Fault Detection Analysis & Diagnosis of Rotor by Six Sigma Methodology

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Abstract:
*The purpose of this dissertation work is to solve the problem of **chronic** issue of Automobile part, using Seven QC Tool of Six Sigma concepts, produced at Mahindra gears & transmission Pvt. Ltd. (MGTPL) situated at Shapar GIDC, Rajkot Gujarat. MGTPL is the leading manufacturing industry of the automobile products in Gujarat. Mahindra has two branches across the India, one is situated in Pune, and another is in Rajkot. MGTPL has three units in Rajkot MGTPL makes many parts like automobile gears, clutch components, differential gears, shafts, axles etc. Amongst them Rotor 4302242 is the part required high accuracy manufacturing. Because Eaton corp. Ltd. USA, is the customer of MGTPL, and rotor is imported by Eaton corp. Ltd. USA. High precision is required in manufacturing of rotor 4302242. Amongst many options here we have used Seven QC Tools of Six Sigma. Project objectives were set in Define phase to increase the yield of functionality. Seven QC tool phenomena are associated with the main causes of the rotor which leads the problem to the end solution. For this industrial Problem formulation is carried out to determine the main causes and impact of those caused on our fault analysis. Rejection of this component is depended on main causes like, internal bore grinding tapered, and peripheral damages on mating surface of the Rotor Speedometer etc. combine use of Magnificent Seven QC Tool and DMAIC concept we have analyze the whole thing and found all defects, and justify the weight age of above particular defects. Finally we can remove the all defects and decrease the rejection of rotor Speedometer from 2 Sigma to 6 sigma level and save 3.2 million rupees loss.*

Keywords: *4302242, DMAIC, MGPTL, Heat treatment, Rotor, Six sigma, Seven qc tools, Defects, etc.*

1. Introduction

In the early and mid-1980s with Chairman Bob Galvin at the helm, Motorola engineers decided that the traditional quality levels-measuring defects in thousands of opportunities - didn't provide enough granularities. Instead, they wanted to measure the defects per million opportunities. Motorola developed this new standard and created the methodology and needed cultural change associated with it. 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. Since then, hundreds of companies around the world have adopted Six Sigma as a way of doing business. This is a direct result of many of America's leaders openly praising the benefits of Six Sigma. Leaders such as Larry Bossidy of Allied Signal (now Honeywell), and Jack Welch of General electric company. Rumor has it that Larry and Jack were playing golf one day and Jack bet Larry that he could implement Six sigma Allied signal. The results speak for themselves.

Table 1 Rejection rate as per sigma level

Quality level in sigma	Rejection in ppm of products
2 sigma	308537
3 sigma	66807
4 sigma	6210
5 sigma	233
6 sigma	3 to 4

Table 1 shows the rejection of product per million numbers of products. By this number we can understand the need of the quality improvement. If industry doesn't aware of quality as well as accuracy then it suffered more loss by way of rejection. Six Sigma is a quality movement, a methodology, and a measurement.

1.1 Process Capability

A process is a unique combination of tools, materials, methods, and people engaged in producing a measurable output; for example a manufacturing line for machine parts. All processes have inherent statistical variability which can be evaluated by statistical methods. The Process Capability is a measurable property of a process to the specification, expressed as a process capability index (e.g., C_{pk} or C_{pm}) or as a process performance index (e.g., P_{pk} or P_{pm})as shown in figure 1. The output of this measurement is usually illustrated by a histogram and calculations that predict how many parts will be produced out of specification.

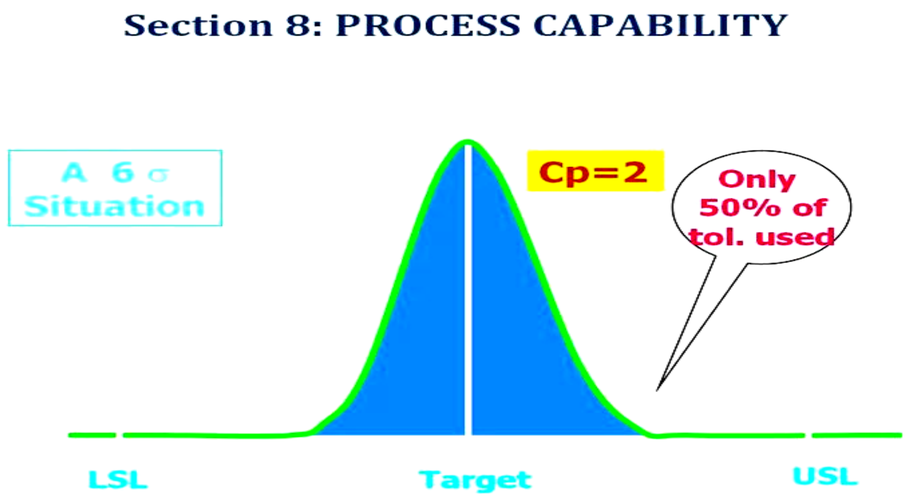

Fig. 1 Six sigma control the Tolerance

1.2 Company profile

Figure 1 shows the external image of unit 3 of Mahindra Gears & Transmission Pvt. Ltd.(MGTPL). MGTPL has three branches across the India. One of the branch of MGTPL is situated at Rajkot. MGTPL has three units in Rajkot.

Fig. 2 Shop floor of MGTPL

Production is most important for every industry. Rajkot is the city of business paradise so there are many business company situated in Rajkot. Mahindra Gears & Transmission Pvt Ltd. (MGTPL) is earlier known as a SAR auto which makes transmission components was established in 1987 at Shapar (Veraval), Dist. Rajkot. MGTPL is one of the leading manufacturers of proven quality gears and other transmission parts in India, since last 21 years.

1.3 Product description

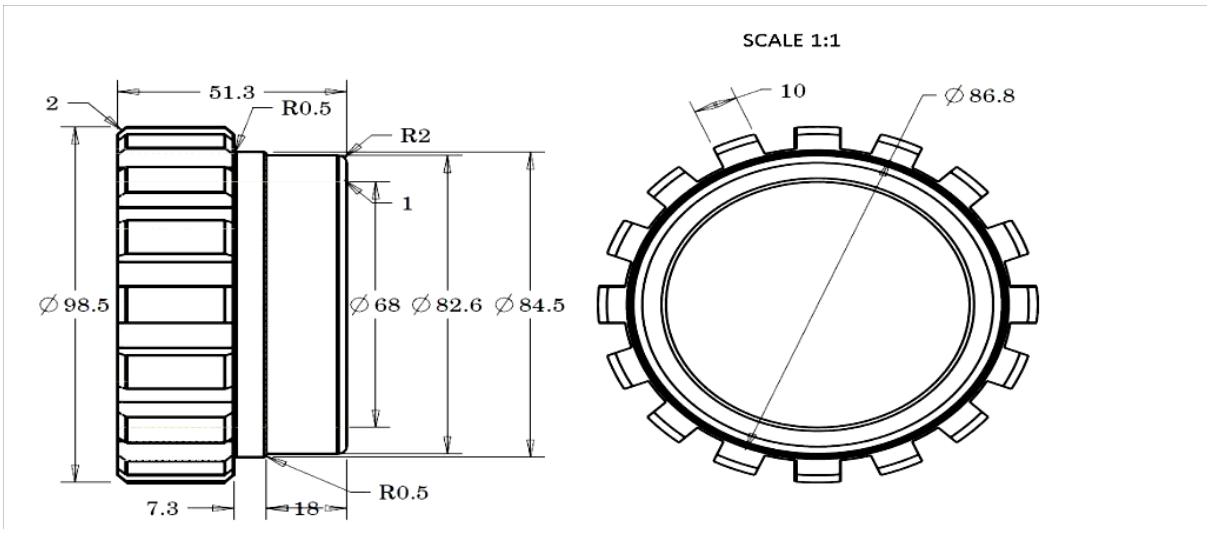

Fig. 3 2D drawing of Rotor

Rotor is used in speedometer to sense the rotation of the axle shaft and give the output as the rpm. Fig. 3 shows the two dimensional view of rotor 4302242, so we can see the peripheral surface of the rotor exactly and the nicks of the opposite side of rotor can be seen from the fig. From above figure all dimensions can be measured. We can also see the top view and front view from fig. 3.

1.4 Annual economic loss

Now we consider the total cost of our work piece to calculate the loss due to the rejection. Cost of Rotor Speedometer is Rs. 800/piece, and rejection is 4100 parts/year. So about total loss of Rs.

32840000 loss/year has to be suffered by Mahindra Gears & Transmission Pvt. Ltd. To minimize this loss Mahindra Gears & Transmission Pvt. Ltd. must take some drastic changes.

2 Problem Formulations

So for my dissertation work we have used the some important tools of six sigma methodology in this product. To find stage of defects where the defects are generated exactly, we prepare the check sheet and classify each and every manufacturing process deeply. Seven qc tools are utilized with the DMAIC concept to find and remove the defects during the manufacturing of rotor. So the defects are found in next topic, with use of cause & effect diagram. After that use of parato analysis in analyze phase we calculate the individual percentage of defects, so we optimize the main causes of rejection of rotor 4302242.

2.1 Check sheet

A check sheet is one of the seven basic quality tools. Data collection can often become an unstructured and messy exercise. It is a simple form you can use to collect data in an organized manner and easily convert it into readily useful information. Data collection is important because it is the starting point for statistical analysis. A check sheet is a table or a form used to systematically register data as it is collected. Fig. 4 shows the all causes with related to each defect, so list out the all defects below for more clarification. Part being ovaled during heat treatment. The peripheral damage is occurred on rotor. Due to the handling error nick damage is occurred. Some parts damage during the cleaning process. During the Internal Diameter Grinding some parts are found defected [7].

Table 2 Check sheet

Sr. No.	Finished Blank (supplier)	After Hobbing	After filling	After heat treatment	After short blasting	After Bore Hard Turn.	After cleaning	O.D. Grind.
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	1	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0
12	0	0	0	1	0	0	0	0
13	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	1	0
18	0	0	0	0	0	0	0	1
19	0	0	1	0	0	0	0	0
20	0	0	0	1	0	0	0	0

Sr. No.	Finished Blank (supplier)	After Hobbing	After filling	After heat treatment	After short blasting	After Bore Hard Turn.	After cleaning	O.D. Grind.
21	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0
24	0	0	0	1	0	0	0	0
25	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	1
27	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	1
32	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0
35	0	0	1	0	0	0	0	0
36	0	0	0	0	0	0	1	0
37	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0
39	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	1
41	0	0	0	1	1	0	0	0
42	0	0	0	0	0	0	0	0
43	0	0	0	1	0	0	0	0
44	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0
47	0	0	0	1	0	0	0	0
48	0	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0
	1	**4**	**1**	**6**	**0**	**1**	**3**	**1**

During the problem identification in Rotor, first classify the defects which are faced by the organization during the manufacturing of this part. The detail study regarding identification of defects will be shown in the chapter of methodology, so here we formulate the problems or defects. Fig. 4 shows the all causes with related to each defect, so list out the all defects below for more clarification.

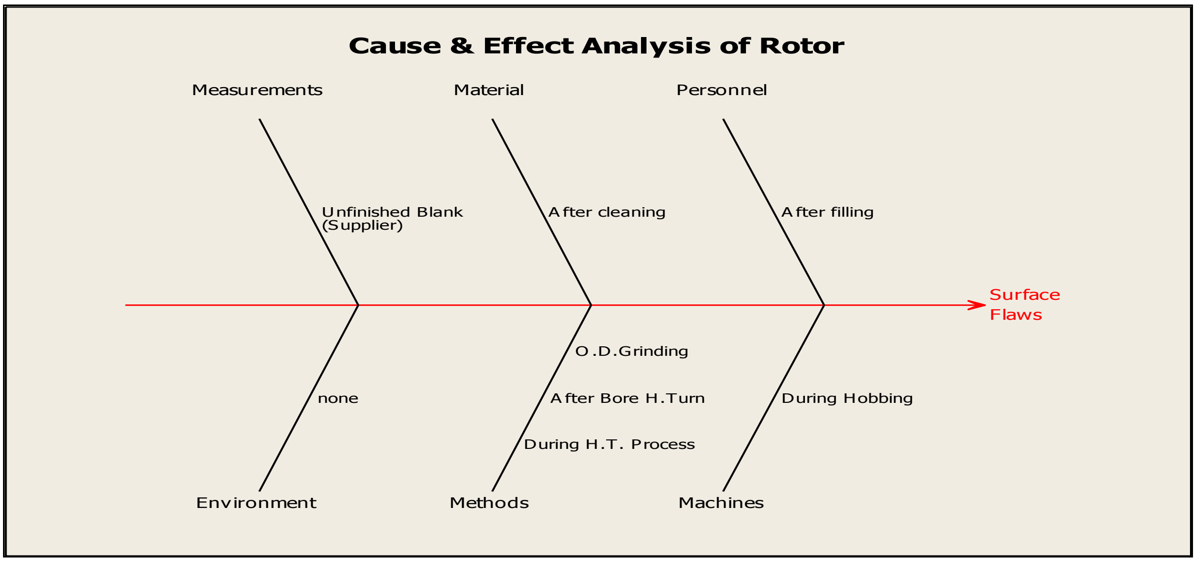

Fig. 4 Cause & Effect Diagram

- Part being ovaled during Heat Treatment.
- The peripheral damage is occurred on rotor.
- Due to the handling error nick damage is occurred.
- Some parts damage during the cleaning process.
- During the Internal Diameter Grinding some parts are found defected.

4. Methodology (DMAIC Cycle)

Nowadays, Six Sigma represents the strategy combing the Six Sigma statistical measure and TQM. The approach used in Six Sigma to solve problems is the DMAIC cycle, which stands for Define, Measure, Analyze, Improve and Control, the steps taken to attain Six Sigma quality management. The DMAIC problem-solving methodology is particularly very useful combine with Seven QC tools [8].

- Define: Identification of the process or product that needs improvement.
- Measure: Identify those characteristics of the product or process that are critical to the customer's requirements for quality performance and which contribute to customer satisfaction.
- Analyse: Evaluate the current operation of the process to determine the potential sources of variation for critical performance parameters.
- Improve: Select those product or process characteristics which must be improved to achieve the goal. Implement improvements.
- Control: Ensure that the new process conditions are documented and monitored via statistical process control methods (SPC).

4.1 Define phase

It is one of the phases of the six sigma methodology in which the experimental set up is carried out and the whole manufacturing processes are described. During the study of each and every processes problem will be found and formulated. Here list out the all processes carried out for manufacturing of our part rotor.

1. Soft turning 2.Hobbing 3. Heat treatment 4. Shot blasting 5. Bore hard turning 6. Zinc plating 7. O. D. Grinding 8. O.D. Lapping.

4.2 Measure phase

It is the second phase of six sigma quality control methodology. In measure phase we take the readings of different operation and summarized them. The development of the process map (SIPOC diagram) gives separation to manufacturing processes.

Table 3 Sipoc Diagram

Supplier	Input	Process	Output	Customer	Quality gate
Horizon	Rough turn.	Finish turn.	Finish turn. done	Store	Y
Store	Finish turn.	Tooth cutting.	Tooth cutting done	Filling	Y
Gear shop	Filling done	Marking	Marking done	Heat treatment	Y
Heat treatment	Marking done	H.T. operation	H.T. done	Shot blast.	Y
Heat treatment. shop	Heat treatment. Done	Short blast.	Short blast. done	Hard turn.	Y
Short blast.	S.B. done	Hard turning	Bore &face hard turn.	Final inspection	Y
Eaton cell	Bore & face hard turn.	Inspection	Ins. done	cleaning	
Eaton cell	I.D. grinding	Lapping	Lapping done	Final inspection	Y
Final ins.	Inspection	Oiling	----	packing	

4.3 Analyze phase

In this phase of DMAIC cycle we equate and calculate each and every error with possible causes and analyze that data in a particular manner so we can improve that stage of defects after this phase. During the investigation we found the major types of defects describe below**.**

4.3.1 Defect occurs in Hobbing process

During the Hobbing operation before use of Six Sigma methodology the two unfinished rotor parts are held together for tooth generation. During Hobbing process heat generation is in large amount. As shown in Figure 4 the meshing surface of the rotors are affected by high heat generation and two rotors are joint at that peripheral surface. After Hobbing at the time of separation peripheral surface of rotor has been damaged. So, we have to consider the improvement. Hold single part at a time, is a way to remove the peripheral surface damage of the rotor.

4.3.2 Trouble shooting in Heat treatment

Table 3 shows the internal bore size before Six Sigma implemented. It seems to be less accurate because the quality level is below 3 Sigma from below readings.

Table 4 Before Six Sigma Reading of Internal Bore

Part Sr. No.	Internal Bore Grinding Reading(mm)	Part Sr. No.	Internal Bore Grinding Reading(mm)
1	**69.833**	26	69.841
2	69.839	27	69.851
3	69.842	28	69.855
4	69.845	29	69.853
5	69.840	30	69.851
6	69.841	31	69.858
7	69.849	32	69.844
8	69.850	33	69.840
9	69.855	34	69.841
10	69.858	35	69.848
11	69.851	36	69.843
12	69.848	37	69.857
13	69.858	38	69.852
14	69.850	39	69.849
15	69.853	40	69.838
16	69.851	41	69.848
17	69.848	42	69.842
18	69.840	43	69.846
19	69.845	44	69.844
20	69.844	45	69.841
21	69.842	46	69.840
22	69.843	47	69.848
23	69.847	48	69.845
24	69.846	49	69.847
25	69.849	50	69.859

Table 4 shows the values of different variables which are plotted on the different axes of contour plot analysis. From above data with use of contour plot Minitab gives the optimum analysis of sample size, rejection rate with different zone as shown in fig. simultaneously Minitab analyze the effect of carbon content also.

Table 5 Values of Three Variables

Carbon percentage C1	Rejection C2	Sample size C3
0.82	3	30
0.84	5	40
0.56	6	50
0.88	4	35
0.90	6	45
0.92	4	40
0.94	7	60
0.96	7	55

Table 5 is shown the contour plot analysis of the Heat treatment process of rotor 4302242. In this analysis use three variables for all three axes X, Y and Z. Here 3 variables are carbon percentage, rejection rate sample size are taken on X, Y and Z axes respectively. From below figure, On X axis carbon percentage is plotted. On Z axis rejection rate is shown, and the sample size is plotted on Y axis.

4.4. Identifying potential solution (Improve phase)

To overcome the defects in Heat treatment shop first we short out the all sources of generating the defects by study the micro study of H.T. process. Then we can see that the error occurs due to the loading operation of rotor, so we consider the different designs of loading equipment and finally we find that due to the bar loading of the product the heat distribution is not uniform in all rotor loaded in bars.

Fig. 5 Bar loading of rotor in H.T.

Fig. 6 Basket Loading of Rotor in H.T.

So, we improve the loading buckets and rotor loads in basket with base of metal net. Then we put these baskets in H.T. furnace. After the H.T. process is finished, we put out all the parts and check the diameter and we see that the defect during H.T. is removed. And diameter ova ling error didn't generate now.

4.5 Control phase

The primary objective of the DMAIC Control phase is to ensure that the gains obtained during Improve are maintained long after the project has ended. To that end, it is necessary to standardize and document procedures, make sure all employees are trained and communicate the project's results. In addition, the project team needs to create a plan for ongoing monitoring of the process and for reacting to any problems that arise.

4.5.1 Standardizing and documenting the improvements

The first step of the Control phase is to document and standardize the improvements that were rolled out during Improve. This takes several forms. The process map of the new process that was created during Improve should be reviewed and updated as necessary to reflect any modifications that may have occurred during roll out. It will be used for training and reference so that the new process will be clear. If many individuals or groups are involved in the process, a deployment flowchart should also be developed to clarify roles and tasks.

5. Conclusion

For the MGTPL project, our objective was to implement the Six Sigma methodology to improve the process capability and minimize the number of defects in rotor. Before implementation of six sigma the annual rejection of rotor is about 4100 parts, and the approximately loss is 3200000

Rs. per year. So we priories this component in our dissertation work in MGTPL. We have executed Seven QC tools combine with the DMAIC cycle to achieve our objective, going through the Define, Measure, Analyse, Improve, and Control phases. At starting stage the quality level is below 3sigma. So we have done micro study of each and every process which is connected to manufacture the rotor component. We have also investigated the handling and transportation issues related to our component. It helps to achieve our target and reduce the loss due to the rejection of rotor up to 3.2 million Rs.

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