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PRODUCTIVITY IMPROVEMENT BY REDUCING DEFECTS IN TURNING PROCESS THROUGH DMAIC APPROACH

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ABSTRACT

In the paper is presented a Six Sigma project, undertaken within company for machining various automobile components, which deals with identification and reduction of defected items of Cab Mounting Bracket and Actuator Mounting Bracket. The objectives are achieved by application of Six Sigma approach to quality improvement project in machining industry. The work follows the DMAIC (Define, Measure, Analyze, Improve, and Control) technique to examine defects, root causes and provide solution reduce these defects. Defects rate is important as industry point of view. It plays a very important role for the improvement of defect rate & financial conditions of company. Actually defects rate causes a direct effect on the profit margin of the product & decrease the quality cost during the turning of the product. By checking & inspection of defects of product at different point in machining where more defects are happen. Maximum type of defects is found in cab mounting bracket and Actuator mounting bracket. That's why it is decided to do work & implement DMAIC methodology in machining industry. The percentage of rejection decreases from 10.09 % to 4.94 % for cab mounting Bracket and 10.97 % to 5.75 % for Actuator Mounting Bracket. The application of several Six Sigma tools such are project charter, cause and effect diagram, design of experiments, S/N ratio, and Sigma level are used.

The possibility of application of several Six Sigma such as design of experiments (DOE) and analysis of variance (ANOVA) techniques were combined to statistically determine the correction of the cutting speed, feed rate and depth of cut with defects as well as define their optimum values needed to reduce the defects. Sigma Level improves after study from 2.90 to 3.16 for cab mounting bracket and 2.88 to 3.09 for Actuator Mounting Bracket.

KEYWORDS: *DMAIC approach, Six Sigma, Defects, Cause and effect analysis, Productivity, Taguchi method*

1. INTRODUCTION

The basis of the Six-Sigma method is statistics; sigma stands for standard deviations from the mean of a collection of data in different way is calculate of variation, while Six-Sigma represents for six standard deviations from the average. When a method reaches the Six-Sigma level that process will be operation close to precision, produce a simple 3.4 defects of each million. By utilizing statistical and analytical tools firms can reduce the amount of variation in a process by removing the causes of variation therefore increasing the output quality of the process.

DMAIC is a theory that enhances quality via looking the information for the fundamental reason for quality issues and applying control. So as to actualize the reasoning of DMAIC display six sigma, we require a system which will push us to really give our thoughts something to do. This system is called DMAIC philosophy. This structure changes over the issue into something unmistakable that can be estimated, so an answer can be arrived at. This strategy can be utilized most viably when any procedure or item does not meet client desires. The DMAIC procedure is a center segment of the Six Sigma methodology.

This case study was carried out at a machining industry where many type of product are machined. The company had several complaints of defects in cab mounting bracket and actuator mounting bracket leading to customer dissatisfaction.

The purpose of work is

- To study and find out optimum parameters for reducing defects in machining industry
- To calculate the current sigma level of machining industry
- To develop in order to get competitive advantage in the long run
- The objective of this research work is was to significantly reduce these defects. For improvement we are using six sigma DMAIC method.
- To give suggestions for improvements by using Six-Sigma DMAIC process improvement methods

Six-Sigma is a culture or theory of value control which occupied the whole association. It is information driven approach which plans to decrease and control defects; bringing about enhanced process or item effectiveness. Six-Sigma is a statistical estimation of just 3.4 defects for each million. DMAIC is a technique to :

1. Identify the opportunities for improvement
2. Define and rectify problems
3. Set up measures to continue the improvement

The fundamental objective of this approach is achieving level of value and dependability that will fulfill and even surpass requests and desires for the present requesting client. It builds up a quantifiable status to accomplish and exemplifies a key critical thinking strategy to increasing customer. Fulfillment and drastically reduce cost and increment benefits. Six-Sigma gives regulation, structure, and an establishment for strong basic leadership in simple statistics. The genuine intensity of Six Sigma is basic since it joins people power with process power.

A term Sigma Quality Level is utilized as a marker of a procedure goodness. Low sigma level identify maximum possibility of defective items produce, while high sigma level identify minimum possibility of defective items produce within process

2. LITERATURE REVIEW

Six sigma a set of management techniques [13] intended to improve business processes by greatly reducing the probability that an error or defect will occur. The DMAIC process is a core component of the methodology. For improvement in existing process we are using this method. The Six Sigma DMAIC [14] methodology can be thought of as a roadmap for problem solving and product/process improvement. Many industries start implementing Six Sigma using the DMAIC technique. Mast and Lokkerbol (2012) [15] is defined six sigma an organized and systematic method for strategic process improvement and new product and service development that relies on statistical methods and it is a method to reduce defect rate defines by not filled requirement of customer.

Gupta (2013) [2] presented a quality improvement study applied at a yarn manufacturing company based on six sigma [11] methodologies. In this project for increasing productivity through reducing the defects rates at the last section of department, DMAIC process is used. Sharma and Rao (2014) carried out a work through DMAIC technique [9] to reducing the process variation of the stub-end-hole hole boring operation of the manufacture of crankshaft. The critical-to-quality (CTQ) characteristic is defining for statistical process. By adopting DMAIC approach, standard deviation is reduced from 0.003 to 0.002. Kumar (2013) focus to demonstrate the empirical application of Six Sigma and DMAIC to reduce product defects within a rubber gloves manufacturing [8] organization. The design of experiments, hypothesis testing and two-way analysis of variance techniques were combined to statistically determine whether two key process variables, oven's temperature and conveyor's speed, had an effect on the quantity of defects produced, and in addition to characterize their ideal qualities expected to diminish the defects. Kumaravadivel and Natarajan (2011) [1] focuses on implementing the DMAIC (Define, Measure, Analyze, Improve, and Control) based Six Sigma Approach in order to reduce the incidence of defects and increasing the level of sigma in sand casting process. Jain and Barode (2018) study the DMAIC methodology to reduce defects. He study the three parameters die temperature, die holding time and metal melting temperature to find out the optimum parameters[6] values for reducing this defects. S.Muthu et al. (2014) describe the Six Sigma DMAIC phases to improve the effectiveness of shell and tube exchanger [12] in a small sized furnace manufacturing company.

The quality and productivity improvement in a manufacturing enterprise through a case study which provides a structure to identify measure and reduce sources of variation in an operational process in question, to optimize [17] the operation variables, improve and continue performance viz. process yield with well-executed control plans. Vijay (2014) has a goal of his research to reduce the cycle time [4] of the sufferers discharge manner the usage of six sigma DMAIC versions in a multidisciplinary hospital in India. He has carried out look at via the five phases of the six sigma DMAIC [16] version the usage of distinct first-class tools and strategies. Gawande (2014) presented a Six Sigma project, undertaken within company for production in bearing, which deals with identification and reduction of production cost [7] and process. For this research work, we are choosing six sigma DMAIC approach for our analysis that is related with reducing the defects in the turning process to improve productivity and improve customer satisfaction.

3. SIX-SIGMA METHODOLOGY (DMAIC)

The DMAIC methodology has a core process: Define-Measure-Analyse-Improve-Control (DMAIC) methodology. The five steps to DMAIC approach are:

3.1 Define Phase

The first stage of the Six Sigma and DMAIC's methodology is "define".The project begins by creating a team charter to identify team members, select the process the team will be improving and clearly define the objective of the project. This stage aims at defining the project's scope and boundary, identifying the customer requirements and goals of the project. However, before characterizing these components inside the project, the Six Sigma team must be set up. At long last, a project charter which is a tool used to report the objectives of the undertaking and different parameters at the start were utilized to state and present the task's data structure. The project charter, in other words, summarized the project's scope, limit, objective and the team's role in this research project. The project charter is presented in Table 3.1.

Table 3.1: Project charter

Project title: Defects reduction in Cab mounting bracket and Actuator mounting bracket
Background and reason for selecting the project: A large amount of cab mounting bracket and Actuator mounting bracket has been rejected by customers due to they were defective. This type of losses is not good for any company because for this time, materials, capital as well as create customers dissatisfaction, which negatively affects the company image.
Project Goals: To reduce the defects by 50% after applying Six Sigma into the cab mounting bracket and Actuator mounting bracket machining process.

Projects Boundary:	Focusing solely on the Cab mounting bracket and Actuator mounting bracket
Predictable monetary Benefits:	A significant cost reduction due to the defects minimization
Expected Customer Benefits:	Receiving the product with the expected quality

3.2 Measure Phase

Second phase of DMAIC process is measure; in this phase creating and executing a collection information plan that giving consistent and important data. One of the metrics defined was simply a number of defects per type. After defining the total number of defects, the DPMO and Sigma level of Cab mounting bracket and Actuator mounting bracket in turning process were calculated. According to the company's records, many defects are generated in process. We consider all defects as a one. The defects data was collected for nine days. The results are shown Table 3.2.

Table 3.2: Rejection % with no. of defected items before study Cab mounting bracket and Actuator mounting bracket

Number of Batches	Rejection % (for Cab mounting bracket)	Defected items (for Cab mounting bracket	Rejection % (for Actuator mounting bracket)	Defected items (for Actuator mounting bracket)
1	9.73	11	12.17	14
2	10.83	13	13.56	16
3	8.77	10	10.81	12
4	8.41	9	11.40	13
5	11.54	12	8.41	9
6	9.26	10	9.17	10
7	8.18	9	10	11
8	11.61	13	11.30	13
9	12.5	14	11.88	12
	Defect %=10.09	101	**Defect %=10.97**	110

Table 3.3: Defects summary (before the improvement) for Cab mounting bucket and Actuator mounting bucket

Type of defect	Type of product	Product per day	Total production for 9 days	Total number of defects	Percentage of defects
All defects considers	Cab mounting bracket	110	1000	101	10.09
	Actuator mounting bracket	110	1000	110	10.97

Table 3.4: Sigma quality level of batches before study for Cab mounting bracket

Batch number	Rejection%	DPU	DPMO	Sigma level	Range
1	9.73	0.097	97000	2.807	
2	10.83	0.108	108000	2.745	
3	8.77	0.087	87000	2.867	
4	8.41	0.084	84000	2.886	
5	11.54	0.115	115000	2.708	
6	9.26	0.092	92000	2.836	
7	8.18	0.081	81000	2.906	Max.
8	11.61	0.116	116000	2.703	
9	12.5	0.125	125000	2.658	Min.

Table 3.5: Sigma quality level of batches before study for Actuator mounting bracket

Batch number	Rejection%	DPU	DPMO	Sigma level	Range
1	12.17	0.121	121000	2.678	
2	13.56	0.135	135000	2.610	Min.
3	10.81	0.108	108000	2.745	
4	11.40	0.114	114000	2.713	
5	8.41	0.084	84000	2.886	Max.
6	9.17	0.091	91000	2.842	
7	10	0.100	100000	2.789	
8	11.30	0.113	113000	2.718	
9	11.88	0.118	118000	2.693	

3.3 Analyse Phase

This phase in the DMAIC enhancement technique involves the analysis of the system, in this case the machining process Cab mounting bracket and Actuator mounting bracket in order to identify ways to reduce the gap between the current performance and the desired goals. Several brainstorming sessions were conducted to identify based on the improvement team members' experience, possible causes as to why the defects occurred.

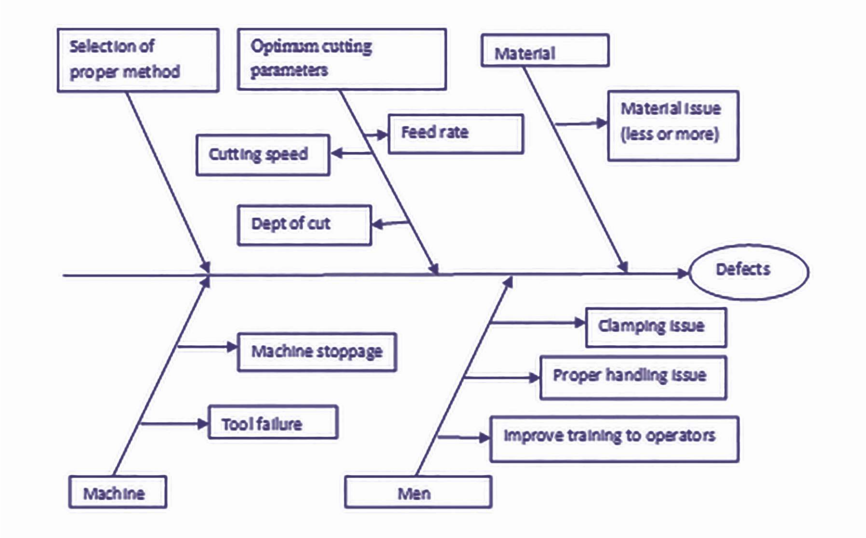

Fig 3.1: cause and effect diagram

3.4 Improve Phase

In this phase, Taguchi DOE is conducted with the three process parameters identified from the analysis phase. Since the relationship between these parameters was not known, it was decided to experiment all these parameters at three levels.

The parameters and levels selected for experimentation are presented in Table 3.6.

Table 3.6: Parameter and level selection for experiment

Factor	1	2	3
Cutting speed(m/min)	130	148	175
Feed rate(mm/rev)	0.2	0.3	0.4
Dept of cut(mm)	1.2	1.4	1.6

It was possible to estimate the effect of these selected parameters and interactions using the 9 experiments with the help of Orthogonal Array (OA). Hence for conducting an experiment with three parameters and three interactions, the L9 orthogonal array was selected.

As per the design layout is given in Table 3.6, the experiments were conducted after randomizing the sequence of experiments, and the data were collected. The experimental data were analyzed by Taguchi's Signal-to-Noise (S/N) ratio method. The S/N ratio is advocated in the Taguchi method to minimize the number of the defect. This analysis is done in Minitab 14 software.

Table 3.7: L9 Orthogonal array sequence for an experiment for Cab mounting bracket

Batch number	Cutting speed (m/min)	Feed rate (mm/rev)	Dept of cut (mm)	Number of defects	S/N ratio
1	130	0.2	1.2	6	-15.56
2	130	0.3	1.4	8	-18.06
3	130	0.4	1.6	5	-13.97
4	148	0.2	1.4	5	-13.97
5	148	0.3	1.6	6	-15.56
6	148	0.4	1.2	4	-12.04
7	175	0.2	1.6	6	-15.56
8	175	0.3	1.2	5	-13.97
9	175	0.4	1.4	4	-12.04

Table 3.8: L9 orthogonal array sequence for experiment for Actuator mounting bracket

Batch number	Cutting speed (m/min)	Feed rate (mm/rev)	Dept of cut (mm)	Number of defects	S/N ratio
1	130	0.2	1.2	7	-16.90
2	130	0.3	1.4	9	-19.08
3	130	0.4	1.6	6	-15.56
4	148	0.2	1.4	7	-16.90
5	148	0.3	1.6	6	-15.56
6	148	0.4	1.2	8	-18.06
7	175	0.2	1.6	6	-15.56
8	175	0.3	1.2	7	-16.90
9	175	0.4	1.4	8	-18.06

The analysis of data acquired through Design of experiments (DOE), Taguchi method is applied for gathering required data by using an orthogonal array and investigating Signal-to-Noise ratio derived from these data. In these experiments response is a number of defected components, 'Smaller the better' S/N ratio characteristic selected and calculating number of defected components through below equation

$$S/N = -10\log\left[\sum_{i=0}^{n}\frac{Y_i^2}{n}\right]$$

3.5 Control phase

In the Control Phase the group is centered around making a Monitoring Plan to keep estimating the success of the updated process and building up a reaction Plan on the off chance that there is a dip in performance. The real challenge of the Six Sigma execution is the sustainability of the accomplished outcomes. Sustainability of the results requires standardization of the advanced methods and introduction of monitoring mechanisms for the key consequences executed.

4. RESULTS AND DISCUSSION

4.1 Main effect plots for defects in Cab mounting bracket and Actuator mounting bracket

Main effect plots for patches are shown in figure 4.1 and f4.2. Main effect plot shows the variation of number of the defected item with respect to parameter considered.

X-axis represents a change in the level of the variable and

Y-axis represents the change in the resultant response.

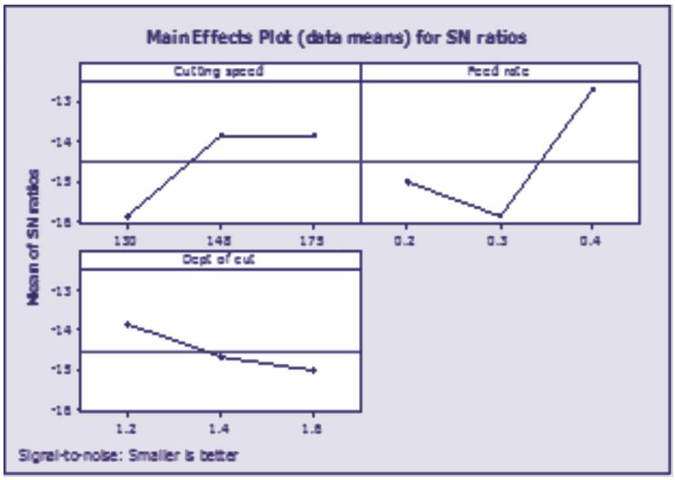

Fig 4.1: Main effects plot of S/N ration for Cab mounting bracket

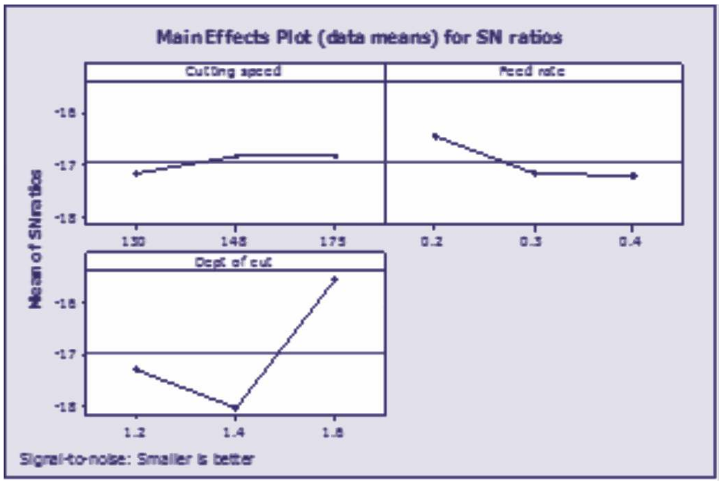

Fig 4.2: Main effects plot of S/N ration for Actuator mounting bracket

4.2 Determination of optimum solution for Cab mounting bracket and Actuator mounting bracket

From figure 4.1 and 4.2, optimum factor levels for patches are identified based on the 'Bigger the Better' S/N ratio characteristic and listed in table 4.1and 4.2. The optimal result has been verified through confirmatory test showed the satisfactory result.

Table 4.1: Optimum levels for Cab mounting bracket

Parameter designation	Process parameters	Optimal level
A	Cutting speed (m/min)	130
B	Feed rate (mm/rev)	0.3
C	Dept of cut (mm)	1.6

Table 4.2: Optimum levels Actuator mounting bracket

Parameter designation	Process parameters	Optimal level
A	Cutting speed (m/min)	130
B	Feed rate (mm/rev)	0.4
C	Dept of cut (mm)	1.4

4.3 Confirmation test for defect for Cab mounting bracket and Actuator mounting bracket

The last step of Taguchi parameter design is to verify and predict the improvement in a number of defect using optimum combinations of parameters.

A confirmation test is conducted with the batch volume of 990 products at the optimum factor settings. Out of 110 components produced in 9 batches. The confirmation experiment results inferred that the rejection rate is brought to 4.94% and 5.75%.

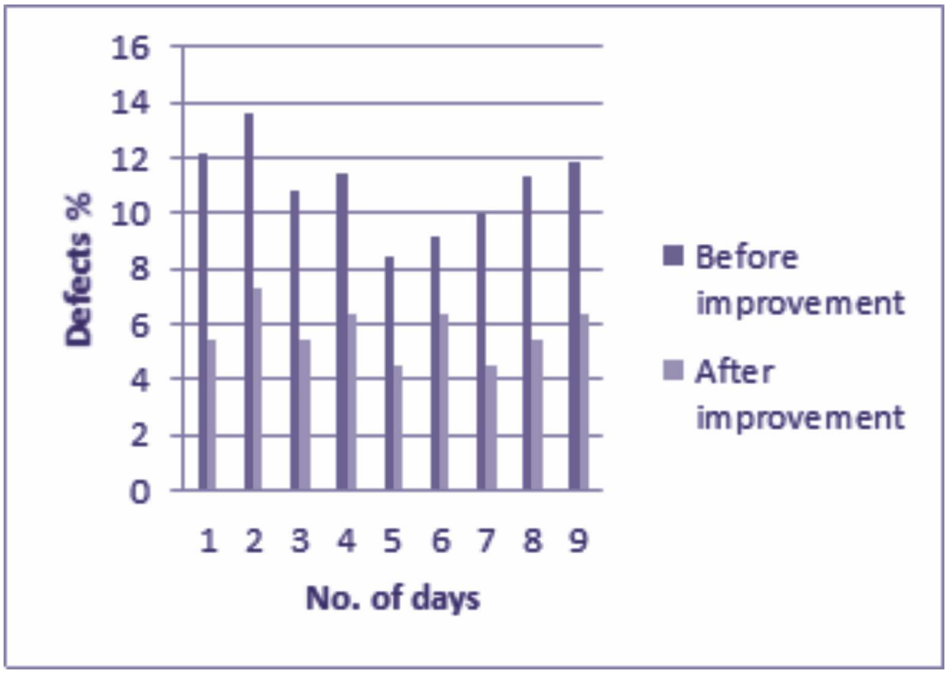

Fig 4.3: Rejection after implementation for Cab mounting bracket

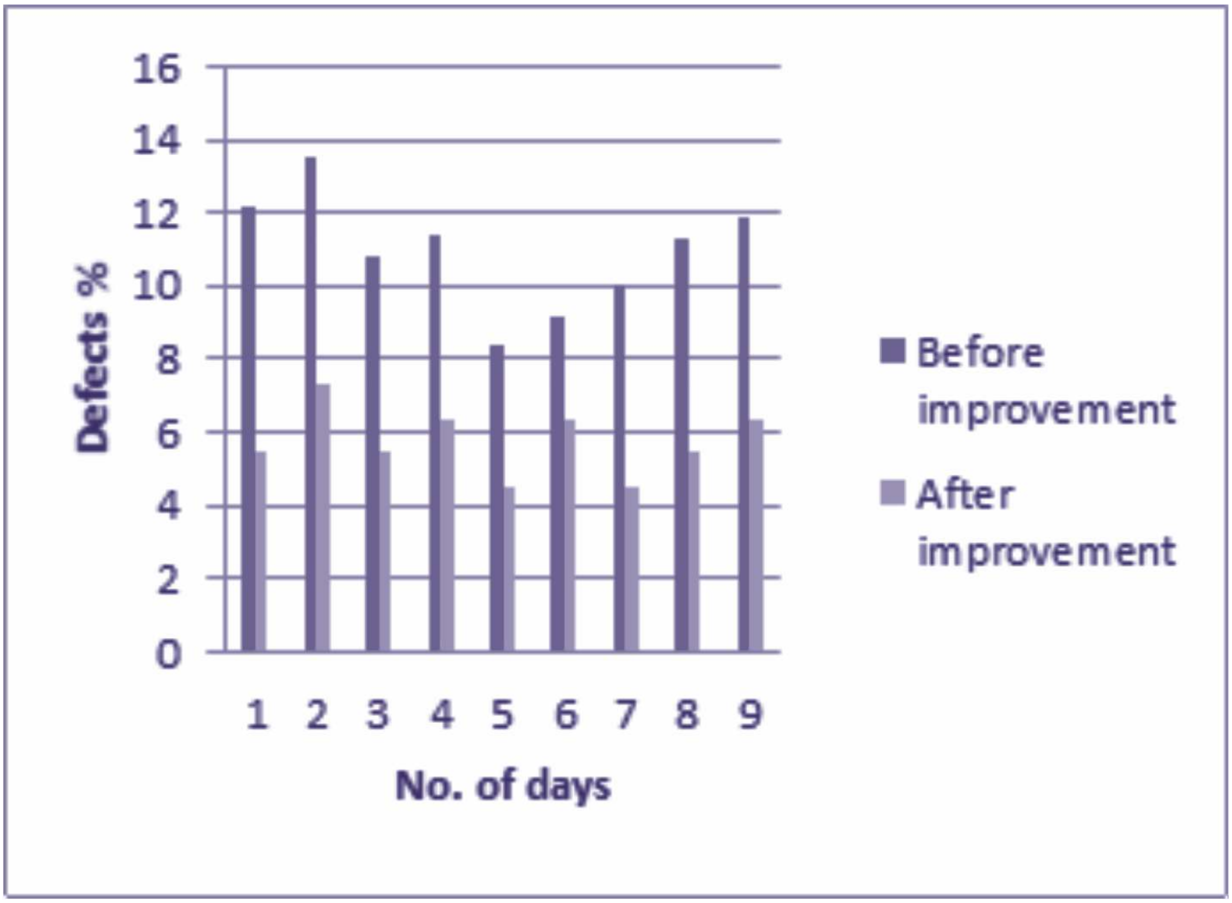

Fig 4.4: Rejection after implementation for Actuator mounting bracket

Bracket

4.4. 1 Cab mounting bracket:

4.4 Calculation of sigma level after study for defect for Cab mounting bracket and Actuator mounting

The defects per unit (DPU) are:

DPU = Total number of defects observed in the batch /Total number of units produced in the batch

=49/1000= 0.049

Defects per opportunities (DPO) is: one

DPO= DPU/1 = 0.049

Defects per million opportunities (DPMO) are:

DPMO = DPO×1,000,000= 0.049 x 1000000= 49000

Sigma quality level = 0.8406 + $\sqrt{29.37 - 2.221 \times \ln(49000)}$ =3.16

4.4.2 Actuator mounting bracket:

The defects per unit (DPU) are:
DPU = Total number of defects observed in the batch /Total number of units produced in the batch
= 57/1000 = 0.057
Defects per opportunities (DPO) is: one
DPO= DPU/1 = 0.057
Defects per million opportunities (DPMO) are:
DPMO = DPO×1,000,000= 0.057 x 1000000= 57000

Sigma quality level = 0.8406 + $\sqrt{29.37 - 2.221 \times \ln(57000)}$ =3.09

5. CONCLUSION

The awareness of quality are nowadays are becoming more and more in global market. To compete in such an environment, companies need to adopt an efficient methodology that can evaluate and take a diagnostic approach to meet customer needs and expectations. Nowadays, the industrial world has realized that the Six Sigma Philosophy is certainly a viable solution to their machining problem. This paper has substantiated the fact that the sigma level of both the cab mounting bracket and Actuator mounting bracket are increasing and overall productivity for adopting six sigma approach are increase.

5.1 Conclusions for defect in Cab mounting bracket

From the experiment following results were obtained.

- It has been found that feed rate is found to be the most significant factor. The best results (small is better) would be achieved with optimum parameter Cutting speed=130 m/min, Feed rate=0.3 mm/rev Dept of cut=1.6mm. With 95% confidence interval, the feed rate affects the defects most significantly.

- From ANOVA analysis, parameters making a significant effect on defects are feed rate.
- Using experiment conducted optimum parameters were determined i.e. Cutting speed=130 m/min, Feed rate=0.3 mm/rev Dept of cut=1.6mm.
- The percentage of rejection decreases from 10.09 % to 4.94 %.
- Sigma Level improves after study from 2.906 to 3.16.
- The number of defective items also decreased from 101 to 49.
- The number of good items also increased from 899 to 951.
- Productivity increases from 88.76 % to 94.1 %.
- Rejection trend after study decreases.

5.2 Conclusions for defect for Actuator mounting bracket

From the experiment following results were obtained.

- It has been found that dept of cut is found to be the most significant factor. The best results (small is better) would beachieved with optimum parameter Cutting speed=130 m/min, Feed rate= 0.4mm/rev and Dept. of cut=1.4mm with 95% confidence interval, Dept of cut effect the defects most significantly.
- From ANOVA analyses, parameters making a significant effect on defects are dept of cut.
- Using experiment conducted optimum parameters were determined i.e. Cutting speed=130 m/min, Feed rate=0.4 mm/revand Dept of cut=1.4mm.
- The percentage of rejection decreases from 10.97 % to 5.75 %
- Sigma Level improves after study from 2.886 to 3.09.
- The number of defective items also decreased from 110 to 57.
- The number of good items also increased from 890 to 943.
- Productivity increases from 87.6 % to 92 %.
- Rejection trend after study decreases.

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