



DMAIC: A Tool for Productivity Enhancement

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Abstract: This research paper deals with a case study which was carried out at JMB Engineering Works, Faridabad, Haryana. (India) which manufacture different types of Hydraulic Piston Rod and Rolls. Rejection of Hydraulic Piston Rod was main problem in the company due to defects of cracking, pitting, poor chrome finish etc. DMAIC approach (Six Sigma Methodology) was used to reduce the defects and increase the productivity. Gauge R & R Study, Histogram, Process Capability Analysis, Pareto Chart, Cause and Effect Diagram, X Bar & R Chart and Design of Experiment (DOE) tools were used to solve the problem. Root cause of the problem was find out and an action plan made for improving and controlling the process.

Keywords: Productivity, Six Sigma, DMAIC, Critical To Quality (CTQ), Defect per Million (DPMO)

I. Productivity

In the economic growth of any country productivity plays a very important roll. Productivity' is about how well people combine resources and services to produce goods. For countries, it is about creating more from available resources such as labour, raw materials, land, skills, capital equipment, intellectual property, managerial capability and financial capital. Higher value, higher incomes and higher production can be achieved with the right choices for every hour worked. Productivity is basically defined as the ratio of the output to the input. The goods produced (or sold) are come under the output for which the input shell be labour, capital, material, energy etc.

According to V.K.R Menon “ Productivity implies development of an attitude of mind and a constant arge to find better, cheaper easier, quicker and safer means of doing a job, manufacturing a product and providing service”

II. DMAIC – Six Sigma Steps

Sigma (σ) is a letter in the Greek alphabet used to denote the standard deviation of a process. The term Six Sigma is come from the field of statistics. One of the most effective business improvement strategies over the years is Six Sigma. Six Sigma is a communal approach, which uses various techniques and tools for productivity improvement. There are DMAIC methodology used to achieve Six Sigma goals; Define, Measure, Analyze, Improve and Control. DMAIC, a five phase closed-loop problem solving pattern that eliminates unproductive steps, and applies technology for continuous improvement. Business process that falls to meet customer requirements is generally used Six Sigma Methodology

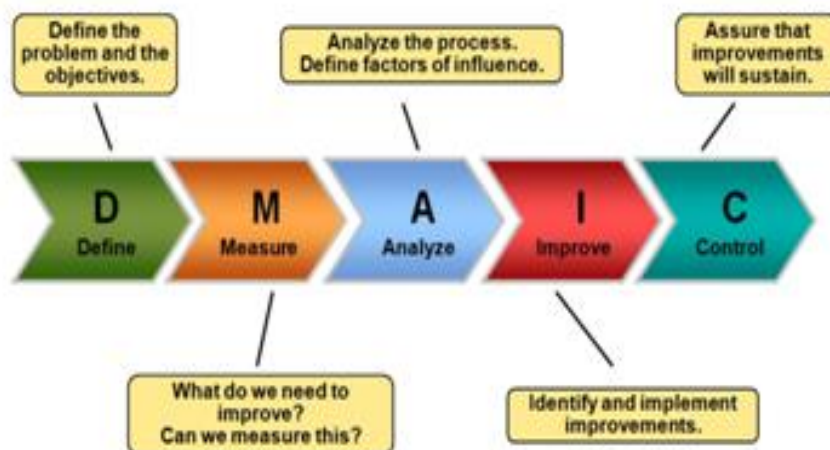


Figure 1: DMAIC Methodology

III. Literature Review

Six Sigma is an important advance in quality management and process improvement in the last two decades. Six Sigma has gained large attractiveness in various types of organizations since the 1990s. Motorola reported \$16 billion benefits after implemented Six Sigma for the period of 1986-2001 (Eckes, 2001; Hendricks and Kelbaugh, 1998; Motorola, 2003). Other firms such as General Electric (GE), Honeywell, and 3M reported similar results (3M, 2003; Arndt, 2004; GE, 2002; Honeywell, 2002). Motorola was the company who developed the Six Sigma in 1980s. Kumar (2002) and Antony (2006) explained that Bill Smith a senior engineer and scientist at Motorola's communication division was the person who introduced the concept of Six Sigma in 1986. According to the Prabhushankar (2008) from the last 50 years Six Sigma has been very successful and is perhaps the most successful business improvement strategy. Six Sigma has spread like "wildfire" (Caulcutt, 2001; Goh, 2002; Chakrabarty and Tan, 2007). Six Sigma is the best improvement strategy which increases the level of productivity and quality in Indian industries. Jiju Antony and Darshak A Desai (2009) were presented the results from an empirical investigation of Six Sigma status in the Indian industry and underrepresented region of investigation on Six Sigma implementation. Pawan Jaglan *et.al*, (2011) illustrated the importance of Six Sigma in small and medium scale industries. Md. Enamul Kabir *et. al*, (2013) described the Six-Sigma framework provides an impetus for establishing best practice with the company. Zhen He, Thong Ngee Goh (2015) explained the background and development of Six Sigma and suggest ways to enhance and extend the effectiveness of Six Sigma in the coming years.

IV. Case Study

Piston Rod is the main component of the Hydraulic Cylinder. Hydraulic Piston Rod should have 55 HRC to 58 HRC hardness, defect free and adequate strength to bear load. But rejection of piston rod is take place due to some defects. The sigma level is below the 3 sigma. So there is a need to reduce the defects from the rod which arise during the process. DMAIC Approach (Six Sigma Methodology) was used to solve hydraulic piston rod rejection problem to achieve the productivity level of greater than three sigma from the present level.

A. Define Phase:

Before define the problem, Process Map and High Level Process Map- a SIPOC (Supplier, Input, Process, Output, Customer) diagram was drawn for hydraulic piston rod as shown in figure 2).



Figure 2: Hydraulic Piston Rod

B. Measure Phase

In measure phase, a measurement system analysis (MSA) was conducted which included the Gauge R&R (Gauge repeatability and reproducibility) studies. The purpose of Gauge R&R study is to ensure that the measurement system is statistically sound. Two persons are needed to perform this experiment. The sample size was 10 and two readings were taken on each sample, thereby making a total of forty readings. The gauge used for this experiment was a Rockwell Hardness Machine. Result of Gauge R & R as shown in table 1. Repeatability and Reproducibility came out to be 21.87 percent and 0.00 percent which put the percentage study variation at 21.87 percent which is less than 30 percent, indicating that Rockwell Hardness Machine was correct.

Table 1: Gauge R & R Study Results

Source	Std DEV (SD)	Study Var (6*SD)	%Study Var (%SV)
Total Gage R&R	0.166738	1.00043	21.87
Repeatability	0.166738	1.00043	21.87
Reproducibility	0.000000	0.000000	0.00
Part-To-Part	0.744070	4.46442	97.58
Total Variation	0.762523	4.57514	100.0

C. Analysis Phase:

In this phase the process is analysis to determine the most likely causes of defects.

i) Histogram:

Histogram was used to show location and variation in the data set. 40 samples size was taken for drawing the histogram

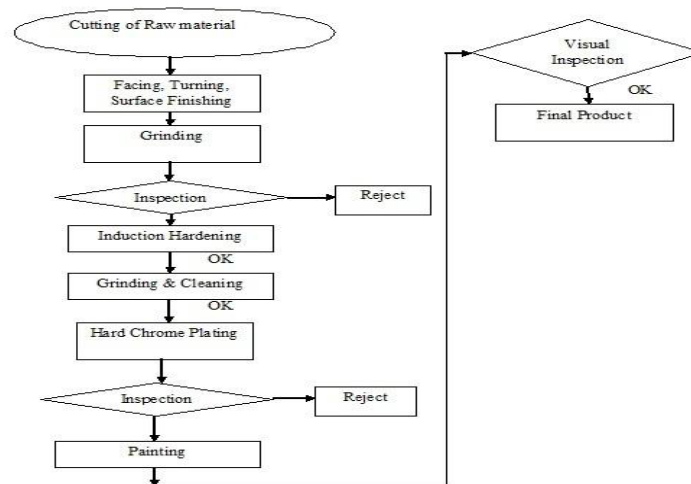


Figure 3: Process Map for Hydraulic Piston Rod



Figure 4: Histogram of Hardness of Rod before Improvement

ii) Process Capability Analysis:

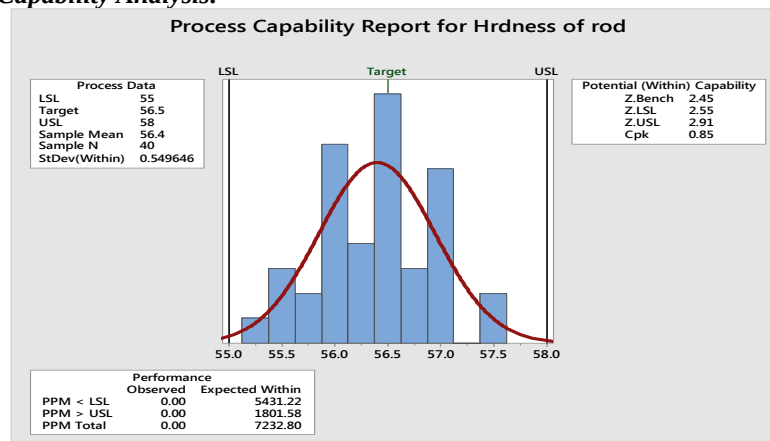


Figure 5: Process Capability Analysis of Hardness of Rod Data before Improvement

Process Capability Analysis used to analyses the process. From the process capability analysis curve, it was found out that Z- Bench sigma value of process was 2.45 and existing DPMO level of the process came out to be 7232.80 so there are lot of opportunities for improvement in the process.

iii) Fishbone Diagram:

Fishbone Diagram is used to show the causes due to which defects come in the rod and from all the SSV's the following suspected sources of variation of the problem are considered for the further study

- 1) Temperature and Current during Hard Chrome Plating.
- 2) Cleaning of Work piece before the Hard Chrome Plating
- 3) PLC circuit
- 4) Chemical composition and Fixture of Hard Chrome Plating.

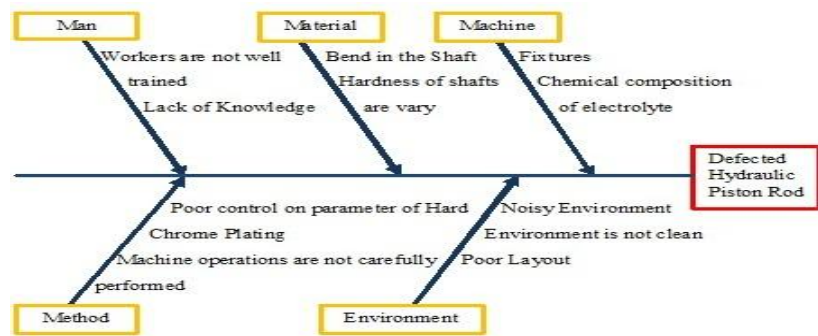


Figure 6: Fishbone Diagram

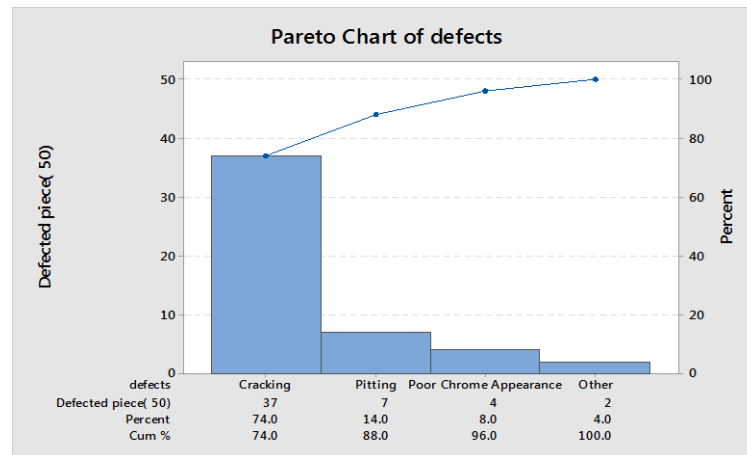


Figure 7: Pareto Chart

D. Improve Phase

In improve phase, Design of Experiments was done to find out the most favorable conditions. These experiments were conducted to optimize the value of the parameters like Temperature and current. A 2*2 Experiment was designed i.e. an experiment with two factors at each level. DOE results in which the p-value for temperature, current and temperature*current are less than the 0.05. This p-value show that temperature, current and temperature*current are the major factor which effects the Hard Chrome Plating.

Table 2: Characteristics Table for Better Condition

Temp (°C)	Current (Amp/in ²)	Hardness (HRC)
45	2.0	57
48.9	2.5	56.7
53.5	3.0	56.3
58	3.5	56
60	4.0	57

Table 3 Action and Control

Sr No.	Recommendation Proposed	Status
1	Before The Hard Chrome Plating of Hydraulic Piston Rod all the electrical connection of equipment to be check if they are loose than tight up	Implemented Instruction passed
2	Check the anode before Hard Chrome Plating, its colour should be dark brown if its colour is yellow than replace it	Implemented Instruction passed
3	After Plating the hydraulic piston rod than check the chromium and sulfate composition in the electrolyte before doing the Chrome Plating of another rod	Implemented Instruction passed
4	Grinding of rod before hard chrome plating to be carefully performed. Grinding operation to be performed by a well trained person	To be Implemented
5	Maintains of fixture to be done time to time and proper fixture to be used for different rods	Implemented Instruction passed
6	Awareness Program about the good hard chrome plating and proper machining operation to be conducted time to time in which tells about the deferent perimeters of hard chrome Plating, their effects and importance of good machining operations	To be Implemented
7	Inspection the cleaning of Hydraulic Piston Rod properly before Hard chrome plating	Implemented Instruction passed

Plan (Improve Phase)

E. Control Phase:

In this phase all the steps and variable are implemented and controlled which is improved in the improve phase. Action Plan (as show in Table 2) was made to improve the process.

V. Results And Conclusion:

Successful implementation and growing organizations interesting Six Sigma methods have been blowing up in the last few years. However there is still the need for more research into Six Sigma to test new theories or models that have been proposed to strength in the methodology. Implementation of Six Sigma is directly related with financial result of company because it targets the customer satisfaction and new innovative ways to exceed the customer hope. Applying DMAIC approach in manufacturing industry the Sigma level has been improved from 2.45 to 3.34 which are equal to save approximate 93258 Rupees per annum.

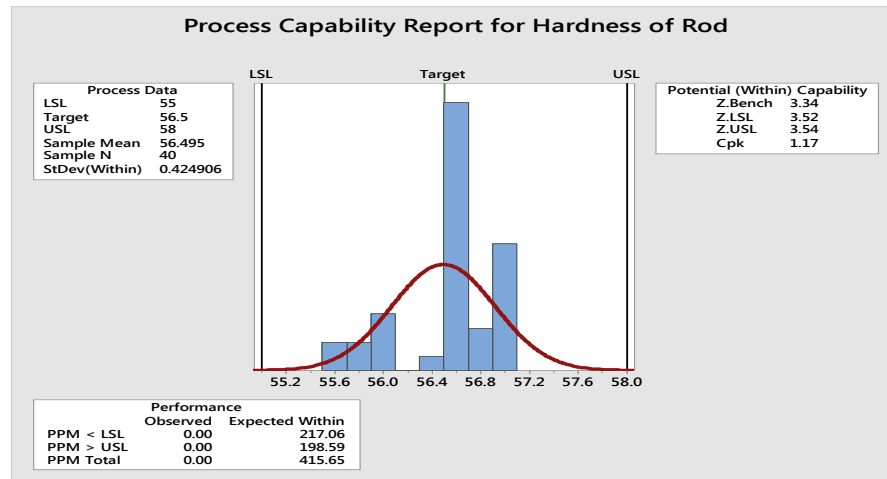


Figure 8: Process Capability Analysis for Hydraulic Piston Rod after the improvement

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