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SIX SIGMA DMAIC METHODOLOGY IMPLEMENTATION IN AUTOMOBILE INDUSTRY: A CASE STUDY

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ABSTRACT

This paper deals with the applications of Six Sigma, DMAIC methodology to improve the Sigma level of the project taken from an automobile industry. Modern manufacturing industries are focusing on many innovative techniques and management practices such as Six Sigma, total productive maintenance (TPM), total quality management (TQM), just in time (JIT), enterprise resource planning (ERP) etc. Six Sigma offers a unique approach that is widely used in industries in order to improve the process and reduce the number of defects. Six Sigma is a fact-based, data-driven philosophy and methodology that improves quality by analyzing data with the help of statistics to find the root cause of quality problems and control by preventing defects. Six Sigma provides 1.5 Sigma drift margin from the process mean to either side, so that final products would be 99.97% defect free, having 3.4 DPMO. One Sigma gives a precision of 68.27%, two Sigma gives 95.45% and three Sigma of 99.73%, whereas Six Sigma gives a precision of 99.9997%.The DMAIC (define-measure-analyze-improve-control) approach has been followed to solve an underlying problem (To reduce the in-house rejections of Cushion P-70 Bolt RR) of reducing process variation and the associated high defects rate. This paper explores how an automobiles industry can use a systematic and disciplined approach to move towards Six Sigma quality levels. The DMAIC phases are utilized to decrease the defect rate of Cushion P-70 Bolt RR *(Splendor bike Shock Absorber attachment bolt)* from 121550 PPM to 4263 PPM and increased in Sigma level from 2.67 to 4.11. The Process Yield increased to 99.6% from a very low level of 87.8% and Process Capability increased to 1.93.

***Keywords**: Six Sigma, DMAIC, DPMO/PPM, Process Capability, Cushion P-70 Bolt RR*

1. Introduction

Six Sigma is a statistical term that measures how far a given process deviates from perfection. “Six Sigma is a fact-based, data-driven philosophy and methodology that improves quality by analyzing data with the help of statistics to find the root cause of quality problems and control by preventing defects”. Six Sigma provides 1.5 sigma drift margin from the process mean to either side, so that final product would be 99.97% defect free, which have only 3.4 defects per million opportunities as given in Table1 [12].

Six Sigma is a business strategy and a philosophy of working smarter not harder. One Sigma level gives a precision of 68.27%, two Sigma gives 95.45% and three Sigma of 99.73%, whereas Six Sigma gives a precision of 99.9997%. Although 99.73% sounds very good quality level but it slowly dawned on companies that there is a tremendous difference between 99.73% and 99.9997% quality levels [10].

Table 1. Sigma levels and DPMO [11]

Process Capability	DPMO	Performance	Cost of Quality %
2	308537	69.1%	> 30
3	66807	93.3%	15 – 25
4	6210	99.4%	10 – 15
5	233	99.7%	5 – 10
6	3.4	99.997%	< 5

1.1 Six Sigma in Normal Distribution

To achieve 6-Sigma Quality, a process must produce no more than 3.4 defects per million opportunities, refer Fig.1 . An opportunity is defined as

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a chance for nonconformance, or not meeting the required specifications [12].

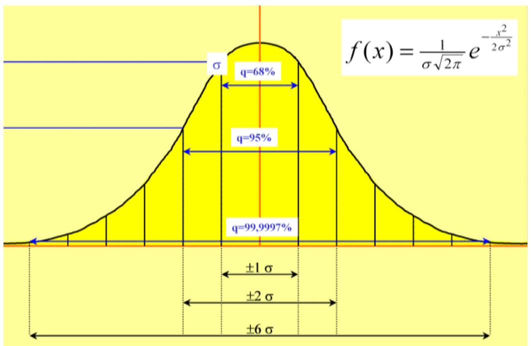


Fig.1 Sigma variations in N.D.C.

DPMO = Number of defects * 1000000 / Number of opportunities for error per unit * Number of unit

This means one needs to be nearly flawless in executing key processes. The process and culture is conditioned for zero defects rather than being one that accepts that it is unavoidable, and acceptable, that mistakes will occur. Hence Six Sigma delivers substantial cost reductions, enhanced efficiencies, sustainable improvements and increased stakeholder value.

2. Literature Survey

Prakash et.al.2012 [1] presented the findings of an initial survey conducted in Indian industries. It was experienced that complete implementation of Six Sigma and its sustenance is difficult, helps organizations in making right preparations for successful implementation of Six Sigma. V.Arumugam et.al.2012 [2] proposed an integrated model to explain process improvement implementation success through two learning activities undertaken by Six Sigma project teams: Knowing-what and Knowing-how. Three hypotheses are proposed in the model were tested using the data collected from 52 Six Sigma project teams from a single organization. Natha Kuptasthien et.al. 2011[3] demonstrated the implementation of Six Sigma technique and DMAIC improvement methodology into a mass manufacturing of printed circuit cables. The result showed that by following the theoretical Six Sigma technique and DMAIC steps, the defects from major tombstone capacitor problem could be reduced from 1,154 DPPM to 314 DPPM and increased 1st yield output from 98.4% to 99.66%. Plecko, A. et.al, 2009 [4] presented a real case study illustrating the effective use of six sigma methodology to reduce waste in individual production. Six sigma DMAIC Methodology was carried out. Company decided to reduce detected non conformities at final inspection from 33% to 10% and to move from 1 sigma level to 3 sigma level. Hongbo Wang , 2009 [5] summarized four issues within the sub-category of the initial Six Sigma concepts: basic concept, DMAIC, DFSS and deployment. Some sectors that benefit from the implementation of Six Sigma are listed out, and the key factors influencing the successful Six Sigma project implementation are identified. Tushar N. Desai et.al. 2008 [6] presented the quality and productivity improvement in a manufacturing enterprise through a case study. Six Sigma (DMAIC) improves the process performance (process yield) of the critical operational process, leading to better utilization of resources, decreases variations and maintains consistent quality of the process output. A.K. Sahoo et.al.2007 [7] implemented DMAIC based Six Sigma approach to optimize the operation variables of a radial forging operation. M. Soković et.al, 2006 [8] presented a Six Sigma project, undertaken within company for the production of automotive parts, which deals with identification and reduction of production cost in the de-burring process for gravity die-castings and improvement of quality level of produced parts. M. Sokovic et.al. 2005[9] modified process design flow of compressor housing with incorporate applications of process map and the cause and effect matrix, a comparison of the old and the modified process design flow is made and the obtained results are discussed.

3. Case study

A real case from a XYZ automotive industry is studied. To reduce the in-house rejections of Cushion P-70 Bolt RR (shown in Fig. 2) and improve process performance with the applications of Six Sigma is selected as a process consideration.

Fig. 2 Assembly parts of two Wheelers

Then Six Sigma DMAIC methodology is used to overcome the problems. DMAIC used the quality tools and statistics for solving the problem in different phases like Define, Measure, Analyze, Improve and Control.

3.1 Define Phase

During the Define phase three tasks (Fig.3) must be undertaken as project scope, project goals and estimating the project time and hard savings. The purpose is to identify the problem, SIPOC analysis, define critical customer requirements, and prepare the team to be an effective project team.

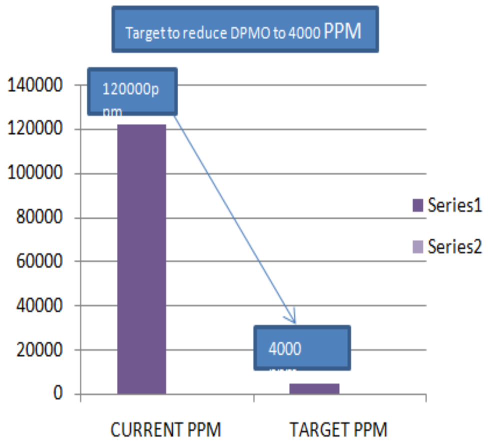


Fig. 3 Current PPM to Target PPM

3.1.1Problem statement

The bolt acceptance is only 87.8% rest are rejected due to dimensional variations viz. overall length of the bolt, threads cutting and chamfer variations, collar side diameter and bolt length. The target is set to reduce the rejections of Cushion P-70 Bolt RR at Zero % rejection level. During manufacturing of Cushion P-70 Bolt RR, 1220 pcs./month out of avg. production of 10000 pcs./month have been rejected in in-house inspection. This will be a step towards achieving a target of 4000PPM rejections.

3.1.2 Goal statement

The bolt acceptance is only 87.8% rest are rejected due to dimensional variations viz. overall length of the bolt, threads cutting and chamfer variations, collar side diameter and bolt length. The target is set to reduce the rejections of Cushion P-70 Bolt RR at Zero % rejection level. During manufacturing of Cushion P-70 Bolt RR, 1220 pcs./month out of avg. production of 10000 pcs./month have been rejected in-house inspection. The objective of the project is to reduce the rejection rate of Cushion P-70 Bolt RR at 4000PPM level.

3.1.3 Drawing of Cushion P-70 Bolt RR

Fig. 4 shows the drawing of Cushion P-70 Bolt RR and all the dimensions like diameter, length, threads length and chamfer provided in the bolt with respective tolerances under which the Cushion P-70 Bolt RR is acceptable.

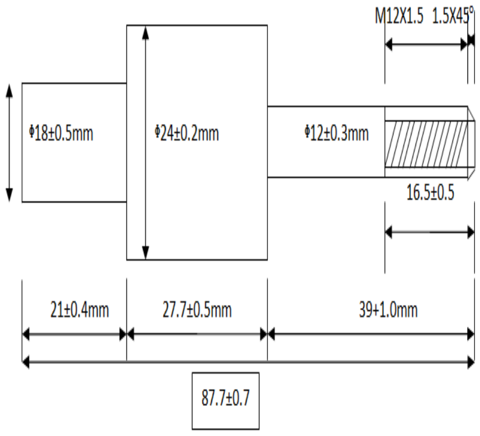


Fig. 4 Drawing of bolt

3.1.4 SIPOC analysis (supplier, input, process, output, customer)

Fig. 5 describes the transformation process of inputs form suppliers to output for customers and gives a high level understanding of the process, the process steps (sub processes) and their correlation to each other.

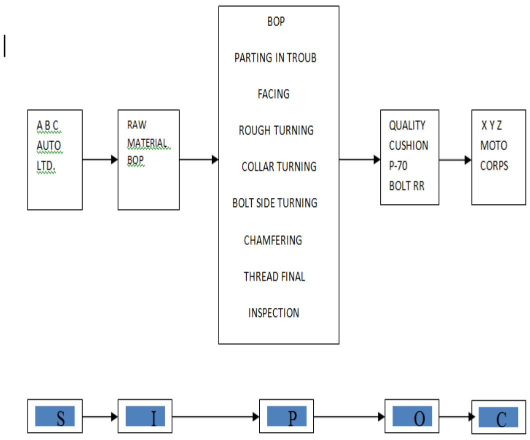


Fig. 5 SIPOC Analysis

3.1.5 Customer CTQ Requirements

The customer data (VOC) revealed that internal customers are mainly affected by the rejections of Cushion P-70 Bolt RR. CTQ tree shown in Fig.6 is prepared on the basis of the VOC and project objective.

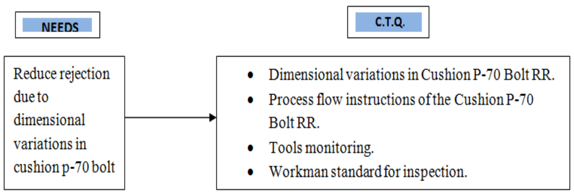


Fig. 6 C.T.Q. Tree

3.2 Measure Phase

This phase deals with the detailed process mapping, Data collection chart, evaluation of the existing system, assessment of the current level of process performance, Process Flow Diagram (PFD), Process Capability analysis and variations in the current process due to dimensional variations etc.

Data collected is a continuous type of data (variable) as shown in appendix attached in the last of paper, In the case of continuous data, the data collection forms are made simple and have clear space for entering the collected numerical data, the same data need to be converted as discrete data by marking ok/not ok to calculate the Sigma level of the process performance.

3.2.1 Sigma level calculation

DPMO = number of defects X 1000000/number of units X opportunities per unit is given Table 2..

Table 2 Sigma Level Calculations

Sigma level calculation	
PARAMETERS	**VALUE**
No. of units	50
Opportunity per unit	1
Total no. of opportunities	50
No. of defects	6
DPMO	120000
Sigma level	2.67

3.2.2 Process Variation

With the help of collected data of the current process we analyze dimensional variations in different processes and is presented in Fig.7

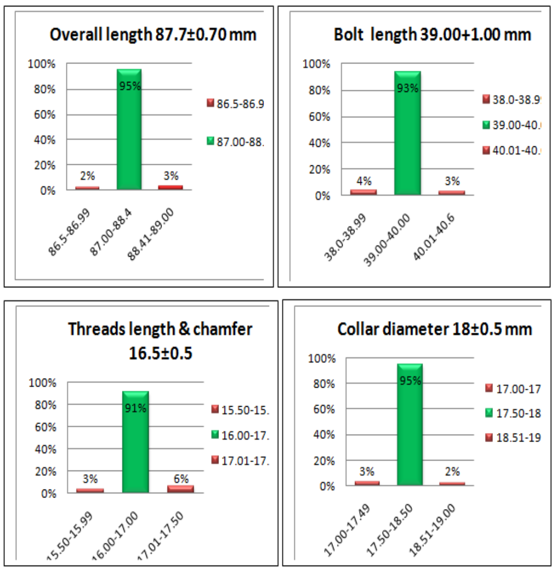


Fig. 7 Process Dimensional Variations

3.2.3 Process Capability

Process capability is commonly measured in terms of the capability index (Cp), which is a ratio without units in Fig. 8. The purpose of this index is to assess whether a process, given its usual short-term variation, can meet established customer requirements or specifications. Cp is a ratio of the tolerance width to the short-term spread of the process You are basically dividing the performance standard (USL - LSL) by the process width. Cp = USL – LSL / 6 x Standard deviation (σ).

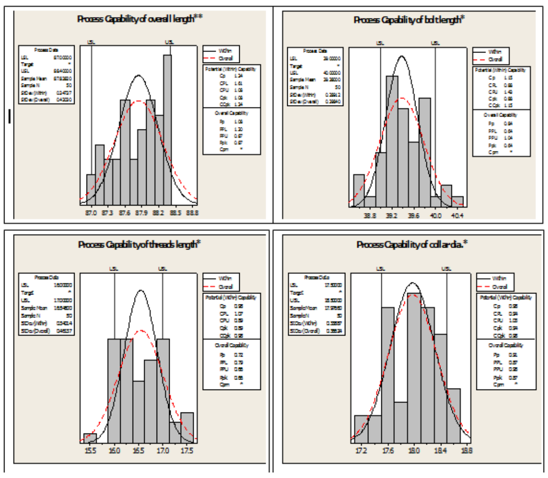


Fig. 8 Process Capability of Current (old) Process

3.3 Analyse Phase

3.3.1 Cause and Effect analysis

Cause and Effect diagram shown in Fig. 9 is mainly used tool during analyze phase since it helps identify the cause of a problem.

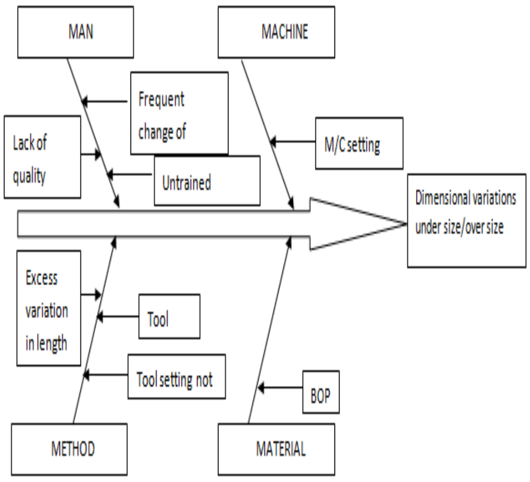


Fig. 9 Cause and Effect Diagram

A Cause and Effect diagram for Cushion P-70 Bolt RR presents a chain of causes and effects, sorts out causes and organizes relationship between variables.

3.3.2 Process Failure Mode and Effects Analysis (FMEA)

The major causes, prioritized on the basis of RPN, are dimensionally variations, material rusty, chamfer uneven, thread U/S and O/S, burr, thread damage etc.; which are responsible for rejections of Cushion P-70 Bolt RR.

Risk Priority Number = (Severity*Occurrence*Detection)

RPN = (S * O * D)

- **Severity**: Quantifying the strictness of the effects how the failure would affects the customer both internal and external.
- **Occurrence**: Likelihood of the failure occurring based on the data and measurement.
- **Detection**: The probability of the failure being detected before the impact of the effect is realized.

3.4 Improve Phase

3.4.1Statistical Process Control

Statistical Process Control is used to check the process variations. With the help of MINITAB software we calculate the individual control charts shown in Fig.10 for the continuous data collected and if any sample moves out of the USL or LSL then it indicates that process is going out of control either to stop the process or need to improve and check the fault wherever it comes. It is a very beneficial tool it alone can improve the process.

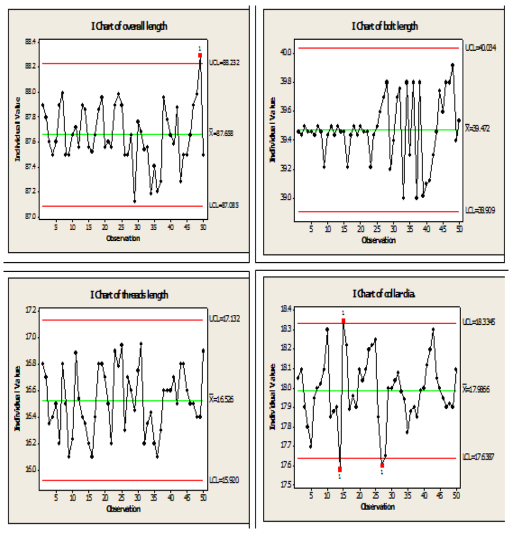


Fig. 10 Individual Control Charts

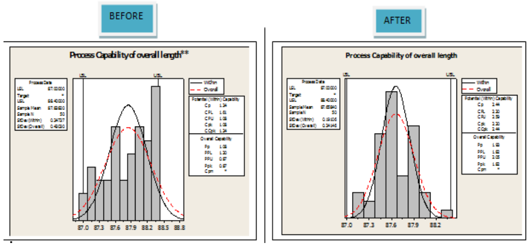
Table 3. Process FMEA

Sr.no.	Process function	Potential failure mode	Potential effects	Potential cause	S	O	D	RPN (S*O*D)
1	Storage (BOP)	Material rusty	Aesthetically poor	Long time storage	5	3	3	45
		Bend	Inconvenience to next operation	Tool blunt and material not put in safe area	4	3	3	36
2	parting	Dimensionally variation	Material rejection/supplier rej.	Without dispatch from supplier	7	4	3	84
		Dimensionally variation	Material rej./supplier rej.	Without dispatch from supplier	7	4	3	84
3	facing	Dimensionally variation	Material rej./supplier rej.	Without dispatch from supplier	7	4	3	84
4	Rough turning	Dimensionally variation	Material rej./supplier rej.	Without dispatch from supplier	7	4	3	84
5	Final turning	Chamfer uneven	Aesthetically poor	Operator negligence	8	3	3	72
		Length not proper	Fitment problem	Operator negligence	7	2	3	42
		Profile NG	Fitment problem	Thread tool wear out	4	3	3	36
6	Side turning	Dimensionally variation	PPM high ranking	Without dispatch from supplier	7	4	3	84
7	Thread rough	Thread	Inconvenience to next operation	Tool blunt and material not put in safe area	4	3	3	36
8	Thread final	Thread U/S and O/S	Inconvenience to fitment	Operator negligence and drill not sharp	4	3	5	60
9	chamfering	Chamfer uneven	Aesthetically poor	Operator negligence	8	3	3	72
10	Gauging +visual inspection	Not qualify in final R/G	Reject	m/c setting not ok, unskilled operator	7	3	4	84
		Burr, thread damage	Material reject /rework/in customer rej. ppm rank increases	Tool blunt and material handling not proper	5	3	3	45

3.4.2 Process Capability Improvement

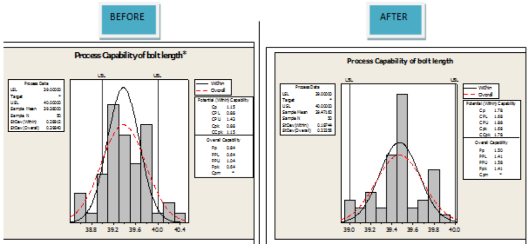
I Process Capability of overall length dimension

Overall capability increases from 1.09 to 1.93.



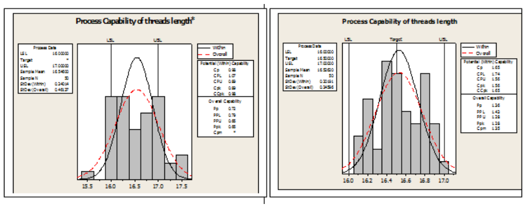
II Process Capability of bolt length

Capability increases from 0.84 to 1.50.



III Process Capability of threads cutting in the bolt

Capability increases from 0.72 to 1.28



IV Process Capability of collar dimension

Capability increases from 0.81 to 1.92

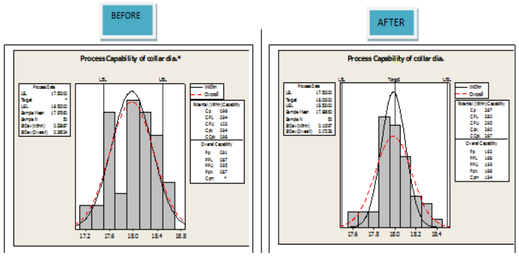


Fig.11 (I,II,III,IV) Process Capability Improvement

3.4.3 Sigma Level Improvements

Table 4. Sigma Level Improvements

SIGMA LEVELS IMPROVEMENTS		
Parameters	**Before Restoration**	**After Restoration**
No. of units	50	50
Opportunity per unit	1	1
Total no. of opportunities	50	50
No. of defects	6	0.2
DPMO	120000	4000
Sigma level	2.67	4.11

Defects per million opportunities decreases from 120000 PPM to 4000 PPM. And therefore Sigma level increases from 2.67 sigma to 4.11 sigma approx as given in Table 4..

3.4.4 Process Yield Improvements

The bolt acceptance is increased from 87.8% to 99.6%. After the implementation of Six Sigma project recommendations dimensional variations are overcome by modifying the process flow instructions and using condition monitoring of tools and inspection gauges and chamfer oversize/undersize problem was also recovered. Pareto chart illustrates reduction in rejections of Cushion P-70 Bolt RR and also represents the improvements in the process after restoration of the process.

By using Minitab software capability analysis of collected data represents that the rejections level of Cushion Bolt P-70 reduced from 121550 PPM to 4263 parts per million as in Fig.12..

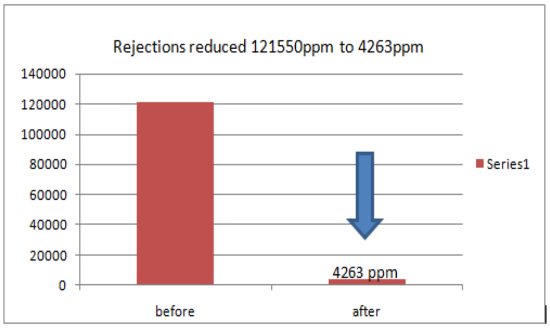


Fig. 12 PPM and Yield improvements

3.4.5 Product Design Improvements

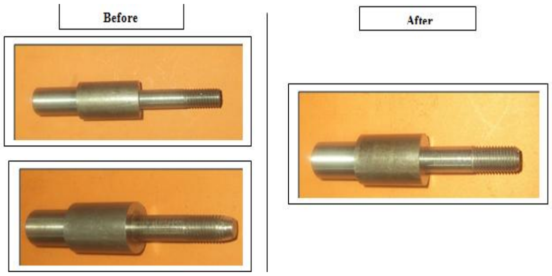


Figure 13 Design Improvements

Overall Improvements

Rejection percentage on daily basis is reduced from 12.2% to 0.4% as shown in the figure 4.20. It is a big achievement with the application of Six Sigma methodology and using various Six Sigma quality tools. The design improvements are presented in Fig.13 and Fig. 14 and standard operating procedure for the improved results are given table 5.

Table 5. Standard Operating Procedure

Sr.No	Operations	Machines	Parameters	Specifications	Tolerences	Inspections
1	parting	lathe	Parting length	88.7	±0.7	V.C
			Outer dia.	26	±1.0	M.M
2	Facing	Turning lathe	Facing length	87.7	±0.7	V.C
3	Rough turning	Turning lathe	Diameter	24	±0.2	
			Length	87.7	±0.7	
4	Collar side turning	Turning lathe	Diameter	18	±0.5	S.G
			Length	21	±0.4	S.G
5	Bolt side turning	Turning lathe	Diameter	12	±0.3	S.G
			Length	39	±1.0	V.C
			Chamfering	1.5x45°		M.M
6	Thread rough	Tapping machine	Thread length	16.5	±0.5	S.G
7	Final thread	Tapping machine	Threads	M12 X 1.25		T.R.G
			Dimension	39	±1.0	S.G
			Dimension	27.7	±0.4	L.G
8	Inspection	Gauges/ Instruments	Dimension	21	±0.4	V.C
			Diameter	18	±0.5	S.G
			Diameter	12	±0.3	S.G
			Chamfer	1.5x45°		V.C
			Thread	M12 X 1.25		T.R.G
			Thread length	16.5	±0.5	S.G
			Appearance	No scratch no thread damage		visual

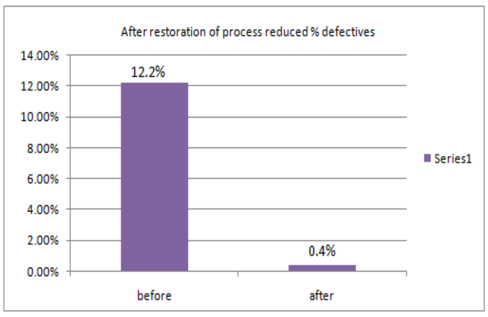


Fig. 14 Overall % defectives

3.5 Control Phase

Having done the hard work, it is time to get the control initiated so that the process does not go back to its old state. If the Six Sigma changes and procedures are not maintained, it will lose its performance. The major areas to be included in the control phase are Planning, Documentation, Process controls, Monitoring and System review.

3.5.1 Standard Operating Procedure (SOP)

Standard Operating Procedure is very descriptive and gives clear instruction to the operator what needs to be done, what precautions to be taken , what data to be prepared with great care and how to report in case of any problems. The standard operating procedure for the improved results are given table 5.

4. Results and Conclusion

The process Sigma level through Six Sigma DMAIC methodology was found to be approaching 4.11 Sigma from 2.67 Sigma, while the process yield increased from 87.8% to 99.6% This Six Sigma improvement methodology, DMAIC project shows that the performance of the company is increased to a better level to enhancement in customer's satisfaction, conformity of delivery schedules, development of specific methods to redesign and reorganize a process with a view to reduce errors and defects.

1. **Sigma impact**: The Sigma level has been increased from 2.67 Sigma (previous process PPM 120000) to 4.11.
2. **Improvement in process yield**: The process yield is improved by optimum utilization of resources from 87.8% to 99.6%.
3. **COPQ impact**: COPQ of Cushion P-70 Bolt RR is reduced from 25% to 12% per year.
4. **Process Capability** increased to 1.93and is presented in Fig.15.

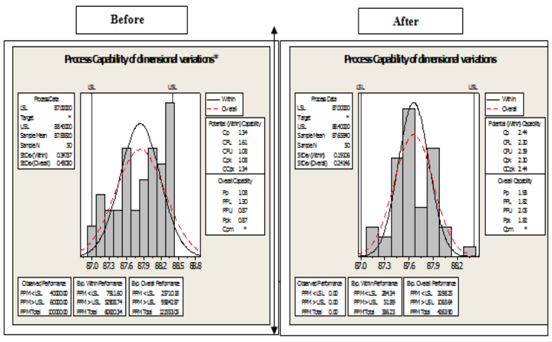


Fig. 15 Process capability results

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