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QUALITY IMPROVEMENT BY USING SIX SIGMA IN AN AUTOMOTIVE INDUSTRY: A CASE STUDY

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Abstract

In the present era of competition, Six Sigma has been considered as a powerful business strategy that employs a well-structured continuous improvement methodology to reduce rejections within the manufacturing processes by the effective application of statistical tools and techniques. This paper presents the implementation of Six-sigma methodology for reducing rejection of automotive part clutch in an automotive industry. The DMAIC methodology has been used to achieve quality level. During this process, data from all possible causes were collected analyses and thereby conclusions were drawn. Implementation of Six Sigma resulted in reduction of rejection of clutch from 15 out of 220 to 2 out of 220 in a single sift and therefore reduced the Defect per Million Output (DPMO) from68181.8 to 9090.9. This increased the Sigma level from 2.99 to 3.86, with an optimalresult. Finally, implementation of Six-Sigma methodology has been results an increase in quality level of the assembly line of that particular clutch in the automotive industry.

Keywords: Six Sigma, Statistical tools and techniques, DMAIC methodology, Sigma level and DPMO.

1. INTRODUCTION

Six Sigma as a business strategy has been well recognized as an imperative for business and operations excellence. This powerful business management strategy has been exploited by many world class organizations such as General Electric (GE), Motorola, Honeywell, Bombardier, Sony to name a few from a long list(Antony Jiju2006). The primary objective of Six Sigma is to reduce variability, in products and processes, to achieve quality levels of less than 3.4 defects per million opportunities (DPMO). The important point to be noted is reducing the defects involve measurements in terms of millions of opportunities instead of thousands (Bhote KR 2007).A term Sigma Quality Level is used as an indicator of a process goodness. Lower Sigma quality level means greater possibility of defective products, while, higher Sigma quality level means smaller possibility of defective products within process (Coskun AR, Tamer C and Serteser M 2011). Six sigma is an organized and systematic problem-solving method for strategic system improvement and new product and service development that relies on statistical methods and the scientific method to make dramatic reductions in customer defined defect rates and/or improvements in key output variables (Linderman, K Schroeder, RG Zaheer, S Choo, As2003). The main focus of Six Sigma is to reduce potential variability from processes and products by using a continuous improvement methodology, which follows the phases: Define, Measure, Analyse, Improve and Control. This approach is known as DMAIC methodology and is employed in tackling problems associated with existing processes/products (Antony Jiju 2005). This paper is an attempt to illustrate the introduction of Six Sigma as an effective quality improvement drive to one of the large-scale automotive parts producing industry in India. The paper discusses the phase wiz implementation of define, measure, analyse, improve, and control (DMAIC) on one of the chronic problems, high rejection of clutches i.e. 15 out of 220 from an assembly line of particular clutch in a single shift. The sigma level calculation has been performed on the basis of above data which has found very less, so it was the main objective of research to enhance the sigma level of the assembly process by reducing the rejection of clutches. The paper concludes with rate of improvements achieved and projected bottom-line gain to the concern by application of Six Sigma methodology.

2. LITERATURE REVIEW

For performing this research work various literatures have been studied to build up basic knowledge about six sigma like Calcutta, Roland (2001) paper titled "Why is Six Sigma so successful?, mentioned how Six Sigma was contributing organizations to become more successful.Kumar M (2007) reports key findings of a Six Sigma survey conducted in a UK manufacturing SME with an objective of assessing the status of Six Sigma in the company. The instrument designed captures the respondent's viewpoint on the Critical Success Factors (CSFs) and barriers faced in Six Sigma implementation and its impact on the performance measures existing within the company. Meanwhile Kwak and Anbari (2006) have identified the benefits, obstacles and future of the six sigma approach. In recent years, the manufacturing industry has successfully applied the six sigma methodologies to numerous projects. However, due to insufficient data or a misunderstanding of the six sigma methodology, some of the project failed.

Antony Jiju (2004) examines the pros and cons of Six Sigma in a detailed manner. This is followed by a section about the future of Six Sigma and its links to statistical thinking. It is believed that, although the total package may change, the application of Six Sigma will continue to grow in the forthcoming years, due to the existence of sound principles of statistical thinking within the six sigma strategy.

Chakrabortty RK, Biswas TK, Ahmed I (2013)used Six Sigma approach to reduce process variability of a food processing industry in Bangladesh. The DMAIC model has been used to implement the Six Sigma Philosophy. Five phases of the model have been structured step by step respectively. Different tools of Total Quality Management, Statistical Quality Control and Lean Manufacturing concepts likely Quality function deployment, P Control chart, Fish-bone diagram, Analytical Hierarchy Process, Pareto analysis have been used in different phases of the DMAIC model. The process variability has been tried to reduce by identifying the root cause of defects and reducing it. The ultimate goal of his study is to make the process lean and increase the level of sigma.

As the goal of present study is to boost up the sigma level of the clutch assembly process, it was the prime requirement of gathering some goal related knowledge. Subsequently such literatures have been studied in which main emphasis has been put on increasing the sigma level. Most of the literatures have been studied to unfold the answers to the questions like, how Six Sigma has been implemented in their research. How the process of DMAIC carried out by the authors? What statistical tools have been used in each phase of DMAIC? Following ***table-1*** shows a summary of goal related studied cases.

Table 1: Summary table of studying cases:

Sr. No.	Author Name	Problem Identified	Method Used	Supporting Tools	Results obtained
1.	Zaman Mehdiuzet al. (2013)	Rejection of welding electrodes in Manufacturing industry	Six sigma DMAIC	· Process map · Pareto chart · Ishikawa (Fishbone) diagram	Sigma level comes at 4.43 from 3.41
2.	KaushikPrabhakaret al.(2012)	Rejection of bush in the bicycle chain, manufacturing company	Six sigma DMAIC	· Brain storming · Process map · Pareto chart · Ishikawa diagram	Sigma level comes at 5.46 from 1.40
3.	Patel D D et al. (2014)	Reduction of production cost & process in bearing manufacturing industry	Six sigma DMAIC	· Cause and effect diagram · Process capability analysis	Sigma level comes at 3.76 from 2.47
4.	Dambhare Set al.(2013)	Rework up to 16% bores per month in an engine block manufacturing company	Six sigma DMAIC	· Control chart · MR chart · Histogram	Rework reduced from 16% bores per month to 2.20% bores per month
5.	Shinde M Set al. (2012)	Weld defects in the Tungsten Arc Welding process used for aerospace application	Six sigma DMAIC	· Detailed process flow chart · Cause and effect Diagram	Sigma level comes at 3.50 from 2.98
6.	Sokovic M et al. (2006)	High production cost of automotive parts producing company	Six sigma DMAIC	· Pareto chart · Thought process · Control chart	Overall reduction in production cost

Literature review and case discussion related to the goal provide the essential vision to accomplishing the research. In the present study an effort has been made to implement Six Sigma with ease on single flow clutch assembly line in an automotive industry. To carry out this research, an automotive industry located in Vadodara, Gujarat, India has been selected.

3. RESEARCH PROBLEM &OBJECTIVE

A research problem is one which necessitates a researcher to find out the best clarification for the given problem, i.e., to find out by which course of action, the goal can be conquered optimally in the context of a given environment. In the present study the main research problems are high rejection of clutches and lowest sigma level of clutch assembly process which was only 2.99 (calculations have been made in define phase). Detailed research problems are as follows:

1. High rejection of clutches in single shift, i.e.**15** out of **220**on single flow assembly line of the industry.
2. High **Defect per Million Output (DPMO)** that is**68181.8**(Calculations have been performed in define phase)
3. Low process sigma level, which is only***2.99***(Calculations have been performed in define phase)

4. Poor Quality level of that particular clutch assembly process.

In this section only the research problems have been discussed, but the clarification and the reason behind these problems have been elaborated in define phase.

Globalization has unwrapped world markets to Indian organizations, which in turn pushing them to bring their products & services to world class level. For that, along with various statistical tools Six Sigma is becoming standard and supportive in India. For above mentioned problem six sigma DMAIC implementation is the only solution to maintain the quality level of clutch assembly process. Considering the specific need of the automotive industry to implement Six Sigma effectively,the main objectives of this research work are to reduce the rejection of clutches producing in an automotive industry in a single shift, enhance the sigma level of the clutch assembly process and some other objectives is listed below in detail:

1. To understand the necessity of Six Sigma in an Organization.
2. To reduce the Defect per Million Output(DPMO).
3. To increase the process Sigma level of that particular process of the clutch assembly.
4. To evaluate and compare Six Sigma and the existing way of working.

To achieve the above mentioned objectives Six Sigma DMAIC methodology has been used in the present research.

4. METHODOLOGY ADOPTED

The paper deals with an application of SixSigma DMAIC (Define–Measure-Analyse-Improve-Control) methodology. DMAIC is a process that eliminates unproductive steps, often focuses on new measurements, and applied technology for continuous improvements shown in ***table-2*** which elaborates DMAIC in detail.

Table 2: Details of DMAIC Phases (Shinde M. S. et al, 2012)

Phase	Details
Define D	Set project goals and objectives
Measure M	Measure the defects where they occur
Analyse A	Evaluate data/information for trends, pattern and root cause
Improve I	Develop, implement and evaluate solution targeted at identifying root causes
Control C	Make sure that almost the problems has been cleared and method is improving

In present research implementation of DMAIC Methodology done in five phases, phase wiz DMAIC implementation to achieve the desired objectives are illustrated below:

4.1 DEFINE PHASE:

The present study has been conducted in an automotive industry **"Setco Automotive Ltd."** situated at Vadodara Gujarat, India. The industry produces various clutches used in heavy vehicles and also various assembly parts of the clutch. The problem was found in a single flow assembly line of a particular clutch in which **15** clutches were rejected out of **220**in one shift **due to clutch plate keyway depth not as per the specification**. The data were obtained from monthly reports from the firm's quality department. Clutch plate is one of the many manufactured components for the transmission assembly. It's a flat metal circular plate into which 4 key ways are made using stamping (manufacturing process) as shown in ***figure-1***. There are set tolerance limits and it is expected that the dimensions of the manufactured jobs must lie in the given tolerance limits else, it should be reworked or rejected. Hence, in the present case the tolerance limits of the depth of the key ways should be 0.635 cm and width should be 2.5 cm as per the specification of the firm.

Figure 1: Clutch plate key way depth

So, on the basis of above cited rejection data, DPMO has been calculated for that particular assembly line with the help of following formula.www.isixsigma.com:

DPMO = (Total defect / Total opportunity) x 10, 00,000

DPMO = (15 / 220) x 10, 00,000

DPMO = 68181.8

On the basis of this DPMO, the sigma level calculation has been carried out with the help of a formula.www.isixsigma.com:

Process sigma level = 0.8406+ {SQRT [29.37 – 2.221 x Ln (DPMO)]}

Process sigma level = 0.8406 + {SQRT [29.37 – 2.221 x Ln (68181.8)]}

Process sigma level = 2.99

Above performed calculations provide a clear vision that there must be something in the whole process of keyway making which causes the variation in the process due to which clutches are rejected. After getting this numerical data, it has got cleared that production of the assembly line is at low sigma level and improvement is required. Since the rejection of clutches occurs due to key ways depth of clutch plate, it has been decided to apply DMAIC process on press shop where keyways were made on the clutch plate. Now it has got necessary to know the process of making key way of clutch plates in detail. For this purpose a process flow chart of keyway making process has been prepared which shows the various steps involve in defining the process. The process flow chart elaborates each and every step of the keyway making process and also provides the area of data collection. Process flow chart is shown in ***figure-2***. Here with process flow chart, define phase has got completed as in this phase main problem has been identified and reason behind it has also been discussed in detail. Finally process flow chart provides area of data collection (highlighted in the chart), which has been carried out in measure phase.

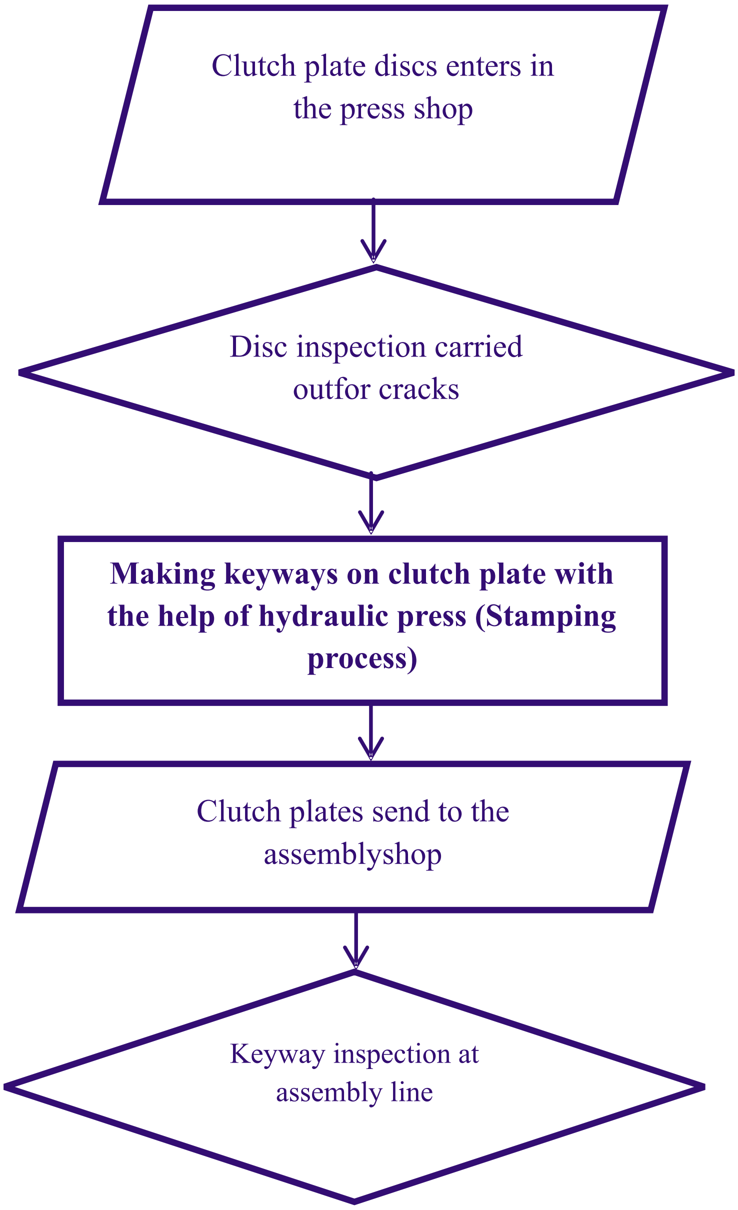

Figure 2: Process flow chart for keyway making process

4.2 MEASURE PHASE:

The measure phase consists of knowing, understanding the process thoroughly, data collection, validation of the collected data and stating whether the process is capable or not. Knowing the process is important as we must know where to and what to collect the data from, which have been already done in define phase and highlighted in bold as seen in the process flow chart. Now measure phase includes taking all the readings of the depths of the key ways, making by stamping process and to see where the mean of all these readings lie with respect to the expected value of 0.635 cm. To solve the problem of identifying the exact keyway where there was variation in depth, a small mark was placed under one of the key way and that keyway was identified as keyway 1 and going clockwise around the clutch plate the key ways was named 2, 3, 4 in successive manner and this process of numbering repeated for each clutch plate. The measurements of the depth of all four keyways were taken in every 15 minutes during a single shift are shown in the ***table-3*** and the data collected was as follows.

Table 3: Measurements of the Depth of Keyways in (cms)

Key ways → / Serial No. ↓	I	2	3	4
1	0.635	0.663	0.635	0.610
2	0.637	0.658	0.632	0.615
3	0.635	0.655	0.637	0.622
4	0.632	0.653	0.635	0.617
5	0.635	0.658	0.635	0.619
6	0.637	0.659	0.632	0.622
7	0.637	0.655	0.635	0.612
8	0.635	0.658	0.632	0.627
9	0.635	0.653	0.635	0.622
10	0.632	0.650	0.637	0.619
11	0.635	0.660	0.635	0.617
12	0.637	0.655	0.637	0.619
13	0.635	0.653	0.635	0.622
14	0.635	0.650	0.632	0.625
15	0.635	0.653	0.635	0.625

The ***table-3*** clearly shows that the depth of key way 2 and key way 4 is not as per the specification or there is high variation in the depth from the mean 635cm (set tolerance as per the firm's specification). Therefore, in order to observe these variations clearly, a process variation chart has been prepared which is shown in ***figure-3***.On process variation chart red and purple lines stands for key ways 2 & 4 which clearly shows the high variation of depth from mean, i.e. 635cm, whereas green and blue lines stands for keyways 1 and 3. The process variation chart helps to show the variation of depth of keyways clearly and also provides a strong base to move forward in the analysis phase. Process variation chart clarifies the variation in depth of keyway 2 and 4 and also raises a question that why this variation are occurring. The variation in depth is a strong reason for rejection of clutch. It penetrates researchers to find all the possible causes of the variation in the reading. There may be any reason behind this variation since the keyway making process has been carried out in various phases as shown in process flow chart. This entire quarry has been solved by deep analysis in the analysis phase.

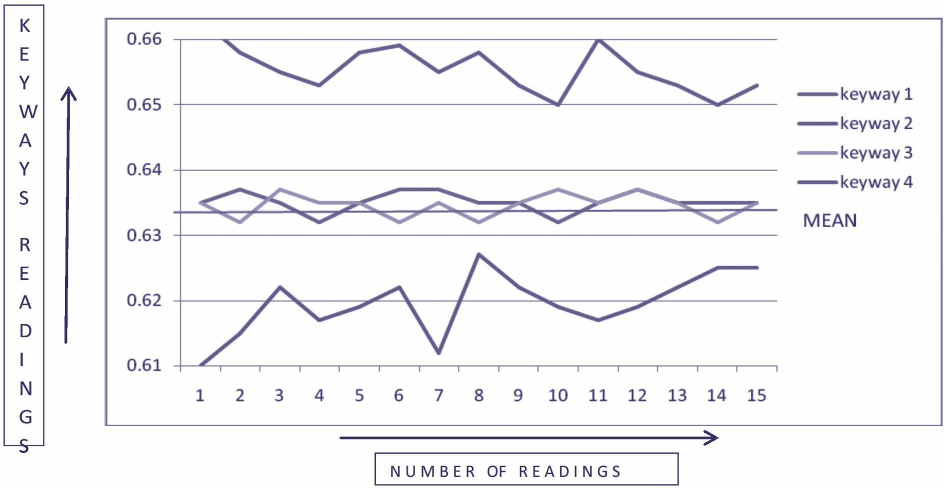

Figure 3: Variation in the Keyway Depth

4.3 ANALYSE PHASE:

From the statistical processes performed we can safely say that keyway 2 and keyway 4 were rejected. Since the process variation chart clearly shows the variation of the depth of keyway 2 and 4 is high, it is necessary to analyze and find the cause which is causing the variation in depths of keyway 2 and 4. A Cause and effect diagram shown in ***figure-4*** is constructed to analyze the causes that are causing the depth variation. A Cause and effect diagram is a graphical tool that helps identify, sort, and display possible causes of a problem or quality characteristic & also:

1. Helps to determine root causes.
2. Encourages group participation.
3. Indicates possible causes of variation.
4. Increases process knowledge.
5. Identifies areas for collecting data.

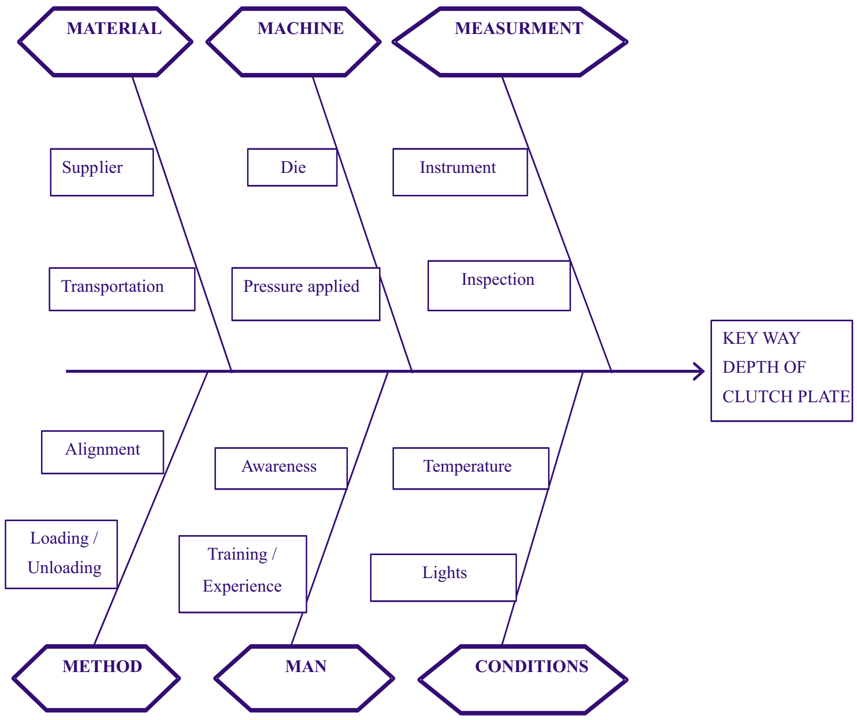

Figure4: Cause and Effect diagram

The cause & effect diagram provides areas of observation, on the basis of that, deep monitoring has been carried out with the help of industrial staff and experts of the process. Each and every area were deeply monitored and analysed by the team, which takes a whole day. From observations while overlooking the process it was noticed that the die teeth dimensions were not according to the necessities, which was causing the variations in keyway 2 and 4.Thus the 'Die Teeth Defect' was identified as the major cause of variation in the keyway depths of keyways 2 and 4 of the clutch plates. To summarize this Pareto chart shown in **figure-5**has been prepared which includes the detailed observation readings like frequency of defects occurring and from which cause they occur and their percentage of occur. An observation **Table-4** has been made to show the data obtained by observation and before which some calculations have been performed for making the Pareto chart.

- **Calculations of Percentage of defects occur & their Cumulative percentage:**

- **Percentage of defects**

1. Due to die teeth = (140/220) * 100 = 63.6 %
2. Due to the clutch plate mounting = (41/220) * 100 = 18.6 %
3. Due to pressure of cut = (23/220) * 100 = 10.5 %
4. Due to material of clutch plate = (10/220) * 100 = 4.5 %
5. Other = (6/220)) * 100 = 2.7 %

- **Cumulative percentage**

1. Due to die teeth = 63.6 %
2. Due to clutch plate mounting = 63.6 % + 18.6 % = 82.2 %
3. Due to pressure of cut = 82.2 % + 10.5 % = 92.7 %
4. Due to material of clutch plate = 92.7 % + 4.5 % = 97.3 %
5. Other = 97.3 % + 2.7 % = 100 %

Table 4: Defect observation table

Serial No.	Key areas of defect	Total production in a shift	Frequencies of defect occur	Percentage of defects occur	Cumulative percentage
1.	Defect due to die teeth	220	140	63.6 %	63.6 %
2.	Defect due to the clutch plate mounting	220	41	18.6 %	82.2 %
3.	Defect due to pressure of the cut	220	23	10.5 %	92.7 %
4.	Defect due to material of clutch plate	220	10	4.5 %	97.3 %
5.	Other	220	6	2.7 %	100 %

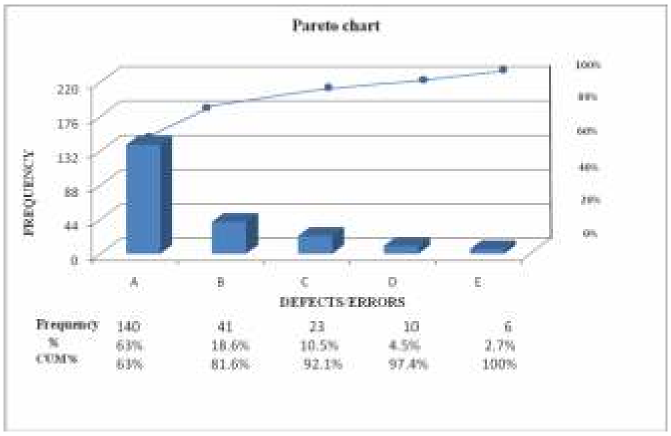

Figure 5: Pareto chart

Where,
A = Defect due to die teeth
B = Defect due to the clutch plate mounting
C = Defect due to the pressure of the cut
D = Defect due to the material of the clutch plate
E = Other

The Pareto chart clearly indicates the root cause which is die teeth defect, since while deep monitoring the defects due to die teeth were occurred 140 times in a single shift. Some other defects were also incorporated while deep monitoring process, but the defect due to die teeth were found high in percentage, therefore it was taken as a root cause and prime importance has been given to this particular case only. Finally Pareto chart provided sufficient data to move forward in improve phase.

4.4 IMPROVE PHASE:

The goal of the DMAIC improve phase was to identify a solution to the problem that has been addressed in analyse phase. This involves brainstorming potential solutions, selection solutions to test and evaluating the results of the implemented solutions. The major tool used in this phase was brainstorming, since the root cause encountered in analyse phase was die teeth defect which required the involvement of each and every person related to the process for getting the optimal solution. The major defect of the cutting keyway on clutch plate was found in die teeth as shown in ***figure-6***, so the decision of brainstorming team was to replace the die with the new one. The assembly line was only 3 months old so, the decision of the brainstorming team was to get it replaced by the supplier.

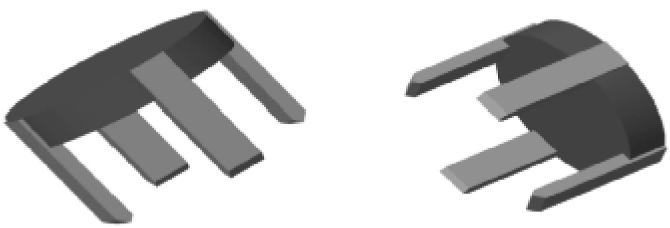

Figure 6: Die teeth

Some other solution was also discussed while brainstorming session like:

1. A computer model or other simulation can be beneficial in the evaluation process using CAD software such as Cero, which can assemble components as well as simulate the working.
2. Other manufacturing processes such as using a laser cut machine, CNC machine or a manual self-validated machine.

For the effective and efficient six sigma implementation, it was the prime importance of choosing the optimal solution for improvement. Thus the best way was to modify the system by replacing the die and hence improving the process. Finally, supplier was called with the new die to replace the existing one. After replacement of die teeth again deep monitoring has been carried out to check the correctness of the replaced die teeth, which has been found accurate. Hence, with this check the most important section of DMAIC methodology, i.e. improve phase has got completed and lastly control phase has been carried out to assure and validate the changes.

4.5 CONTROL PHASE:

The primary objective of the DMAIC Control phase was to make sure that almost the problems has been cleared and the process of making keyway has got improved, hence to ensure this DPMO and process sigma level of the assembly line have been again calculated, which has shown below:

After implementing Six Sigma DMAIC, rejection of the clutch during one shift has been reduced from**15 out of 220 units to 2 out of 220 units** according to the data obtained by the firm's quality department.
Then DPMO has been calculated again for this data,
DPMO = (Total defect / Total opportunity) x 10, 00,000
DPMO = (2 / 220) x 10, 00,000
DPMO = 9090.9

After that process sigma level of improved process has been calculated on the basis of new DPMO,

Process sigma level = 0.8406 + {SQRT [29.37 – 2.221 x Ln (DPMO)]}

Process sigma level = 0.8406 + {SQRT [29.37 – 2.221 x Ln (9090.9)]}

Process sigma level = 3.86

After performing above calculations, it has got cleared that improve on sigma level has been achieved by six sigma DMAIC implementation and the objectives have also been conquered. A chart has been prepare don the basis of above calculations, to show the visible results of an increase in sigma level achievement, which is shown by sigma level before and after implementing the Six Sigma DMAIC process as shown in figure-7.

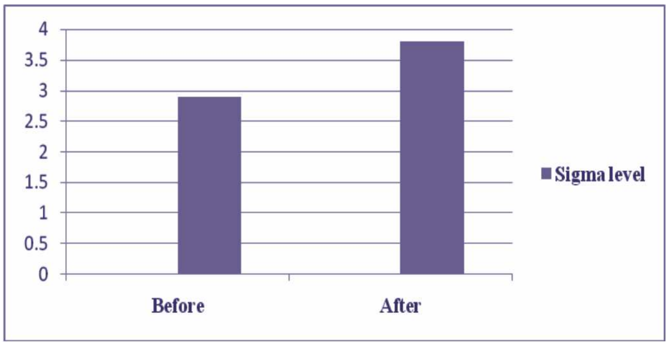

Figure 7: Visible results

5. RESULT & DISCUSSIONS

The basic objective of this study was to implement Six Sigma improvement methodology at one of the critical assembly lines of the automotive industry and illustrate the benefits drawn out of the same. The DMAIC methodology was applied to one of the chronic problems having considerable impact on the quality and productivity of the assembly line in question. Based on the rigorous analysis of various root causes several improvement measures were suggested. The implementation of DMAIC methodology resulted in understanding the problems of all aspects, qualitatively as well as quantitatively, and laying out the improvements through effective analysis of the roots of the problem. The problem of variations in depth of keyways of clutch plates was addressed satisfactorily and the rejection rate was brought down to **87 %.** The financial benefits projected as a result of this pilot Six Sigma project was to the tune ofINR **2, 08,000** for assembly line per shift. This project was taken up on one the many different clutches undergoing the same process. The potential of improvement thus appears significant if the same improvement methodology can be applied to all the assembly line of other clutches. The cumulative savings can be of very large magnitude justifying the application of Six Sigma improvement methodology across the clutches on different assembly lines.

6. CONCLUSION

This research is concerned with a case study with an aim to analyse the problem of rejection of clutch in an automobile industry due to the variations in depth of keyway of the clutch plate and to reduce it by six sigma DMAIC implementation. After implementation of Six Sigma, promising results have been obtained. Following are the important observations reflecting quality improvement of the assembly line as a result of six sigma DMAIC implementation:

a. Rejection of clutches reduced from **15** out of **220** to **2** out of **220** in single shift, which shows a huge reduction of **87%** in rejection**.**

b. Increase in process sigma level from **2.99 to 3.86**, which is increased by **30%.**

c. Significant reduction in Defects per Million Opportunity (DPMO) from **68181.8** to **9090.9.**

d. Reduction in "Loss of money due to rejections" of assembly line which was generating INR **32, 80,000** per shift before implementation .Now it is generating INR **34, 88,000** per shift, resulting in substantial saving of INR **2, 08,000** for assembly line per shift.

For the successful implementation of Six Sigma in an automotive industry critical factors like correct methodology, accurate use of tools and techniques, top management involvement and work force support are essential.

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