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Implementation of DMAIC Approach to Reduce Defects in Grinding Processand Quality Improvement

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ABSTRACT

Six Sigma's problem solving methodology DMAIC has been one of several techniques used to improve quality. This paper demonstrates the empirical application of Six Sigma and DMAIC to reduce product defects within a twin radiator part manufacturing organisation. The paper follows the DMAIC methodology to investigate defects, root causes and provide a solution to reduce/eliminate these defects due to grinding process. The analysis from employing Six Sigma and DMAIC indicated that the load applied, coolant flow rate and wheel rpm influenced the amount of part produced. In particular, the design of experiments (DOE) and two-way analysis of variance (ANOVA) techniques were combined to statistically determine the correlation of the load applied, coolant flow rate and wheel rpm with defects as well as to define their optimum values needed to reduce/eliminate the defects. As a result, a reduction of about 4.97 % in the defect was achieved, which helped the organisation studied to reduce its defects and hence improve its Sigma level from 2.72 to 3.15.

Keywords: Grinding Defects; Patches; Productivity; Quality; DMAIC; Taguchi Experimental Design; Analysis Of Variance; ANOVA; Signal To Noise Ratio; S/N.

I INTRODUCTION

Six Sigma is new, emerging, approach to quality assurance and quality management with emphasis on continuous quality improvements. The main goal of this approach is reaching level of quality and reliability that will satisfy and even exceed demands and expectations of today's demanding customer. 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.

II SIX SIGMA APPROACH

The Six Sigma Approach is customer-driven. For a business or a manufacturing process, the Sigma Capability is a metric that indicates how well the process is being performed. The higher the Sigma capability, the better, because it measures the capability of the process to achieve defect-free-work (where a defect is anything that results in customer dissatisfaction) The Six Sigma Approach is also data-driven. It focuses on reducing process variation, centring the process and on optimizing the process. The emphasis is on the improvement of process capability rather than the control of product quality, which includes the improvement of quality and reduction of cost of quality. In short, The Six Sigma Approach focuses on: Customer needs, data-driven improvements & the inputs of the process. And this results in: reducing or eliminating defects, reducing process variation, increasing process capability.

III SIX SIGMA PHASES

Approaches to Six Sigma dictate the use of a model to drive a disciplined approach to the solution of quality problems. The most commonly used model is the five-phase model commonly known by the acronym DMAIC (Define, Measure, Analyze, Improve, and Control). The model acts as a roadmap for improvement projects, leading the teams. Fig. 1 shows how it works,

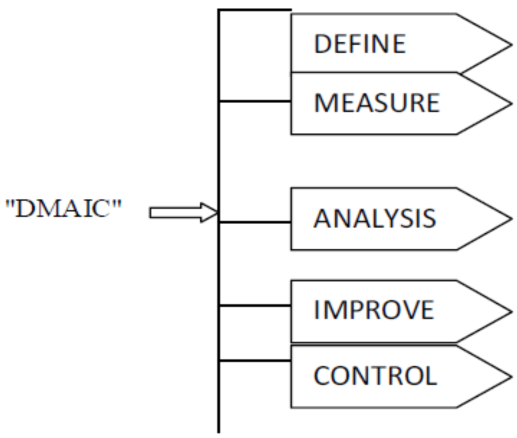

Fig. 1 Six Sigma Phases

3.1 Define Phase

The definition of the problem is the first and the most important step of any DMAIC project because a good understanding of the problem makes the job much easier. Thus, we can say that the definition of the problem forms the backbone of any DMAIC project. The present case study deals with reduction of rejection due to grinding process defects in a Laxmi Engineering Pvt Ltd, Bhopal. The company face rejection in the grinding process. The important grinding defects of industry were chosen for complete analysis.

3.2 Measure Phase

The measure phase identifies the defects in the product, gathers valid baseline information about the process and establishes improvement goals. DMAIC approach is based on measured data. Following defects like burr, patches, shade, damage and deep lines will be studied.

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Fig. 2 Defects in Grinding Process

3.2.1 Data Collection

The first step was to collect and select these data. Production and rejection statistics of completed 9 batches are collected from the company's record and it infers that the rejection was in increasing trend as shown in Figure 3.

Table 1 Rejection status with no. of good and defected items before study

No. of Batches	Good items	Defected items	Rejection %
1	448	52	10.4
2	480	20	4
3	435	65	13
4	460	40	8
5	439	61	12.2
6	409	91	18.2
7	418	82	16.4
8	402	98	19.6
9	466	34	6.8
Total	**3957**	**543**	**Avg. =10.86%**

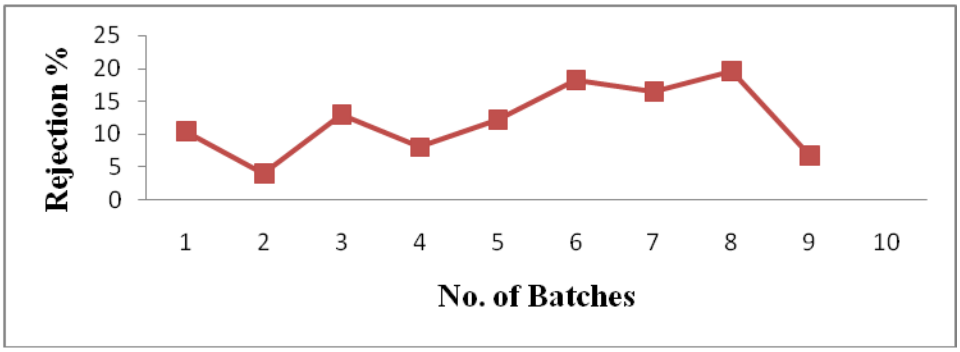

Fig. 3Rejection trend chart before study

Table 1 inform about the rejection % and no. of good and defected items before study. Total no. of good items is 3957 and poor items is 543 with avg. rejection % is 10.86%.

3.2.1.2 Calculation of Present Sigma Level

The existing process capability is expressed in terms of sigma quality level for the purpose of comparing the improvement after the case study.

Table 2 summarises the sigma level calculation for all batches and it clearly indicates that process performance is poor and it needs improvement. Existing process capability is varying from 1.86 σ to 3.23 σ with an average of 2.51 σ and the defect level ranges between 40,000 to 196,200 units with a mean of 10.86 % out of a million outcomes.

Table 2 Sigma quality level of batches before study

Batch	Rejection %	DPU	DPMO	sigma level	Range
1	10.4	0.104	104000	2.76	
2	4	0.04	40000	3.25	**Max**
3	13	0.13	130000	2.63	
4	8	0.08	80000	2.91	
5	12.2	0.122	122000	2.67	
6	18.2	0.182	182000	2.41	
7	16.4	0.164	164000	2.48	
8	19.6	0.196	196000	2.35	**Min**
9	6.8	0.068	68000	2.99	
	Avg. defect level=10.86%			**Avg. sigma quality level=2.72**	

3.3 Analyse Phase

This phase is intended to analyse the data to determine the direction of process improvement. In this case, it is important to identify the possible sources of variation which lead to patches. A cause and effect study is conducted and parameters, thought to contribute to more patches are listed as shown in Figure 4.

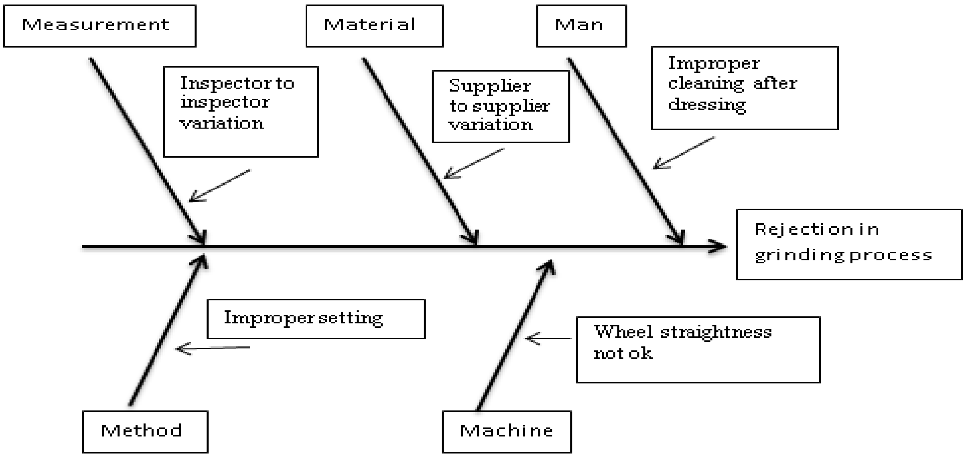

Fig. 4 Cause and effect diagram for rejection in grinding process

Identification of the vital few items from the Pareto principle is most easily conveyed using a Pareto diagram.

Table 3 Defect name and there quantity

S.No.	Defect Name	Defect Quantity
1	Burr	337
2	Patches	554
3	Shade	210
4	Damage	115
5	Deep lines	24

It is apparent that from this short list (Table 3) that patches are the main problem. This graph has been prepared using the work sheet in (Table 5). The defects are arranged in rank order in column-1. The number of defects appears in column-2. In (Figure 5) all defects are shown graphically to find out a most effective defect over these defects.

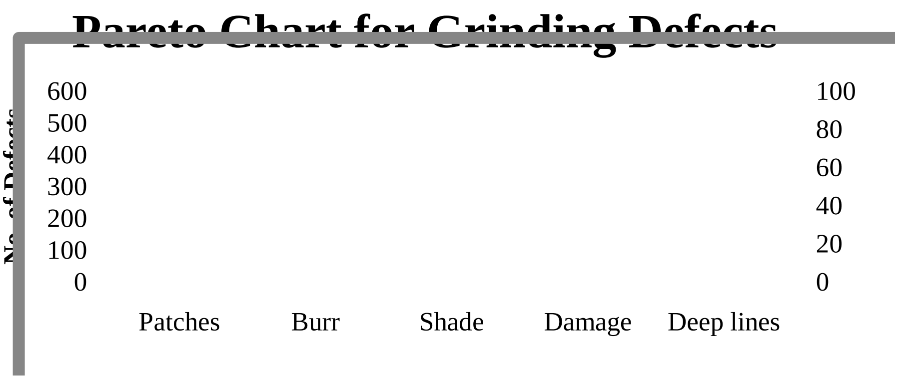

Fig. 5 Pareto Chart for Grinding Defects

The three major causes, wheel rpm, cooling flow rate and load applied are responsible for the variations to occur on a product during the grinding operation. So, an industrial experimentation is carried out on a grinding machine to eliminate the variations occurring on a product by making some changes on these causes. These three causes are the key parameters in a grinding machine. Hence, an effect can be surely achieved, once a change is made on these causes.

3.4 Improve Phase

In this phase, Taguchi DOE is conducted with the three process parameters identified from the analysis phase. The parameters and levels selected for experimentation are presented in Table 4.

Table 4 Parameter and level selection for experiment

Factor	1	2	3
Load Applied (KN)	160	190	210
Coolant Flow Rate (LPM)	5	10	15
Wheel (RPM)	25	35	45

L9 orthogonal array was selected. As per the design layout given in Table 5.6, the experiments were conducted after randomizing the sequence of experiments, and the data were collected. The experimental data were analysed 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 defect.

Table 5 L9 orthogonal array sequence for experiment

SN	load applied, KN	coolant flow rate, LPM	WHEEL rpm	No of good items	S/N ratio
1	160	5	25	401	52.06
2	160	10	35	422	52.28
3	160	15	45	310	50.94
4	190	5	35	321	51.09
5	190	10	45	369	51.70
6	190	15	25	418	52.24
7	210	5	45	301	50.81
8	210	10	35	311	50.95
9	210	15	25	359	51.58

The experiment is carried out as per the factor settings in each test condition and 4500 components are produced in 9 batches. The number of good components is recorded as response for each test. Since the experiment response is number of good components, 'Bigger the better' S/N ratio characteristic selected and calculated using the below.

$$\frac{S}{N_{(Bigger)}} = -10 \log\left(\frac{\Sigma\left(\frac{1}{y_i^2}\right)}{n}\right)$$

3.5 Control Phase

The real challenge of the Six Sigma implementation is the sustainability of the achieved results. Due to variety of reasons, such as people changing the job, promotion/ transfer of persons working on the process, changing focus of the individual to other process-related issues elsewhere in the organization and lack of ownership of new people in the process, quite often maintaining the results are extremely difficult. After implementation, the data were compiled with respect to the defects for one month and the rejection percentage was found to be 4.97 %. Hence, as a result of this project, the rejection percentage reduced from 10.86 to 4.97 %.

IV RESULTS AND DISCUSSIONS

4.1 ANOVA for Patches Defect

The results for patches defect were obtained from the 9 experiments performed of Taguchi. The experimental results analysed with ANOVA are shown in the Table 6. The F value calculated through MINITAB 15 software is shown in the second last column of ANOVA table which suggests the significance of the factors on the desired characteristics. Larger is the F value higher is the significance (considering confidence level of 95%). The results show that only cooling flow rate is the most significant factor. In the Table 7 ranks have been given to the various factors. Higher is the rank higher is the significance. Coolant flow rate is the most significant factor.

Table 6 ANOVA for patches defect

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Load applied (KN)	2	3.4417	3.4417	1.7208	2.11	0.322
Coolant flow rate (LPM)	2	7.2395	7.2395	3.6197	4.43	0.184
Wheel (RPM)	2	2.6564	2.6564	1.3282	1.63	0.381
Error	2	1.6347	1.6347	0.8173		
Total	8	14.9723				
S = 0.904071 R-Sq = 89.08 % R-Sq (adj) = 56.33%						

Table 7 Response table of Means for patches defect

Level	Load applied (KN)	Coolant flow rate (LPM)	Wheel (RPM)
1	13.667	19.000	9.667
2	18.000	12.333	11.333
3	8.333	8.667	19.000
Delta	9.667	10.333	9.333
Rank	2	1	3

4.2Main Effect Plots For Patches Defect

Main effect plots for patches are shown in the figure 6. Main effect plot shows the variation of no. of defected item with respect to load applied, coolant flow rate and wheel RPM. X axis represents change in level of the variable and y axis represents the change in the resultant response.

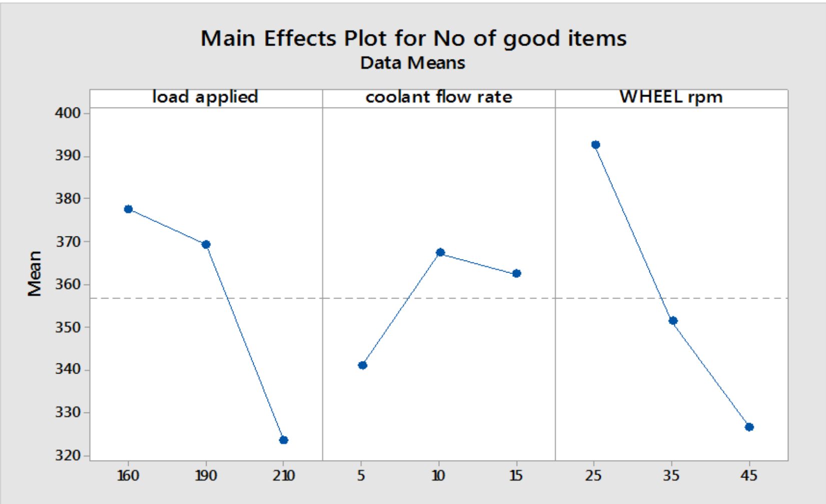

Fig. 6Main effects plot for means for no. of defected items for patches

4.3 Determination of Optimum Solution for Patches

From figure 6.2, optimum factor levels for patches are identified based on the 'Bigger the Better' S/N ratio characteristic and listed in Table 68. Optimal result has been verified through confirmatory test showed satisfactory result.

Table 8 Optimum levels for patches defect

Parameter designation	Process parameters	Optimal levels
A	Load applied (KN)	210
B	Coolant flow rate (LPM)	5
C	Wheel (RPM)	45

4.4 Confirmation Test

The last step of Taguchi parameter design is to verify and predict the improvement in number of defect (response) using optimum combination of parameters.

A confirmation test is conducted with batch volume of 4500 pieces at the optimum factor settings. Out of 500 components produced in 9 batches. The confirmation experiment results inferred that the rejection rate is brought to 4.97% in average as shown in Table 9.

Table 9 Rejection % with no. of good and defected items after study

No. of Batches	Rejection %	Good items	Defected items
1	4.8	476	24
2	3.6	482	18
3	5.2	474	26
4	3.6	482	18
5	6.8	466	34
6	7.6	462	38
7	5.2	474	26
8	4.2	479	21
9	3.8	481	19
	Avg.= 4.97%	**4276**	**224**

Rejection trend have been plotted as shown below fig 7.

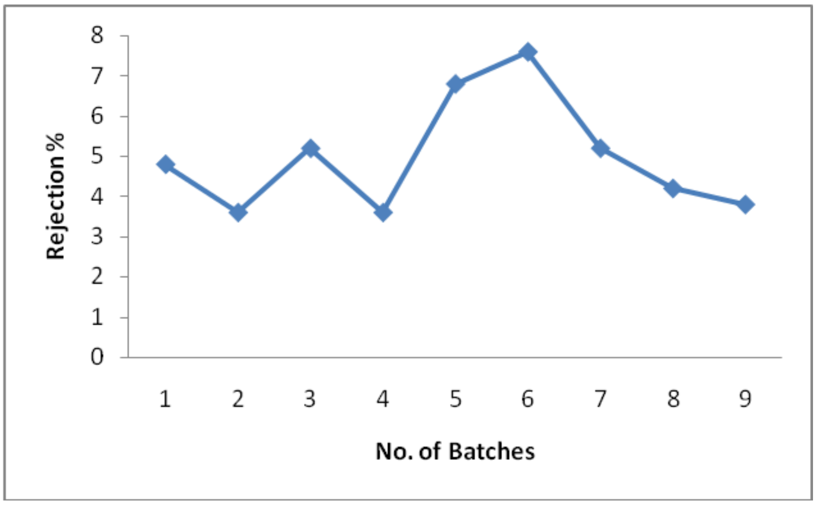

Fig. 7 Rejection trend after study for patches

4.5 Calculation of Sigma Level After Study

The defects per unit (DPU) are:

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

=224/4500=0.04977

Defects per opportunities (DPO) is: one

DPO= DPU/1=0.04977

Defects per million opportunities (DPMO) are:

DPMO = DPO×1,000,000= 0.04977x 1000000= 49777

Sigma quality level = $0.8406 + [29.37 - 2.221\times\ln(49777)]^{1/2} = 3.153$

V CONCLUSION

From the experiment following results were obtained.

- It has been found that coolant flow rate is found to be the most significant factor & its contribution to patches defect is 47.51 %. The best results for patches (Bigger is better) would be achieved with optimum parameter= load applied= 210 KN, Coolant flow rate = 5 LPM and Wheel RPM= 45 RPM. With 95% confidence interval, the coolant flow rate effects the patches defect most significantly.
- The patches defect is mainly affected by load applied, Coolant flow rate and Wheel RPM. With the increase in load applied the patches decrease, as the coolant flow rate increases the patches defect first increase and decrease and as the wheel RPM increase patches defect decreases.
- From ANOVA analysis, parameters making significant effect on patches are coolant flow rate.
- Using experiment conducted optimum parameters were determined (load applied= 210 KN, Coolant flow rate = 5 LPM and Wheel RPM= 45 RPM). The percentage of rejection decreases from 10.86 % to 4.97 % as shown below.

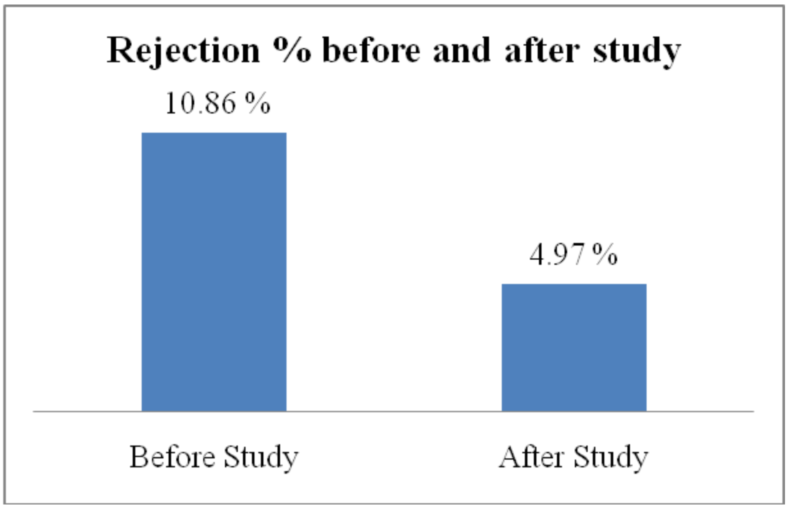

Fig. 8 Rejection % before and after study

- Sigma Level improve after study

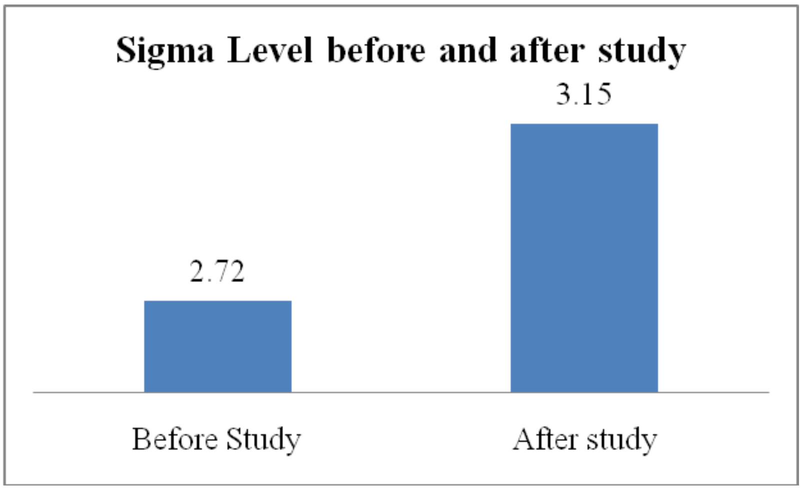

Fig. 9 Sigma Level before and after study

- Number of defective items was also decreases from 543 to 224.
- Number of good items was also increases from 3957 to 4276.
- Productivity increases from 87.9% to 95 %.
- Rejection trend after study decreases.

Table 10 Findings of study

	Rejection	**Percent saving**	**Total Item produced**	**Defective item**	**Good item**	**Productivity**
Before	10.86 %	5.39%	4500	543	3957	87.9%
After	4.97 %			224	4276	95%

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