RESEARCH ARTICLE OPEN ACCESS

Lean-Six Sigma Case Study to Improve Productivity in a Manufacturing Industry

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ABSTRACT
Industries are in a path of adopting new technologies, equipment, approach to improve productivity and profitability. The change in mind of the industries is due to the raising demand from the customer for a quality products or services at a low cost with reduced lead time, further it is free from defects. These factors push the industries to focus on their improvements. The intent of this research work is, to improve the quality in manufacturing sector by combination of Lean and Six sigma. This projects addresses the productivity improvement of an industry by reducing the rejections using Lean Six Sigma DMAIC approach. The rejection data of last six months of the industry has been studied for rejection rate and its effect on industry's production. Based on statistical data potential components are chosen for analysis, causes that led to rejections are analysed with lean Six Sigma framework. Loss due to tool failure, modification of cutting parameters for reduced production lead time is one of the major problems that causes the frequent rejection of components. Increased feed rate and speed results in tool wear, further use of unstandardized parameters cause such failure although it decreases the cycle time. Various combinations of cutting parameters were analysed using Taguchi methodology to study the effect of DOC, spindle speed, feed rate, cutting force and nose angle on cycle time. After evaluating the results a framework for standard cutting parameters which results in reduced cycle time as well as tool wear is framed out to follow. Scatter plot analysis were carried out to examine the investigation which showed that wear increases with increase in feed and speed and Wear increases with increase in DOC. It can be noted that changing the speed from 450 to 400, feed from 0.2 to 0.15, and DOC from 1 to 0.75 we can reduce the 6.1% time required to complete a turning operation further tool life is improved to extent of 20.00%.

Keywords: Six Sigma, productivity, DMAIC, Lead time, Lean

Date of Submission: 08-09-2017 Date of acceptance: 22-09-2017

I. INTRODUCTION

The productivity is the measure of industry's efficiency, the efficiency of industries is determined upon various factors such as plant layout, process planning, raw material specification, machinery technology [1, 3]. The conversion efficiency which changes the level of productivity is largely affected by numerous factors. Defect is one of the important key factor which is focused to improve the productivity performance because the high productivity performance has a direct relationship with equipment efficiency and process control [2, 4]. Hence various technologies and methodologies are used to achieve the expected performance. Six sigma is one such philosophy or methodology followed to achieve productivity performance by improving product and process quality. Lean Six Sigma is a two staged business approach to continual improvement which focuses on reducing waste and product variation from manufacturing, service or design processes [3, 6]. Lean refers to maximizing customer value and minimizing waste. Six Sigma is the on-going effort to continually reduce process and product variation through a defined project approach. The entire work is set to follow DMAIC approach. In this project the required background knowledge is obtained from various sources of literature reviews such as google search, referring books and accessing journals by centring the keywords as Lean, Six Sigma, Lean Six Sigma, manufacturing industry, rejection rate, tool failure, cutting inserts, cutting parameters and productivity. The quality and productivity improvement in a wheel production plant using DMAIC approach [5, 8], several statistical tools and techniques were effectively utilized to make inferences during the project. As a result of the project, the rejection level of Ingates and Cracks after the six sigma methodology has been reduced to 1.45% from 1.64% for Ingates and 0.69% from

0.77% for Cracks [7, 9]. The technical pathway of implementing the technique in industries for improving the productivity and quality finally, by changing the traditional layout to balanced layout model as per DMAIC approach [10, 16] remarkable improvements have been achieved. Surface finish is one of the prime requirements of customers for machined parts. It is one of the prime requirements of customers for machined parts. Productivity is also necessary to fulfil the customers demand. In addition to the surface finish quality, [18, 19] the material removal rate (MRR) is also an important characteristic in turning operation and high MRR is always desirable. The effect of cutting parameters on MRR, it was observed [4, 10] that spindle speed (the most significant factor) contributed 63.90%, depth of cut (second most significant factor) contributed only 11.32% and feed rate contribution was least with 8.33% for Ra. The contribution for feed and RPM was 60.91% and 29.83%.whereas the depth of cut contributed only 7.82% for material removal rate. It was concluded that interesting to note that spindle speed and depth of cut has an approximate decreasing trend. The feed has the variable effect on surface roughness. It is interesting to note that spindle speed, feed rate and depth of cut for Material Removal Rate have increasing trend. The cutting parameters there by to study the effect of cutting parameters on tool wear, work piece surface temperature and material removal rate in turning of AISI D2 steel. Their work focused on optimization method of the cutting parameters (cutting speed, depth of cut and feed) in dry turning of AISI D2 steel to achieve minimum tool wear, low work piece surface temperature and maximum material removal rate (MRR). Their experimental layout was designed based on the Taguchi's L9 Orthogonal array technique and analysis of variance (ANOVA) were performed to identify the effect of the cutting parameters on the response variables. Results showed that depth of cut and cutting speed are the most important parameter influencing the tool wear [9, 17]. The minimum tool wear was found at cutting speed of 150 m/min, depth of cut of 0.5 mm and feed of 0.25 mm/rev. Similarly low w/p surface temperature was obtained at cutting speed of 150 m/min, depth of cut of 0.5 mm and feed of 0.25 mm/rev. Whereas, at cutting speed of 250 m/min, depth of cut 1.00 mm and feed of 0.25 mm/rev, the maximum MRR was obtained. Thereafter, optimal range of tool wear, w/p surface temperature and MRR values were predicted. The contribution for feed and RPM was 60.91% and 29.83%.whereas the depth of cut contributed only 7.82% for material removal rate [4, 12]. The results revealed that cutting speed is the significant parameter on tool wear, depth of cut showed significant parameters for material removal rate (MRR). Finally, the relationship between cutting parameters and the performance measures [8, 15]. A summary is a recap of the important information of the source, but a synthesis is a re-organization, or a reshuffling, of that information. Based on the comprehensive literature review conducted during this project the following information have been noted; The tools of the LSS methodology enriched the efforts towards waste reduction, The adoption of the LSS framework provided a systematic and guided approach to identify the problem and to provide a feasible solution for sustaining the improvement made, Six Sigma methodology results in the reduction of rejection rate, By implementing Lean principles motion waste can be reduced during flow of product, Increase in Sigma level also contributes to equipment effectiveness, To ensure the quality and the sustainability, six-sigma will play a vital role in the long run in our country. The implementation of Six Sigma will also save money, which will result higher profit of the organization, After the implementation of Lean principles with the Breakthrough Machine it is identified that throughput of the Industry is increased with less inventory, Six Sigma practice definitely enhanced the customer satisfaction, Cutting parameters are the major factors which determine surface finish and MRR, Flank wear is the common type of wear that occur due to unstandardized cutting parameters, Optimal settings of the parameters can be accomplished using Taguchi's design of experiments approach. Hence it is understood that Lean Six Sigma is the choice of the manufacturing industries to decrease the rejection rate and to increase the productivity. Optimizing cutting parameters can yield better productivity by ensuring best quality. The framework is set to follow DMAIC approach as shown in figure 1

Fig 1: DMAIC approach

II. PROJECT METHODOLOGY

The project methodology is framed in order to obtain an optimal result in specified period of time with improved productivity. The project methodology is designed using the Six Sigma DMAIC approach to obtain the solution.

2.1 VOICE OF CUSTOMER

The voice of customer is obtained from the personnel's of the industry. The voice is obtained from the production head of this industry in this project.

VOC : There are more rejection in certain products of domestic dealers.
CTQ : High rejection rate**.**

2.2 COLLECTING THE DATA

The current state of the process is understood, this involves collecting data on measures of production, rejection, quality and cost of around 500 components. A sample of data is shown below in table 1.

Table 1: Sample rejection data

Part Name	**Production Quantity**	**Rejection Quantity**	**MTR-COST**	**M/C-COST**
BONNET	73	19	70	34
BONNET	12	12	70	34
BONNET	76	9	70	34
BONNET	63	9	70	34
ELLEN CASING	58	8	0	191
BONNET	59	8	70	34
ELLEN CASING	93	4	0	191
HEAD	2	2	438	147
CASING	48	2	270	62
CASING	44	1	270	62

2.3 ANALYSING THE DATA:

The data which are collected are sorted based on the multi-perspective view of referring a problem which is based on

- Quantity of Rejection
- Cost due to rejection

The Pareto is drawn to find the crucial components which affect the productivity of the industry, based on the concept of sorting out the vital few from trivial many. The Pareto is drawn on the two perspective as stated above to find the way in which there is more scope and increased profitability with improved productivity of the project lies. Pareto chart of rejected components based on rejection quantity is shown in figure 2 and Pareto chart of rejected components based on cost is shown in 3.

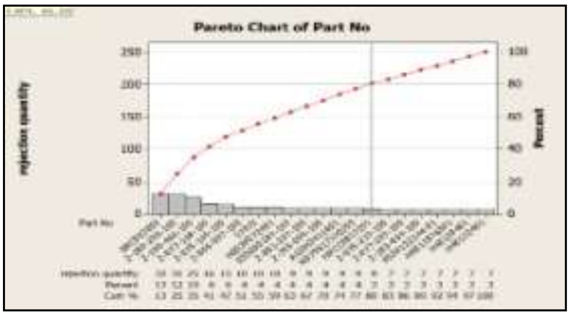

Fig 2: Pareto chart based on rejection quantity

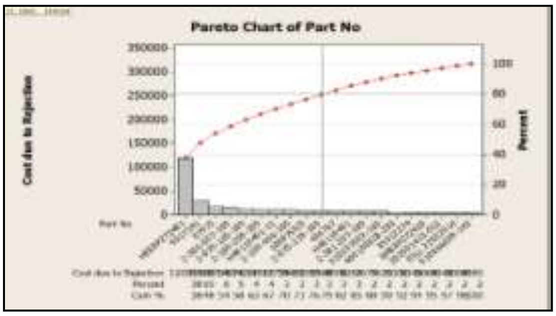

Fig 3: Pareto chart based on cost

The causes that led to the rejection of those components were analysed by closely observing the operations and process from the beginning of the lead time till final inspection. Then the reasons were tabulated as shown in table 2.

Table2: Parts with their Non conformance

PART NAME	**NON-CONFORMANCE**	**ROOT CAUSE**
CASING	BORE FACE STEP MARK	M/c running condition piece disturbed
CASING	PIECE DAMAGE PROBLEM AND BORE UNWASHED	M/c running condition check pressure problem so piece disturbed
BRACKET	BORE RUNOUT PROBLEM	M/c running condition

BRACKET	OD RUNOUT	M/c running condition
ROTOR	CENTER DAMAGE PROBLEM	M/c running condition piece rotate so damage
HEAD	PIECE DAMAGE PROBLEM	M/c running condition piece disturbed in insert broken
PLAQUE-D	ID PLUS FOUND	X' offset wrong input in setting time operator careless
VALVE BODY	ID OVALITY PROBLEM	M/c running condition clamping tight problem
PRESSURE BAR	HOLE SIZE PLUS	M/c running condition chip locked

2.4 IDENTIFYING THE ROOT CAUSES USING CAUSE AND EFFECT DIAGRAM

Fig 4: Fish bone diagram of part no: 2-075-165-100

Fig 5: Fish bone diagram of part no: 2-386-007-100

Fig 6: Fish bone diagram of part no: 2-077-168-100

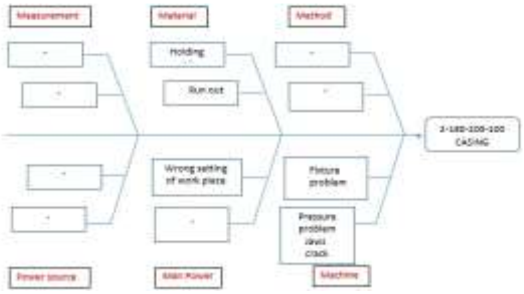

Fig 7: FISH BONE DIAGRAM OF PART NO: 2-180-200-100

Fig 9: FISH BONE DIAGRAM OF PART NO: 2-381-207-100

The root cause analysis was carried out for all the parts with the use of cause and effect diagram as shown in below figures 4 to 9. The above cause and effect diagram is tabulated as below

Table 3: Root causes

PART	METHOD	MANPOWER	MACHINE
035000184-163 1"SEAT RING	-	Part mix up by operator carelessness Chuck pressure not maintained Offset wrong input	Insert broken Machine running condition
2-075-165-100 BRACKET	Mistake in previous operation	Wrong Setting of work piece	Indexing problem Insert broken
2-077-168-100 BRACKET	Mistake previous operation	Wrong use of tools Careless mix-ups	Spindle orientation in ATC Running condition
2-180-200-100 CASING	-	Wrong setting of work piece	Fixture problem Running condition Pressure problem Jaws crack
2-381-207-100 HEAD	Tool not fit properly Insert broken wrong depth of cut Mistake in previous operation	Part mix up by operator carelessness insert broken wrong depth of cut	Insert chip out Running condition
2-386-007-100 HEAD	Shift change so tool not fit properly wrong offset entered	Wrong offset entered Insert change time wrong input	Spindle orientation Insert broken Tap tight
AGSH3411601 PRESSURE BAR	No proper method in communication to next operator	Improper cleaning of chips Operator carelessness No proper communication to next operator Offset wrong input	-
DRC002853 BOLDED PLATE	-	Operator careless	Chuck pressure problem Running condition Clamping problem
N3796171H2/03 PLAQUE-D	-	X offset wrong input Operator careless Wrong handling	End mill broken Insert broken

From the above results it is observed that most of the problems arise due to tool failure, tool wear, unstandardized cutting parameters etc., hence an experimental investigation was carried out to study the effect of cutting parameters on tool life and cycle time which is shown in figure 9.

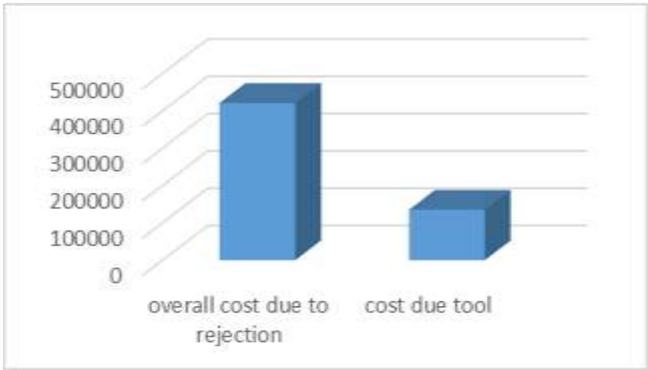

Fig 9: Cost incurred due to tool

2.5 EXPERIMENTAL PROCEDURE

The material, characteristics of tool and detail of experimental design set-up are listed in Table 4 and conditions are given in the Tables 5

Table 4: Experimental design set-up

Machine tool	**HMT Lathe, 5 kW power rating**
Work piece	CASTING
Size	Φ50 mm x250mm
Cutting condition	Wet
Cutting tool	CNMG120408-MR7,TK2000
Tool holder	DCLNR 2020K12-M
Flank wear test	Video Measuring System

Table 5: Process parameters

Factors	**Spindle speed**	**Feed**	**Depth of cut**
UNITS	N	Mm/rev	mm
Level-1	400	0.15	0.75
Level-2	450	0.2	1
Level-3	500	0.25	1.25

Tests were carried on CNC Turning center under wet condition in which turning operation has been selected. In this analysis, three levels, three factors and nine experiments are identified. Hence 3 inserts with 9 cutting edges were chosen for different process parameters. According to Taguchi approach L09 orthogonal array has been selected.

2.6 INSERT WEAR MEASUREMENTS

Machining time for each sample has been calculated along with it, the flank wear of the tool profile have been measured precisely using Video measuring system. The results of the experiments have been shown below.

Table 6: Tool wear and Cycle time

SPEED rpm	**FEED mm/rev**	**DEPTH OF CUT mm**	**TOOL WEAR**	**CYCLE TIME**
400	0.25	1.25	0.33	50.00
400	0.15	0.75	0.20	83.33
400	0.2	1	0.26	62.50
450	0.25	0.75	0.52	44.44
450	0.15	1	0.33	74.07
450	0.2	1.25	0.24	55.55
500	0.2	0.75	0.25	50.00
500	0.25	1	0.39	40.00
500	0.15	1.25	0.46	66.66

For the above results following tool wear were occurred are shown in following figure 10.

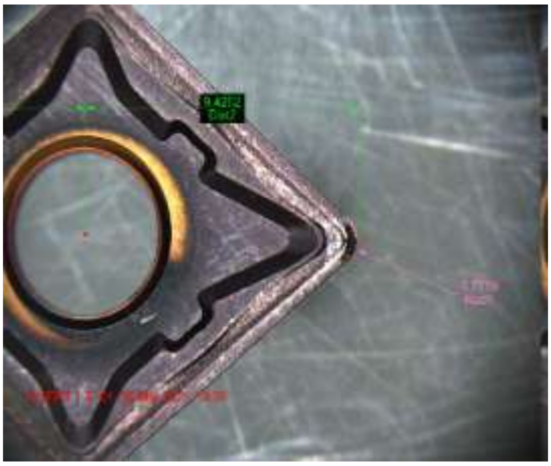

Fig 10 Insert edge 1

Similarly all the edges were analysed and the wear for particular edges were measured.

III. RESULTS AND DISCUSSION

3.1 REGRESSION ANALYSIS:

The results obtained were then put forth into regression analysis to plot out the correlation between each and every factors with tool wear. The regression analysis were carried out using the software Minitab version16.

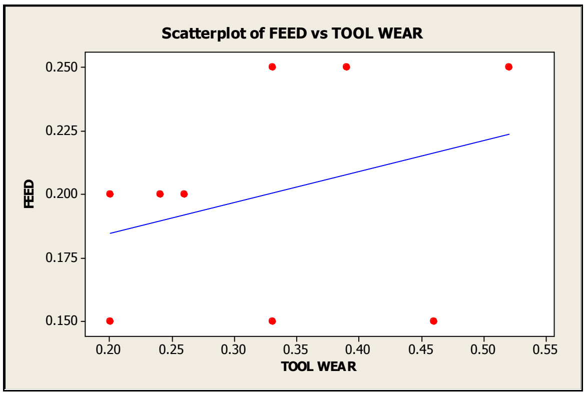

Fig 11: Feed vs. tool wear

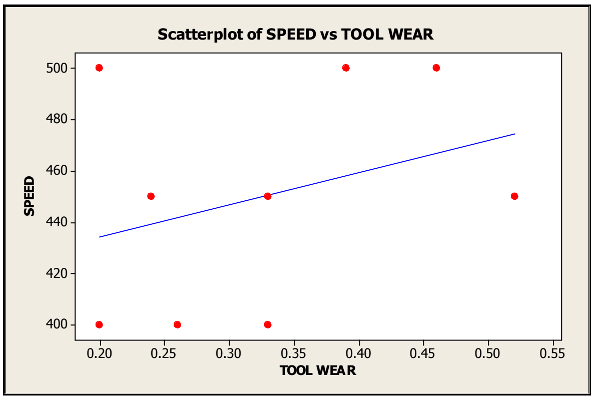

Fig 12. Speed vs. tool wear

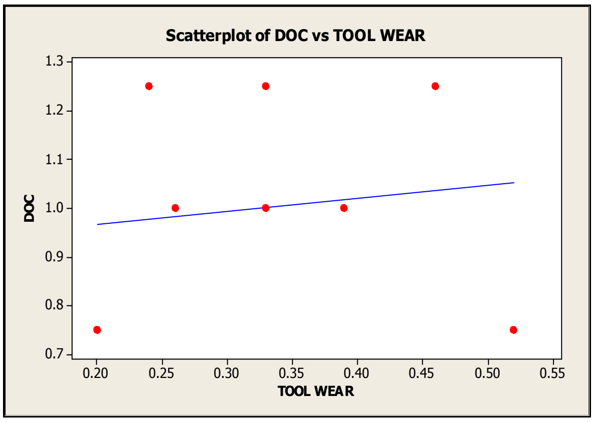

Fig 13. Depth of cut vs. tool wear

3.2 INFERENCE FROM REGRESSION:

Wear increases with increase in speed and feed to a greater extent and Wear increases with increase in Depth of cut as well but marginally in comparison to speed and feed

3.3 ANALYSING TAGUCHI DOE:

The observed values were analyzed using Minitab to get the Signal to Noise ratio results to decide the best parameters. From the table 7 we choose the best combination based on the higher value of Signal to noise ratio by which we could get the best combination which have the least tool wear.

Table 7. Mean value in account of tool wear

Speed	Feed	Doc	Tool wear	Signal to noise ratio	Mean
400	0.25	1.25	0.33	9.62	0.33
400	0.15	0.75	0.20	13.97	0.20
400	0.20	1.00	0.26	11.70	0.26
450	0.25	0.75	0.52	5.67	0.52
450	0.15	1.00	0.33	9.62	0.33
450	0.20	1.25	0.24	12.39	0.24
500	0.20	0.75	0.25	13.97	0.20
500	0.25	1.00	0.39	8.17	0.39
500	0.15	1.25	0.46	6.74	0.46

From the table 8 we choose the best combination based on the higher value of Signal to noise ratio by which we could get the best combination which have the least cycle time.

Table 8 Mean value in account of cycle time

SPEED	FEED	DOC	CYCLE TIME	SIGNAL TO NOISE RATIO	MEAN
400	0.25	1.25	50.00	-33.97	50.00
400	0.15	0.75	83.33	-38.41	83.33
400	0.20	1.00	62.50	-35.91	62.50
450	0.25	0.75	44.44	-32.95	44.44
450	0.15	1.00	74.07	-37.39	74.07
450	0.20	1.25	55.55	-34.89	55.55
500	0.20	0.75	50.00	-33.97	50.00
500	0.25	1.00	40.00	-32.04	40.00
500	0.15	1.25	66.66	-36.47	66.66

Table 9 Best parameters

	Machining Parameters	Cycle Time in min	Tool Wear
BEST PARAMETERS	400, 0.15, 0.75	83.33	0.2
	500, 0.2, 0.75	50.00	0.25
	450, 0.15, 1	40.30	0.33
	450, 0.2, 1.25	53.95	0.24
	500, 0.15, 1.25	31.05	0.46
Followed in industry	450, 0.2, 1	55.55	0.28

The table 9 lists the best combinations selected from the two tables from which the combination with best values of low tool wear and least cycle time is selected. The combination with spindle speed 500 rpm, feed rate 0.2 rev/min and depth of cut 0.75 gives out a flank wear of 0.25mm and with cycle time of 50.00 minutes is selected. The improvement is shown in figure 14.

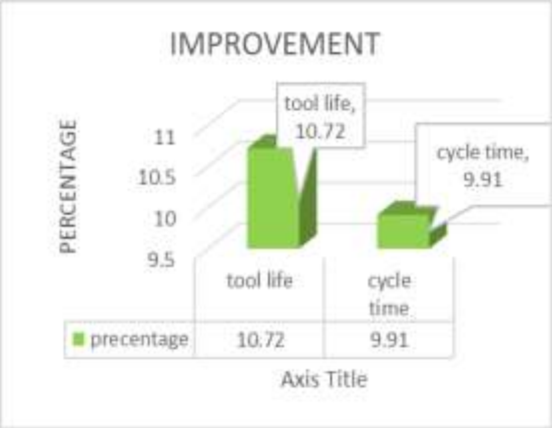

Fig 14. Improvement Achieved

IV. CONCLUSION

The study shows that improving working methodology improves productivity, by optimizing the cutting parameters in our investigation we were able to reduce the rejection (due to unstandardized cutting parameters), improve tool life and reduce cycle time. By which cost incurred due to these factors is also reduced, hence the company is benefited economically as well. Taguchi experimental design method was an effective way of determining the optimum cutting parameters to achieve less tool wear and optimal cycle time.as a result it was understood that feed rate and speed has major contribution to tool wear whereas depth of cut has minor contributions in our case. Hence by changing speed from 450 to 500, feed of 0.2 remains same, and DOC from 1 to 0.75 we can reduce the 9.91% time required to complete a turning operation further tool life is improved to extent of 10.72%.

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Dr. Shanmugaraja M. “Lean-Six Sigma Case Study to Improve Productivity in a Manufacturing Industry.” International Journal of Engineering Research and Applications (IJERA), vol. 7, no. 9, 2017, pp. 38–46.