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Productivity Improvement in Manufacturing Industry Using Industrial Engineering Tools

M. Tech. Scholar Rupesh Mahajan, Prof. Nitesh Mishra
Department of Mechanical Engineering,
SDITS,
Khandwa (M.P.)

Abstract- This study presents a novel analysis for the control of manufacturing flaws. This investigation focuses on the tube bending process. The chosen component was generally rejected due to defects in a cross section of the tube flatness. Six Sigma, the zero-defect approach, is used in this research. A strategy for increasing productivity is a method for increasing the production of brake shoes. The collection of data is intended to provide an analytical foundation, that is, to turn data into information that decision makers and value may use. However, before data can be collected, a data collection plan must be developed. Data is obtained in order to identify, analyse, and eliminate the manufacturing facility's bottleneck station. The collected data is viewed immediately on the shop floor through continuous assessment of each machine using a stop-watch.

Keywords- Productivity Improvement, Manufacturing Industry, Industrial Engineering Tools.

INTRODUCTION

Six Sigma is a new and growing approach of quality assurance and management that focuses on continual improvement in quality. The fundamental objective of this strategy is to reach a quality and dependability level that matches or surpasses today's demanding customer requirements and expectations. The phrase "Sigma level of quality" is used as an indication of process benevolence. A lower level of sigma quality implies more potential for defective goods, while a greater level of Sigma quality means a reduced probability for defective products in the process.

Six-Sigma is a statistical measurement of 3.4 faults per million and is regarded the philosophy of management committed to mistake removal, waste removal and repair. It sets a quantifiable state to attain and reflects consumers' problem-solving techniques. Satisfaction has lowered expenses and improved revenues considerably. Six Sigma's power is straightforward because it blends human power with process power. Assume that the company focuses on customer happiness.

In this scenario, Six Sigma will give a way and tools to identify and fix difficulties with internal and external processes to increase customer satisfaction by recognising changes in organisational processes that might negatively affect custodian vision.

The advantages of recruiting Six Sigma workers are numerous. Some of the advantages include: cost savings, productivity improvement, decreased shortages, reduced cycle time and enhanced customer satisfaction. The following are only two successful instances with their special advantages after "Six Sigma" implementation. Six Sigma also yielded great outcomes. Furthermore one of the first success stories started with Motorola, Six-creator. Sigma's Ten years after the implantation of Six Sigma, the plant in Illinois in Schaumburg was a huge success. While Frederick Taylor, Walter Stewart or Henry Ford has played key roles in "Six Sigma" development at the beginning of the 20th century, Motorola's vice-president, Bill Smith is believed to be "Father of Six Sigma."

In today’s competitive world, customers want perfection, and there is no room for error. Meet the needs of today’s customers, make them happy or take new ways to exceed their expectations. Six Sigma helps to achieve this goal. Six sigma is a highly stringent method that allows us to concentrate on embryonic items or deliver almost perfect services. Six sigma can help us decrease or accept the unpredictable nature of their operations. The core assumption of Six Sigma is that if you can quantify the "faults" in a process, you can figure out how to reduce them and get as close to "zero flaws" as feasible. The term "sigma" refers to the dispersion distribution of any process or technique's mean value (mean value).

Six sigma is a strong force. Leading companies such as GE, Motorola, and Ford have achieved remarkable success and improved customer satisfaction by radically changing the way they work and improving the products and services they offer. These leading companies are so satisfied with six sigma that they are willing to invest $ 10 billion in 6 sigmato get a multi-billion dollar response disability.

The British Department of Commerce and Industry said in its definition: Six Sigma is: "Uses data retrieval methods to obtain comparable quality. Six Sigma analysis can focus on a production or service element, with ' special emphasis on design, production, and statistical analysis of customer activity".

Defining a "Six Sigma" management system, Motorola University said: ''A Six Sigma management system can improve the understanding of a company's strategy and the indicators that best reflect the strategy's success. Provides a priority source of information for project planning that will improve measurement and use leaders to manage work to achieve quick, lasting, and improved results. "

Six sigma is therefore a statistical thinking that evaluates its growth in terms of faults. Obtaining a six sigma means that your process has just 3.4 sales per million (DPMO). Six Sigma is a management approach that emphasises knowledge, measurement, and application improvement to decrease failures.

II. REVIEW OF LITERATURE

Mohammad Alnadi& Patrick McLaughlin et al. (2021) conducted a literature review on published leadership and Lean Six Sigma literature. The preceding literature used a theme analysis to assist find significant traits and relate behaviour to specific elements. [1].

Alnadi and McLaughlin et al. (2020) Leadership styles also contain certain behaviours that leaders should take care of to make Lean Six Sigma effective. [2]

Bertha Viviana Ruales Guzmán, Alessandro Brun, Oscar Fernando Castellanos Domínguez, et al. (2019) This paper analysed the literature that studied the relationship between Quality Management and productivity as few studies have done before. [3].

Nogueira et al. (2018) specifically address leadership behaviours and styles that may impact the effective implementation of Lean Six Sigma. The authors studied the literature and determined the leadership behaviours that support Lean Six Sigma, as well as understanding how leadership behaviours aid the Lean Six Sigma process [4].

Rajat Ajmera et al. (2017) consider using the six sigma DMAIC method to reduce defect rates in selected textile industries. This is a systematic approach to minimize defects through five steps in the DMAIC method (definition, measurement, analysis, optimization, and control). Six different sigma devices were used in different phases. The Pareto research was designed to identify the major types of defects. [5].

Nachiket Kulkarni et al. (2017) provided the application of the DMAIC method to improve the production process of shunt shoes. The purpose of this article is to introduce the application of the DMAIC method, which identifies a reliable quality strategy for the data used to improve its processing [6].

Santosh Subhash Chandra Dubey and Dr Arun Kumar et al. (2017) examined the main reasons to implement effective TQM and why SMEs oppose the adoption of TQM. The results will encourage and help them to eliminate or reduce barriers for SMEs in applying TQM to achieve enterprise success in future research. [7]

Mohd khairulnizamzahari and Norhayatizakuan et al. (2016) examined the relationship between quality management and employee performance. Three hundred fifty questions were posed to 10 manufacturing companies in Malaysia, and the sample consisted of 294 completed surveys (response rate of 84.0%). Before the pilot test, a validity test was performed to test the relevance of the question. Statistical analysis and regression are used to predict and evaluate this relationship. [8].

Jyoti Prakash Majumdar et al. (2016) learn the key reasons to achieve success in complete quality management and the reasons that lead to the hesitation of small and medium enterprises to adopt complete quality management. The results will encourage and guide future research to eliminate or reduce the difficulty of SMEs in applying TQM to achieve business success [9].

C. Manohar & A. Balakrishna et al. (2015) talked about improving product quality and productivity through fault analysis and the application of the Six Sigma DMAIC method (measurement-measurement-specification). improvement-control) of a tire manufacturer, which can provide a system to identify, define and eliminate variable sources of work, improve work performance, improve and maintain efficiency, i.e., A good control plan can reduce the defects in casting production, thereby increasing the results obtained [10].

III. DATA COLLECTION

1. Define Phase:

At this point, the goals and scope of the project are determined, information about processes and customers is collected, and products to be delivered to customers (internal and external) are specified.The purpose of this case study is to reduce the reduction of defective products caused by bending errors in Bhopal Bend Joints Pvt Ltd. The company's repulsion in pipe bending over and over again. The critical bending errors in the industry were chosen for comprehensive analysis.The following equation provides a general 6-sigma basic premise for the DMAIC method of carrying out the project.

2. Measure Phase:

The principle of the measurement step is to appraise or understand the current state of the process. This involves collecting data on quality, cost or lead time/cycle time. It

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is imperative to list all key procedure variables. This step provides a detailed mapping of processes to identify key errors. After discussion with the departmental engineers, data from production engineers and supervisors were collected using team members during this phase.

Table 1 is showing the Defect's name in the bendings. Therefore; it is best to name several issues, identify opportunities for improvement and list the following issues in its operation:

Table 1. Defects Name in Bending

S.No.	Defect Name
1	Flattering of a cross-section of the tube
2	Crinkling
3	Thinning of walls
4	Spring back during bending
5	Cracking or splitting on outside bend
6	Buckling/Wrinkles
7	Galling/Scoring/Drag
8	Scratches/Gouges/Impressions/ and Indentations

Table 2. Data collection period.

Period	Variables (CTQ)
July (2021)	Total No. of Defects

This control sheet is also called a "defective concentration chart" and is a data collection sheet. Using the checklist, we have compiled the frequency of deficiencies (see Table 5.2 and 5.3). The fundamental defect does not occur with the same frequency, some defects arise very often, and some occur less frequently.

For analysis, we collected defect names and number of defects from the bending department of well-known manufacturing industry in Bhopal's Bend Joints Pvt Ltd.

Table 3. Defect Name and Quantity.

S.No.	Defect Name	Defect quantity
1	Flattening of cross-section of tube	1423
2	Crinkling	1326
3	Thinning of walls	1156
4	Spring back during bending	415
5	Cracking or splitting on outside bend	324
6	Buckling/Wrinkles	271
7	Galling/Scoring/Drag	156
8	Scratches/Gouges/Impressions/ and Indentations	121

Table 4. Defect Name and Quantity with Frequency

S.No.	Defect Name	Defect quantity	Frequency
1	Flattening of cross-section of tube	1423	27
2	Crinkling	1326	53
3	Thinning of walls	1156	75
4	Spring back during bending	415	83
5	Cracking or splitting on outside bend	3243	89
6	Buckling/Wrinkles	271	94
7	Galling/Scoring/Drag	156	97
8	Scratches/Gouges/Impressions / and Indentations	121	99
Total No. of defects		5192	100

3. Taguchi Method:

Since the relationship between these parameters was unknown, it was decided to experiment with them at three levels. The parametersand levels selected for experimentation are presented in Table 4.

Table 5. Parameter and Level Selection for Experiment for Flattening.

Factor	1	2	3
Outer Diameter (mm)	114.3	150.7	190.4
Gap (mm)	2.5	2.65	2.85
Pressure (MPa)	4.9	5.6	7.4

Using the Orthogonal Array (OA), nine experiments can estimate the effects of these selected parameters and interactions. Therefore, the L9 orthogonal array was chosen to experiment with six parameters and three interactions. According to the design layout in Table 5, perform experiments after randomizing the experimental sequence and collect data. The experimental data were analyzed by Taguchi's signal-to-noise ratio (S / N) method. S / Nratio are recommended in the Taguchi method to minimize the number of defects.

Table 6. L9 Orthogonal Array.

Outer Diameter(mm)	Gap (mm)	Clamping Pressure (Mpa)
114.3	2.5	4.9
114.3	2.65	5.6
114.3	2.85	7.4
150.7	2.5	5.6
150.7	2.65	7.4
150.7	2.85	4.9
190.4	2.5	7.4
190.4	2.65	4.9
190.4	2.85	5.6

Experiments were performed according to the factor settings in each test mode, and 900 components were

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produced in 9 batches. Record the number of defective components in response to each test. Since the experimental answer is the number of faulty components, the following formula is used to select and calculate the signal-to-noise ratio "less is better" and register it as shown in Table 6.

Table 7. SN Ratio.

Outer Diameter	Gap	Clamping Pressure	No. of Defect items out of 100	SN ratio of Defect Items out of 100
114.3	2.5	4.9	19	25.57
114.3	2.65	5.6	7	16.9
114.3	2.85	7.4	15	23.52
150.7	2.5	5.6	22	26.84
150.7	2.65	7.4	26	28.29
150.7	2.85	4.9	6	15.56
190.4	2.5	7.4	16	24.08
190.4	2.65	4.9	4	12.04
190.4	2.85	5.6	5	13.97

IV. RESULTS AND ANALYSIS

1. Analysis of Variance:

The results obtained from the experiments were verified with the help of ANOVA, which can predict the importance of the input parameters for all the desired response tasks. Shows the most important factors that affect the results. The confidence interval of the analysis was 95%. The results are shown in Table 7. Balanced defect results were obtained from 9 experiments performed by Taguchi. The experimental results with ANOVA are shown in Table 6.1.

The value of F selected by the MINITAB 15 software is shown in the last second column of the ANOVA table. This value indicates the importance of the element to the desired attribute. The larger the F value, the higher the value (given the 95%confidence level). The results show that only licking feeding is the most important. In Table 6.2, different numbers are arranged. The higher the level, the greater the significance. The distance of the mandrel is the most important factor.

Table 8. ANOVA for Flattening Defect.

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Outer Diameter (mm)	2	3.4417	3.4417	1.7208	2.11	0.322
Mandrel Gap (mm)	2	7.2395	7.2395	3.6197	4.43	0.184
Clamping Pressure (MPa)	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 9. Response Table.

Level	Outer Diameter (mm)	Mandrel Gap (mm)	Clamping Pressure (MPa)
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

The effect of the flat is shown in Figure 6.1. The large translation shows the change in numbers. The relationship between the faulty product and the outer diameter, the removal of the mandrel, and the clamping pressure. The x-axis represents the change in the level of the variable, and the y -axis represents the change in the obtained result.

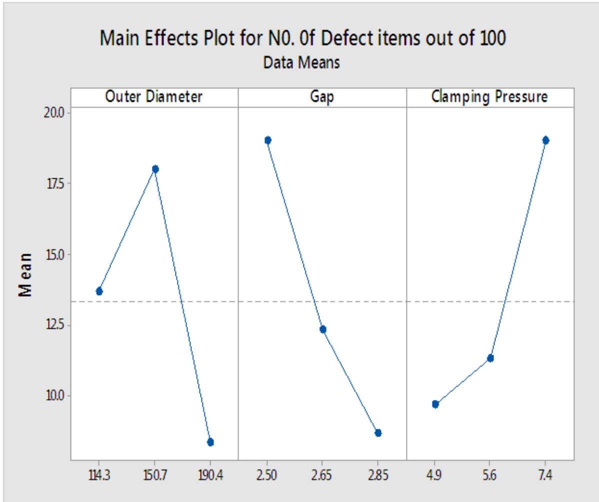

Fig 1. Main Effects Plot.

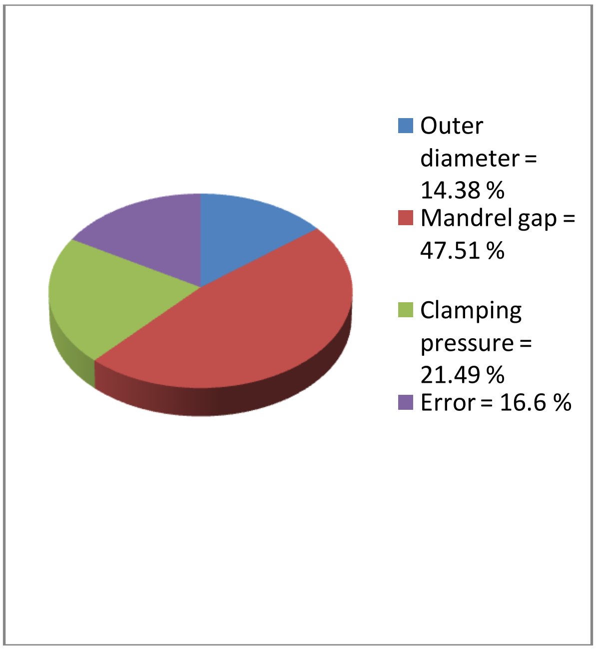

Fig 2. Percentage Contribution of Process Parameters on Flattening Defect.

2. Pie- Chart:

A graphical chart is used to visualize the percentage contributions to accurately distinguish the contributions of the parameters (outer diameter, mandrel distance, clamping pressure, and including defects). As described below.

- **Outer Diameter**-showing in dark blue, only 14.38% the smallest.
- **Mandrel Gap-** shown in red gives 47.51%, which is the largest contribution. The spacing is responsible for flat production.
- **Green Pressure Rating-** only 21.49%.
- **The error is shown in purple**, 16.6%.

3. Determination of Optimum Solution:

Figures 1 identified optimum factor levels for based on the 'Smaller Better' S/N ratio characteristic listedin Tables9.The optimal result has been established through assenting test showed the satisfactory result.

Table 10. Optimum Levels for Flattening Defect.

Parameter designation	Process parameters	Optimal levels
A	Outer Diameter	190.4 mm
B	Mandrel Gap	2.85 mm
C	Clamping Pressure	4.9 MPa

V. CONCLUSIONS

It has been found that the mandrel gap is found to be the most important factor & its contribution to flattening defect is 47.51 %. The best results for flattening (lower is better) would be attain with optimum parameter, Outer Diameter= 190.4 mm, Mandrel Gap = 2.85 mm, and clamping pressure= 4.9 MPa. With a 95% confidence interval, the mandrel gap affects the flattening defect most drastically.

The flattening defect is generally pretentious by outer Diameter, mandrel gapand clamping pressure. With the increase in outer diameter, the flattening defect first increases and decreases. As the mandrel gap increases, the flattening deficiency decreases, and as the clamping pressure increases,the flattening defect increases.

From ANOVA investigation, parameters making important effects on flattening are mandrel gap and clamping pressure.

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