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Identification of Source's of Variation in an Automobile Parts Manufacturing Unit by Applying DMAIC Methodology

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***Abstract*—Identification of sources of variation and control of that variation is an important factor for the improvement of yield and quality conditions of product of any company. Actually defects rate causes a direct effect on the profit margin of the product and decrease the quality cost during the manufacturing of product. The present study is based on identification of variations in an automobile parts manufacturing unit specially, gears process. This process has large department where the gears manufactured in different processes and may be effects the quality of organization. The objective of the present study is to identifying the sources of variation using DMAIC (Define, Measure, Analyze, Improve & Control). In the DMAIC methodology different tools were used in each phase. In define phase, pareto chart and process flow charts were used to identify the problem. In measure and analyze phase, product search component and multi-vari technique were used to analyze the problem and in improve and control phase DoE(Design of Experiments) techniques were used to identify the root cause of problem.**

Keywords—Total Quality Management, DMAIC, Six Sigma, Cost of poor quality, Suspected sources of variations

I. INTRODUCTION

The reputation of any organization depends upon the quality of product. In this competitive scenario, the organizations are focusing to maintain the quality of processes to improve the quality of product. In any manufacturing process main thing should maintain by the organization that is quality of product. The study is related to automobile industry especially Gear Manufacturing unit. This study identifies the different problems occurring during manufacturing of Automobile parts (Gears) in different processes, it also highlights the critical success factors which are most important in quality point of view. It also describes the preventive action against any failure. In the Quality improvement process, DMAIC methodology is applied by the practical examples which as applied in practical field.

DMAIC or Six Sigma techniques

The DMAIC is a quality improvement strategy for an organization and now a day it is being used in many industries. "Six Sigma" is a long-term, forward-thinking initiative designed to fundamentally change the way corporations do business..." (Harry and Schroeder, 2000). Basically it is a quality improving process of final product by reducing the defects; minimize the variation and improve capability in the manufacturing process. The objective of DMAIC technique is to reduce the rejection rate due to poor quality. It increases the customer satisfaction, retention and produces the best class product from the best process performance [Pyzdek, Thomas. 2003] In order to use the Six Sigma in an organization, there are many things that are needed to achieve the financial goals in the organization as below,

- Understand the needs and who are your customers, and what is product that you want to provide the customers.
- Review of the data, consumer survey report, and feedback of customers and determine the product standard that we provide and quality service.
- Find out what are the defects are occurring and why these are produce during the manufacturing of process and how to reduce these problems by the different method.
- After implementation of different improvement actions, set up good matrices and follows up these actions and become the new standard of operating process.

Methodology used in Six Sigma

Present Methodologies for Six Sigma Implementation as Pyzdek (2003) has classified Six Sigma tools into three categories:-

(i) Basic Six Sigma methods (are further categorized as problem solving tools, 7M tools, and knowledge discovery tools).

(ii) Intermediate Six Sigma methods include a host of enumerative and analytical statistical tools like Distributions, Statistical inference, Basic control charts, exponentially weighted moving average (EWMA) charts etc.).

(iii) Advanced Six Sigma methods are Design of experiments (DOE) Regression and correlation analysis Process capability analysis etc. At the heart of the Six Sigma approach is the application of DOE techniques. These techniques help to identify key factors and to subsequently adjust these factors in order to achieve sustainable performance improvements. While the basic and intermediate methods are relatively easier to understand and use, the advanced methods are perceived to be difficult to comprehend and interpret. Design of Experiments (DOE) is one such tool. The complexity of these DOE techniques that are often cited by companies as to the reason why they are unable to employ Six Sigma.

Design of Experiment (DoE) technique used

An alternative to the Classical and Taguchi experimental design is the lesser known but much simpler Shainin DoE approach developed and perfected by Dorian Shainin (Bhote and Bhote, 2000), consultant and advisor to over 750 companies in America and Europe. Shainin's philosophy has been, "Don't let the engineers do the guessing; let the parts do the talking." Shainin recognized the value of empirical data in solving real world problems. Shainin developed techniques (Shainin and Shainin, 1990; Shainin, Shainin and Nelson,1997) to track down the dominant source through a process of elimination (Shainin,1993b), called progressive search. These techniques, also referred to as the Shainin System for quality improvement, developed over a period of over 40 years, are simple but at the same time powerful and easier to interpret and implement in an industrial environment. In a way, these may be considered as the non-parametric equivalent of Taguchi's DoE as they do not make any restrictive assumptions about population parameters. The Shainin techniques are primarily known to produce breakthrough improvements in eliminating chronic quality problems. These are highly effective in pinpointing towards the root cause and validating it. No statistical software was needed to analyze the data. In fact, Shainin DoE does not even require knowledge of difficult statistical tools. Simple operation like counts, additions, subtractions, etc., addition, the success of the projects can lead to a very positive effect on the morale of the employees in terms of convincing them that Six Sigma can be implemented without complex statistics and big jargons. The subject of the Shainin methods is very vast. However, there is a lot of scope for more research on this methodology particularly comparative research of some of the Shainin a method like Paired Comparison and B Vs C Analysis vis-à-vis the more popular statistical tools like factorial designs and nonparametric testing. Although these methods are not necessarily the best, according to Steiner et al. (2008), the guiding principles of the Shainin tools are powerful, and at least, in combination, unique. Also, these tools are best suited for batch to high volume production.

II. CASE STUDY USING DMAIC METHODLOGY

This Case study consist of Five Phase of DMAIC

1. Define Phase

Problem Definition

The operational process concerned with "Face Run out oversize after heat treatment".

- The average Rejection in last Six month is 6%.
- Maximum Rejection was 9% and Minimum rejection was 3%.

Project Planning:

Project Planning is the essential Part to achieve Goal. The aim of project planning was to set a time Period within which the project can be successfully completed.

Table :1 Project planning

Phase	July				Aug				Sept			
	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4
Define				√								
Measure & Analyze					√	√	√	√				
Improve									√	√		
Control											√	√

Pareto Analysis:

The purpose of the Pareto analysis is to highlight the most important among a (typically large) set of factors. In quality control, it often represents the most common sources of defects, the highest occurring type of defect, or the most frequent reasons for customer complaints, and so on. Pareto chart is graphical charts that helps in break the big problems down into parts and helps in identify which part are the most important. We collected Data of past six month of our problem.

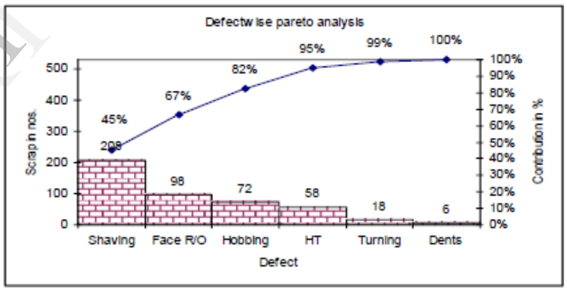

Fig:1 Pareto analysis

COPQ (Cost of Poor Quality)

After analyzing the Pareto Chart and Previous collected data it was found that,

- Number of pieces rejected last month (for the part number identified for study)- 16
- Number of pieces scrapped last month- 2
- Number of pieces reworked last month- 14
- Scrap cost/piece- 1550
- Rework cost/piece- 20
- Total scrap cost (Rs. Lakhs) for last month- 3100
- Total rework cost (Rs. Lakhs) for last month- 280
- Total Rejection cost (Rs. Lakhs) for last month- 3380
- Extrapolated Total rejection cost (Rs. Lakhs) for one year- 0.41 lacs

2. Measure& Analyze Phase

The purpose of this step is to objectively establish current baselines as the basis for improvement. This is a data collection step, the purpose of which is to establish process performance baselines. This phase presents the detailed process mapping, operational definition, data collection chart, evaluation of the existing system, assessment of the current level of process performance etc. For identification of variation three tools were used in these phases that were Paired Comparison, Product Process Search and Multi-vari analysis.

Paired Comparison

Paired comparison models are used to analyze data from experiments in which a p objects are compared in block of size 2. One advantage of this type of design is that the differences in the outcome measures under one product treatment or the other reflect only the effect of that product since everything else in the units receiving the treatments is absolutely identical.

Can be used only when the SSV's are measurable on both Good and Bad products:

•Good and Bad parts are selected based on the response defined in the Problem definition

•Response can be either attribute or Variable

•SSV scan be either attribute or Variable

•If the SSV's are attribute, then they need to be converted to a scale of at-least 1-5

•Generally this is applicable to input material related SSV's:

$$Y = f(X)$$

Where Y is response and X is SSV (which is Input material parameters and Process parameter values) whose data is already available for Bad and good components.

Data Collection

• 8 Good and 8 Bad parts were selected based on RESPONSE ('Y')

• When selecting Good and Bad, Best of Best (BOB) and Worst of Worst (WOW) parts selected.

• Each SSV ('X') was measured on the 16 parts and results were recorded in a table-2

• Identified BOB and WOW responses using the data.

• Selected one parameter at a time for analysis

• Then, arranged the values in the ascending order and indicated whether the value had come from a Good or Bad by putting 'G' or 'B' within bracket

Step1.Count for SSV (Rib Thickness)

Table: 2 Count for SSV(Rib thickness)

Sr. No.	Rib Thickness	Response
1.	19.68	G
2.	19.70	B
3.	19.70	B
4.	19.70	G
5.	19.72	G
6.	19.72	B
7.	19.74	G
8.	19.75	B
9.	19.75	B
10.	19.75	B
11.	19.78	G
12.	19.80	B
13.	19.80	G
14.	19.82	G
15.	19.82	B
16.	19.86	G

From the above data it was concluded that both the Top and bottom value belongs to same Category i.e. good, So the total count is zero which means maximum and minimum thickness falls under same category. This means that Rib thickness was not contributed to face run out.

Step2.Count for SSV (Distance)

Table: 3 Count for SSV (Distance)

Sr. No.	Distance	Response
1.	0.6	B
2.	0.8	G
3.	0.8	G
4.	0.8	B
5.	0.9	G
6.	1	G
7.	1	B
8.	1.2	G
9.	1.2	B
10.	1.3	G
11.	1.4	B
12.	1.6	B
13.	1.8	G
14.	2	G
15.	2	B
16.	2.4	B

From the top, checked where was the first time either good was changing to bad or bad was changing to good then from the drawn a line at the transition point. Similarly, from the bottom, it was checked where the first time either good was changing to bad or bad was changing to good, drawn the line at the transition point.

There was having two values same in the transition line which was reduce to ½ count and add both, and the total count came was to be 2.5, which was less than 6 (from the table 4). It was observed that distance from flange face to rib face did not contribute to face run out.

Table: 4 Standard min. value of count

Count	Confidence level (CL %)
6	90%
7	95%
10	99%
13	99.9%

Step 3.Count for SSV (Face Run Out before Heat Treatment).

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Table: 5 Count for SSV

Sr. No.	Face Run Out	Response
1.	0.05	G
2.	0.05	G
3.	0.06	G
4.	0.06	G
5.	0.08	G
6.	0.08	G
7.	0.09	B
8.	0.09	B
9.	0.1	B
10.	0.1	B
11.	0.12	G
12.	0.12	B
13.	0.14	B
14.	0.14	B
15.	0.16	B
16.	0.21	B

Here more than two values were same according to Shanin rule treat the entire block as one data and drawn the transition line and counted the number above transition line and also counted the number below transition line.

From the collected data before heat treatment process, after calculating total counts it was 11 which was greater than 6 (from table 3.5) which shown face run out before heat treatment contributed to the face run out after heat treatment.

From the above, data it was analyzed that the before heat treatment there were some variations in the process which contributed to the face run out after treatment. Objective was clear to eliminate the source of variation. On further drill down the selected source of variations before heat treatment process came out were as follow:-

1. Face run out before broaching process.
2. Broaching Process.

The tools used for these suspected sources analysis were Product Process Search (PPS) and Multi Vari Analysis (MVA's).

Product Process Search (PPS)

This tool is used to identify the SSV related to the Process parameter. It is used when the SSV's are related to input material dimensions, but the dimensions will get changed during processing preventing the application of Paired comparison. SSV's can be either attribute or variable, Response can be either attribute or variable. In this tool Data Collection is different from paired comparison.

Data Collection

Table: 6 Data for face run out

S.NO.	FACE R/O	RESPONSE	S.NO.	FACE R/O	RESPONSE
1	0.02	G	51	0.025	G
2	0.03	G	52	0.02	G
3	0.02	G	53	0.015	G
4	0.03	B	54	0.025	G
5	0.02	B	55	0.015	B
6	0.025	G	56	0.025	G
7	0.03	G	57	0.02	G
8	0.05	G	58	0.04	G
9	0.05	G	59	0.02	G
10	0.035	G	60	0.03	B
11	0.02	G	61	0.02	G
12	0.02	G	62	0.03	G
13	0.025	B	63	0.02	G
14	0.05	G	64	0.025	G
15	0.02	G	65	0.03	G
16	0.02	G	66	0.05	G
17	0.045	G	67	0.05	G
18	0.02	B	68	0.035	G
19	0.045	G	69	0.02	G
20	0.02	G	70	0.02	G
21	0.035	G	71	0.025	G

Firstly, some random parts were selected that will be processed (say 71 no's) for measurement of suspected source of variation (SSV) and then measured the process parameter were studied then the result was arranged in the ascending or descending order to pick up the eight good and eight bad responses. The data is shown in Table. 3.8.

Count for SSV (Face run out before Broaching):
Table: 7 Count for SSV (face r/o before broaching)

Sr. No.	Face Run Out	Response
1.	0.015	G
2.	0.015	G
3.	0.015	G
4.	0.015	G
5.	0.015	G
6.	0.015	G
7.	0.015	G
8.	0.015	G
9.	0.015	B
10.	0.015	B
11.	0.02	B
12.	0.02	B
13.	0.02	B
14.	0.02	B
15.	0.02	B
16.	0.02	B

Here it was found that Min value contains both good and bad. Hence count was zero. Which shows that face run out before the broaching was not the reason for face run out after broaching.

Multi- Vari Analysis (MVA's)

Multi-Vari Analysis or Multivariate technique consists of collection of methods that can be used when several measurements are made on each individual or object in one or more samples. We will refer measurement as variable and to the individuals or objects as unit. Multivariate technique has spread in many areas for examples multi-vari technique can be used by researchers for educational purposes, business, literature, religion etc shows some example of multi variance observation.

Multi-Vari analysis can help narrow a list of potential causes down to a precious few by focusing attention on the source of variation that need further study.

Data Collection

First step of data Collection was to check whether there were any stream in the process. It was found that there was no streams in the process, hence there were two types of variation that could be occurred, one was Time to Time and other was Part to Part.

Then 3-5 units each time were collected continuously and left some time block and collected another 3-5 continue like this for the entire time fixed. If the rejection% was less (say<=0.5%),then it was necessary to collect data continuously without given any time interval between two time blocks.

Table: 8 Multi Vari Analysis of Hobbing Process

T1	S1		T3	S1
	0.15			0.16
	0.05			0.15
	0.07			0.05
AVG	0.09		AVG	0.12
RANGE	0.1		RANGE	0.11
T2	S1		T4	S1
	0.12			0.04
	0.07			0.08
	0.08			0.06
AVG	0.09		AVG	0.06
RANGE	0.05		RANGE	0.04
Part to Part	0.11		Part to Part Variation is Higher than Time to Time Variation	
Time to Time	0.07			

After collecting data from different time intervals and after calculating their ranges and averages, it was found that Part to Part variation was high than time to time variation as given below.

Part to Part variation-**0.11**

Time to time variation-**0.07**

From here, it was concluded that broaching process was the reason for face run out. Now the next step was to found the cause of variation in the broaching process. For this brainstorming was done to found the suspected sources sources of variation in broaching process.

SSV's for Broaching Process

The following sources were considered to find the main suspected source which was causing face run out in broaching process :

1. Flatness of resting plate.
2. Resting plate thickness (for strength).
3. Play between broach slide & main guide ways of broaching machine.
4. Alignment of two broach holders.
5. Machine leveling.
6. Broach Holder.

Verification of SSV's

1. Flatness of resting plate- It was thoroughly checked and was found that it conform the manufacturing standards.
2. Resting plate thickness for strength- It was thoroughly checked and was found that it conform the manufacturing standards.
3. Play between broach slide &main guide ways- It was thoroughly checked and was found that it conform the manufacturing standards.
4. Alignment of two broach holders- It was thoroughly checked with the help of mandrel and found that it did **not** conform to the manufacturing standards.
5. Machine levelling- It was thoroughly checked with spirit level and found that it conform the manufacturing standards.
6. Broach Holder- The broach holders were checked and lower broach holder did not conformed the manufacturing standards**.**

The misalignment of two broach holders was due to worn out pins in the lower Broach holder. Hence new broach holder was made with the help of maintenance department and introduced the permissible parameter of broach holder in checklist for preventive maintenance.

3. Improve Phase

Conclusions of earlier phase are used as an input to this phase. Once optimum settings are set then, it is necessary to validate it. This was done, by using the Shainin B vs. C analysis, which is a confirmation tool to verify whether the actions taken have actually improved the process (Bhote and Bhote, 2000). In this case, 6B vs. 6C, i.e., 6 batches (10 units per batch) with modification and 6 (10 units per batch) without modification (B– with modification and C– without modification) was analyzed to validate the improvement action, i.e., the modification of machine operating parameters. The data in table exhibited the responses with B and C conditions. As per rule of this technique, the final analysis is done based on the 'end-count scheme'. In this case, end count is 11 (greater than 6), which confirms that identified root causes are correct.

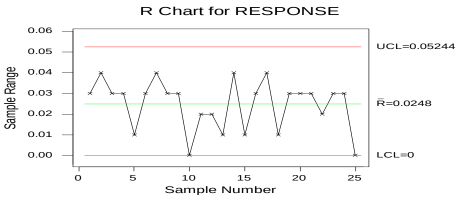
Table: 7 Validation of Root cause- BvsC

Piece / Lot	Better (B)	Current (C)
1	0.01	0.07
2	0.04	0.10
3	0.03	0.08
4	0.01	0.04
5	0.02	0.07
6	0.03	0.05

The data in table exhibited the responses with B and C conditions. As per rule of this technique, the final analysis is done based on the 'end-count scheme'. In this case, end count is 11 (greater than 6), which confirms that identified root causes are correct. From the analysis, it is clear that the improvement has taken place at 95% CL. The worn out pins in the lower Broach holder was the main root cause and that was replaced with new broach holder. The improvements identified were also used to set the action plan for other varieties of such components for horizontal deployment.

4. Control phase:

The focus of the control phase is to sustain the gains of the improvement phase. This is usually achieved by documentation and standardization of the control measures. To check further is any control required or not, DoE (Design of Experiment) techniques used. By calculating overall average and Range and after finding process capability. It was clear that there is no need of any control. In this phase only recommendation was to check
regularly with the help of control charts as shown in fig.



III. CONCLUSION

It is discussed in the study about all phases needed to eliminate the variations in the gear manufacturing unit and the Shainin techniques were used for problem formulation which was very helpful in the study, The problem was formulated using many quality control tools, like flow chart, Pareto chart for defining phase, Product Search and multi-vari analysis in measure & Analyze phase, R-bar chart and histograms in control phase. This case study was carried out with worked in a systemic way and tried to improve quality management system of the organization.

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