answer to what is Six-sigma is Six-Sigma is a statistic. Six-Sigma processes will produce less than 3,4 defects or mistakes per million opportunities. Many successful six sigma projects do not achieve a 3,4 defects or less. That just indicates that there is still opportunity.

A third answer to what is six sigma is that six sigma is a process. To implement the Six-Sigma management philosophy and achieve the Six-Sigma level of 3,4 defects per million opportunities or less there is a process that is used. The Six-Sigma process is define, measure, analyze, improve and control DMAIC. [8]

When answering the question what is Six-Sigma understand that Six-Sigma is not a set of new or unknown tools. Six-Sigma tools and techniques all are found in total quality management [2]. Six-Sigma is the application of the tools on selected important projects at the appropriate time.

3. Problem Definition

The following information are brainstormed and captured in Problem definition. All the information are vital and has to be captured before we go for M&A phase

1) Problem statement
2) Physical phenomenon leading to the Problem
3) Part number selected for study
4) Pareto for all defects, indicating the problem selected for study
5) Other similar part numbers having the problem
6) Process where the problem is detected
7) Average rejection for the last 6 months
8) Maximum rejection in a month
9) Minimum rejection in a month
10) In the last manufacturing process stage where the problem is generated, number of machines/presses used for processing
11) Objective of the Project
12) Annual savings that will be realized if the problem is reduced to zero
13) Response type (Variable/Attribute) and Instrument used
14) Specification if the response is variable
15) Can the method used for detecting the problem create variation due to the person : Yes/No
16) If yes, how much is the variation % to tolerance (Gage R&R % to tolerance)
17) Photograph/Sample of the defective product
18) Process mapping indicating the various stages and the stage where the problem is generated and detected
19) Trend chart for the monthly rejection for the last 6 months
20) Trend chart for daily rejection for the last one month
21) Pareto stratified
22) Machine-wise (if there are more than 1 machine used in the process creating the problem)
23) Stream-wise (if applicable)
24) Optimal machine conditions that needs to be maintained in the machine used for the process where the problem is generated (This has to be done depending on the nature of the problem)
25) Machine audit to check for abnormalities, and details of any corrections done on the machine
26) Concentration chart showing the defect pattern (if applicable)
27) Suspected Sources of Variation (SSV's) for the problem

Problem Definition

1. Problem statement

State the problem, we have to be very specific. Example: If there is a rejection in bore diameter, specify whether the rejection is due to oversize or undersize or both.

Example: Compression force variation in shock absorber. We have to specify clearly whether the problem is less force or more force or both

If the problem is a defect like crack, blister etc.., specify whether the problem is observed as random phenomenon on the product or concentrated to one specific area

2. Physical phenomenon leading to the problem
Identifying the physical phenomenon leading to the problem is very important to the understanding of the problem and subsequently listing down the suspected sources of variations. Reason technically what physical changes happen leading to the problem.

3. Part number selected for study
Even though the problem may be there in many part numbers, identify a part number on which applying the DOE techniques.
The selection of the part number should be based on the following two factors a) % of rejection b) frequency of running of the part number

4. Other similar part numbers having the problem:
Identify all the other part numbers in which the actions can be horizontally deployed once the root cause(s) are identified.

5. Pareto of all defects indicating the problem – Construct this Pareto based on last 6 months rejection data

6. Process stages where the problem is detected:
   a) Identify the first stage where the problem is detected
   b) Identify also the further stages where the problem is detected
   c) Identify the stages where the problem is generated (Mark these stages in the process flow)

   Example:
   Problem: Face run out more than specification
   Stages: After broaching, final inspection
   Problem: Crack
   Stages: After hot forming, final inspection.

7. Average rejection for the last 6 months:
- Rejection here includes both "SCRAP" and "REWORK"
- Calculate the average monthly rejection percentage by averaging the rejection for the last 6 months
- Rejection percentage is only for the problem statement

8. Maximum rejection in a month:
Based on the last 6 months rejection, identify the month and the rejection percentage which is the highest among all the 6 months

9. Minimum rejection in a month:
Based on the last 6 months rejection, identify the month and the rejection percentage which is the lowest among all the 6 months

10 Number of machines/presses:
In the last manufacturing process stage where the problem is generated, if there are multiple machines/presses used identify how many presses are used. This will help in making the pareto machine wise

11. Objective of the project:
For problem solving project, state the objective as to what level we have to bring down the rejection from the current level. The thumb rule is the rejection should drop by 80% from the current level (Eg: if the current average rejection is 10,000 ppm, the target should be 2,000 ppm)

For Optimization project, state the objective as to what level the productivity has to be increased from the current level and what other benefits will be obtained

Response type :
Ask the question "How can this problem be detected". If the answer is the problem can be detected through measurement, then the response type is "Variable". If the answer is the problem cannot be detected through measurement, then the response type is "Attribute"

When asking this question "do not think about the current detection method in the shop". Example: Diameter generated after grinding may be current inspected using Snap gage, but the it can be measured, then the response type should be "Variable" and not "Attribute"

Some responses even though attribute can be made as variable through checking the product parameters.

But this can be done only after the relation is established through a DOE tool called "Paired comparison". Example: Soft can be measured by checking the specific gravity or hardness, but this has to be done only after establishing the relationship through Paired comparison.

13. Specification:
Identify the specification for the part number selected for the study if the response is variable

14. Can the method used for detecting the problem create variation: Yes/No

15. Optimal conditions of the machine:
Before starting the six sigma project, check all the optimal conditions of the machine and correct any abnormality if any as per the current Process standards. The DOE tools should be used only if there are no machine abnormalities and still the defects are generated. All machine abnormalities like mould parallelism, daylight variation, uniformity of the temperature in mould, functioning of thermocouples, timers, slide repeatability, spindle play etc. should be checked and corrected if required
This is a very important part of Problem definition.

16. Defect Concentration chart:
When doing defect concentration chart, one piece may have the defect in multiple places and also the severity level in each place could be different.
Check the defective piece and mark the severity number in the respective places where the defect has come
Do the same for all the 30 defective pieces
Add all the severity numbers in each zone
If in any one zone there is more than 80% of the total then the defect is concentrated, otherwise it is coming randomly

17. Problem Definition – Instrument selection
If the response is variable, then we will have an instrument to measure
The instrument Resolution (Least count) should be <= 10% of the tolerance. This is a "Mandatory requirement" for measurement
Instrument should be Calibrated as per normal practices.

18. Problem Definition – List down SSV's
When the nature of the problem is such that it is generated from a Manufacturing process, then the first level SSV's will be only a) Input material parameters and b) The manufacturing process.
Do not list down the "Manufacturing process" listed SSV's, do not know whether the problem is generated by the process or the input material
In M&A phase, the first objective will be to find out whether the problem is created by the process or the input material and accordingly "funnel" further.
Problem Definition – List down SSV's
SSV's listing is based on "Process knowledge".
Use "ASME Trouble shooting of manufacturing processes – Handbook" to ensure that all the SSV's are addressed
Problem Definition – List down SSV's
For systematic thinking purpose, the SSV's are listed in the following categories and in the same order
Process Parameters (Parameters that are set and can change during processing)
Machine Parameters (Hardware characteristics)
Processing material parameters (eg: coolant, draw oil)
Tooling related parameters
Operator error related parameters
Work environment related parameters
Input material related parameters.

Tools used for listing down SSV's
Fish bone diagram
Brainstorming
Process mapping
FMEA. Key Points. Once the project scope is clear, Problem has to be defined
Key part of problem definition is listing of Suspected Sources of Variations (SSV's)
Do not list Design related SSV's
To start with list only Variation related SSV's

4. DMAIC Process

DMAIC is a closed-loop process that eliminates

Unproductive steps, often focuses on new measurements, and applies technology for continuous improvement. Table 1 presents the key steps of six sigma using DMAIC process. (Adapted from McClusky, 2000).[2]

Define: Define the requirements and expectations of the customer. Define the project boundaries Define the process by mapping the business ?ow
Measure : Measure the process to satisfy customer's needs
Develop a data collection plan
Collect and compare data to determine issues and shortfalls
Analyze : Analyze the causes of defects and sources of variation Determine the variations in the process Prioritize opportunities for future improvement
Improve : Improve the process to eliminate variations Develop creative alternatives and implement enhanced plan
Control : Control process variations to meet customer requirements Develop a strategy to monitor and control the improved process
Implement the improvements of systems and structures

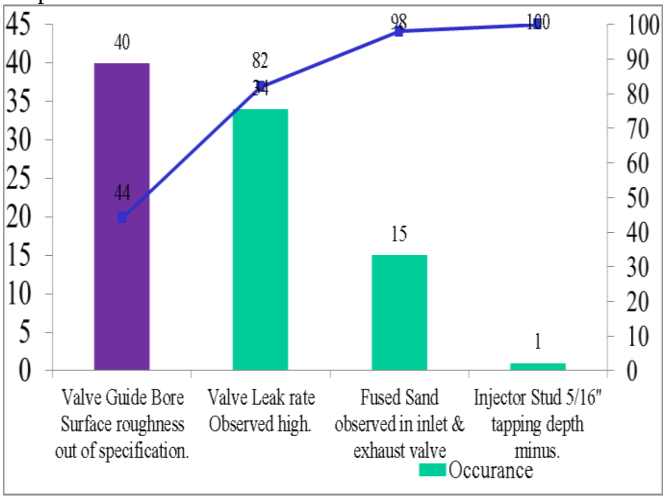
5. Case Study under Observation

Problem statement: To reduce the rejection of EA16 engine cylinder head due to valve guide surface roughness out of specification.

Pareto analysis: Formal technique useful where many possible courses of action are competing for attention. Pareto analysis is a creative way of looking at causes of problems because it helps stimulate thinking and organize thoughts. This technique helps to identify the top 20% of causes that needs to be addressed to resolve the 80% of the problems. The value of the Pareto Principle for a project manager is that it reminds you to focus on the 20% of things that matter. Of the things you do during your project, only 20% are really important. Those 20% produce 80% of results.

The Pareto effect is named after Wilfred Pareto, an economist and sociologist who lived from 1848 to 1923. This method stems in the first place from Pareto's suggestion of a curve of the distribution of wealth in a book of 1896. Whatever the source, the phrase of 'the vital few and the trivial many' deserves a place in every manager's thinking. It is itself one of the most vital concepts in modern management. The results of thinking along Pareto lines are immense. Fig. 1 shows the pareto chart

Step 1: Identify and List Problems
Step 2: Identify the Root Cause of Each Problem
Step 3: Score Problems
Step 4: Group Problems Together By Root Cause
Step 5: Add up the Scores for Each Group
Step 6: Take Action

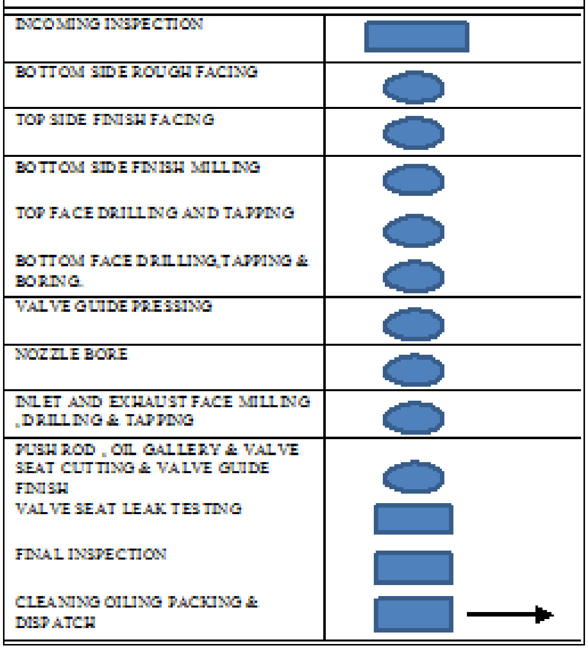


THE PARETO analysis shows that valve guide surface roughness out of specification is the major reason for rejection.

Based on Pareto analysis this defect was selected for problem solving using six sigma techniques.

Fig.2 shows the process mapping.

FIG.2



Part number selected for study
- D7.302.10.0.02

Last manufacturing process stage where the problem is generated

PUSH ROD, OIL GALLERY & VALVE SEAT CUTTING & VALVE GUIDE FINISH

Suspected physical phenomenon's that can lead to the problem

Less Tool Speed, Material Hardness, Excess tool wear. The Process mapping helps to identify the problem generation and detection stage. The problem is generated at valve guide finish operation and inspection is done at final stage as shown in process flow

Response is variable. Specification is 8 Rz. Maximum Rejection is 14 %. Machines make BFW. Model BMV 60 TC 24, Stroke X 900, Y 610 Z 610. Machine parameter audited spindle run out. Surface finish tester Calibration. Machining done on single machine.

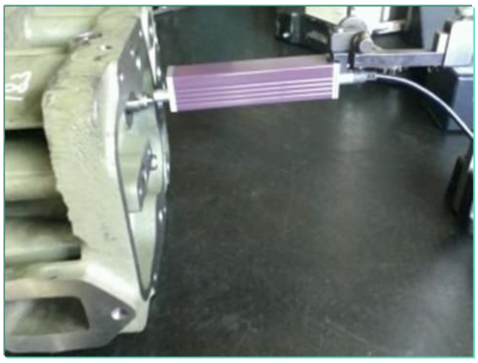
Cost of Poor Quality Calculation

Number of pieces rejected last month (for the part number identified for study)
Number of pieces scrapped last month Number of pieces reworked last month
Scrap cost/piece Rework cost/piece Total scrap cost (Rs. Lakhs) for last month
Total rework cost(Rs. Lakhs) for last month
Total Rejection cost (Rs. Lakhs) for last month
Extrapolated Total rejection cost (Rs. Lakhs) for one year

Operation	
Inspection	
Storage	
Dispatch	

Photograph of Valve Guide

Photograph of Cylinder Head under Study

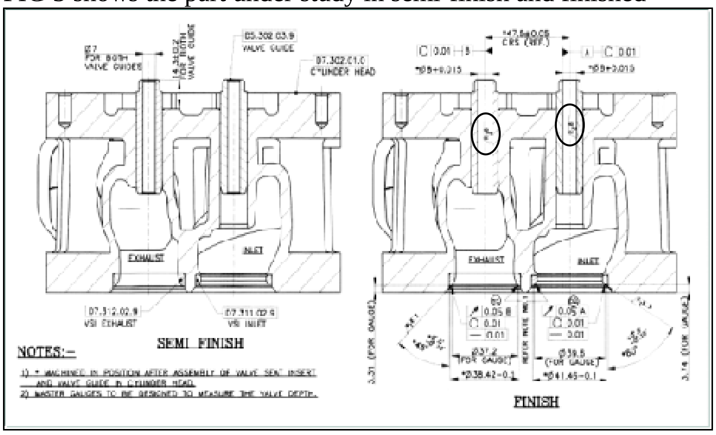


Inspection of Surface Finish

Cost of Poor Quality was calculated using the below template and was found to be 6.2 Lacs.

Number of pieces rejected last month (for the part number identified for study)	40
Number of pieces scrapped last month	40
Number of pieces reworked last month	0
Scrap cost/piece	1306
Rework cost/piece	0
Total scrap cost (Rs. Lakhs) for last month	52240
Total rework cost(Rs. Lakhs) for last month	0
Total Rejection cost (Rs. Lakhs) for last month	0
Extrapolated Total rejection cost (Rs. Lakhs) for one year	6,26,880

FIG 3 shows the part under study in semi-finish and finished



6. Conclusion

Ultimately, Six Sigma is a superb strategy that addresses leadership, tools and infrastructure issues. Engineering programs have begun to incorporate elements of Six Sigma into their curricula. Successful implementation and growing organizational interest in six sigma method have been exploding in the last few years. The above paper describes steps in Six Sigma Implementation in problem solving and steps in define phase to eliminate the rejection due to surface finish of valve guide out of specification.Pareto analysis and cost of poor quality are major tools used in problem definition. Defining the problem clearly in six sigma plays a major role in success of projects.

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