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Industrial Engineering Tools in Manufacturing Industry to Improvement Productivity

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Abstract- This research study proposes an innovative analysis for controlling the defects in manufacturing industry. In this analysis, pipe bending process is concentrated. The component selected has often rejected due to flattening and crinkling of cross section of tube defects. Six Sigma, the zero defect approach, is used in this study. Define measure, analyse, improve and control (DMAIC) problem solving methodology is applied for problem analysis. Taguchi's experimental design is used for process validation and improvement. The confirmation experiment showed that the rejection rate was reduced to 6.77 % from 21.66 % in case of flattening defect while rejection rate was reduced to 8.22 % from 16.77 % in case of crinkling defect. The application of Six Sigma program with Taguchi technique has developed an innovative cost effective methodology for controlling defects in less experimental time.

Keywords - defects; pipe bending; productivity; quality; Six Sigma; define measure, analyse, improve and control; 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.

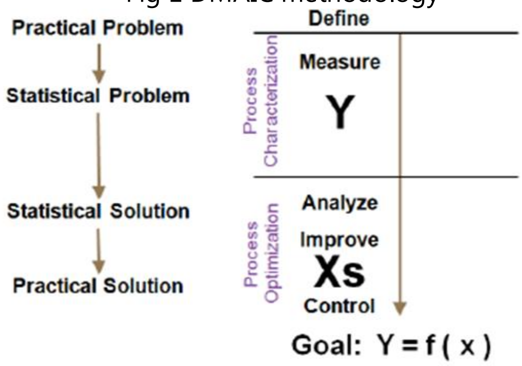
Six Sigma is a quality improvement initiative for improving textile processes by reducing variation and defects (Senthil & Sundaresan, 2010; Das et al, 2007). There are already abundant cases of successful application of Six sigma DMAIC methodology in automotive industry (Chen et al, 2005), small scale enterprises (Desai, 2006), die-casting process. They integrated Lean tools such as Current State Map, 5S System, and Total Productive Maintenance (TPM) within Six Sigma DMAIC methodology to improve the bottom-line results and enhanced customer satisfaction. The findings showed marked improvement in the yield of die-casting process thereby generating substantial cost saving. [2].

Six Sigma is a business improvement strategy used to improve profitability, to drive out waste, to reduce quality costs and improve the effectiveness and efficiency of all operational processes that meet or exceed customers' needs and expectations [3].DMIAC is adopted in manufacturing company to identify, quantify and eliminate sources of waste in an operational process, up to optimization usage of the available resources, improve the sustain performance of the production line improvement with well executed control plans in future [4].Six Sigma has revolutionized the world of business and has offered a new measure of success in customer satisfaction and quality. For companies in the textile industry to compete with others and remain in the market they had to improve quality and minimize defects in their products. Therefore they embraced various quality initiatives such as Six Sigma based on Define–Measure–Analyze–Improve–Control (DMAIC) tools. DMAIC methodology of six sigma is a problem solving method where six sigma tools are used to analyze the process data and finally the root causes behind the defects produce in the product are identified. Six sigma is a quality improvement process of final product by reducing the defects, minimizing the variation and improving capability in the manufacturing process.

III. SIX SIGMA METHODOLOGY (DMAIC)

The DMAIC methodology follows the phases: Define, measure, analyze, improve and control. Although PDCA could be used for process improvement, to give a new thrust, Six Sigma was introduced with a modified model i.e. DMAIC. The methodology is revealed phase wise (Fig.1) and is implemented for this project.

Fig 1 DMAIC methodology



1. Define Phase

This phase determines the objectives & the scope of the project, collect information on the process and the customers, and specify the deliverables to customers (internal & external).

The present case study deals with reduction of rejection due to bending defects in a Bend Joints Pvt Ltd, Bhopal. The company face rejection in the pipe bending. The important bending defects of industry were chosen for complete analysis. The below equation gives the general six sigma basic premise to the DMAIC methodology to conduct project.

$$Y = f(X)$$

With respect to above relation with pipe bending, the parameters indicating to six sigma basic premise are as follows,

Y = reducing the critical defects in pipe bending & increasing the productivity & maintaining the consistency in the quality.

X = causes for defects

As quality plays a pivotal role in all aspects of life, reducing the number of defectives in manufacturing industry is an important function. Six Sigma project, undertaken within company for production of bend joints, which deals with identification and reduction of production cost in the pipe bending process and improvement of quality level of produced parts.

The present company is facing 14-15% of rejections of bend pipes for every month for their production. This study deals with the reduction of bending defects in is Bend Joints Pvt Ltd, Bhopal.

B. Measure Phase

The purpose of the Measure step is to evaluate and understand the current state of the process. This involves collecting data on measures of quality, cost, and throughput/cycle time. It is important to develop a list of all of the key process variables. This phase presents detailed process mapping, determination of the critical defect. In this phase, after discussions with the section engineers, production engineers and supervisors data is collected with the help of team members. So a list of problems better to say opportunities for improvements were identified, following problems were listed down in their operations-

Table 1 Defects name in bending

S.No.	Defect Name
1	Flattering of cross-section of 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

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Data collection period

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

The check sheet also called a 'Defect Concentration Diagram' is basically a data collection sheet. By using check sheet we have collect the frequency of defect. The entire defect is not occurred in same frequency, some defect is appearing very frequently and some is in less frequent. For analysing purpose we have collected defect name and defect quantity from bending section of a renowned manufacturing industry that is Bend Joints Pvt Ltd, Bhopal.

Table 2 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

2. Pareto Analysis- The Pareto diagram shows the total number of defects on Y axis and Nature of defect on X axis. From the diagram, we can identify the critical defects by 80-20 Rule. They are Flattening and Crinkling.

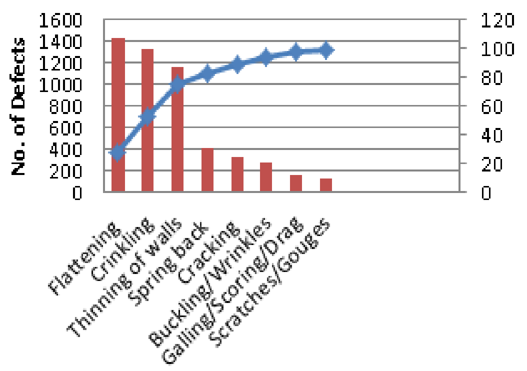

Fig 2 Pareto diagram for defects

3. Analyze Phase

This phase describes the potential cause's identification which has the maximum impact on the flattening and crinkling defects. This phase concentrates on the identification of the root causes of the critical defects and helped to examine the processes that affect CTQs and decide which X's are the vital few that must be controlled to result in the desired improvement in the Y's, this leaded to generate ideas for improvement and reduce variation.

Cause-Effect (CE) analysis is a tool for analysing and illustrating a process by showing the main cause and sub-causes leading to an effect (symptom). It is sometimes referred to as the "fishbone diagram" because the complete diagram resembles a fish skeleton. The fishbone is easy to construct and interactive participation. Once a defect, error, or problem has been identified and isolated for further study, we must begin to analyse potential causes of this undesirable effect. In situation where causes are not obvious, the cause and effect diagram is a formal tool frequently useful in un-layering potential causes. The cause and effect diagram constructed to identify potential problem areas in the pipe bending manufacturing process mentioned in the following figure:

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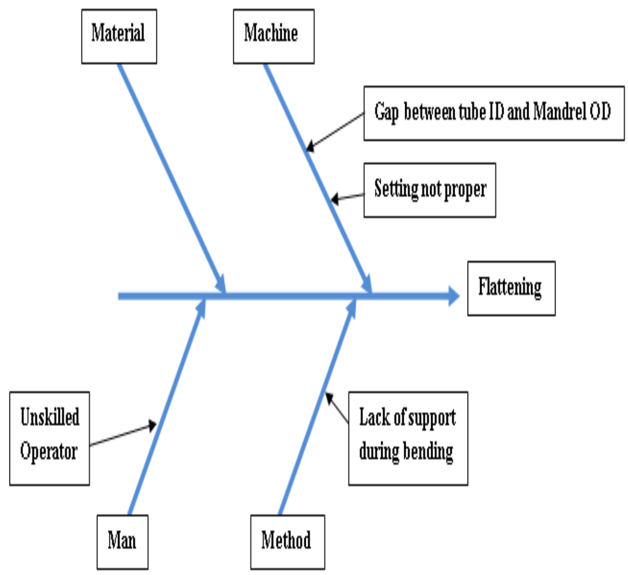

Fig. 3 Cause and Effect diagram Analysis for Flattening

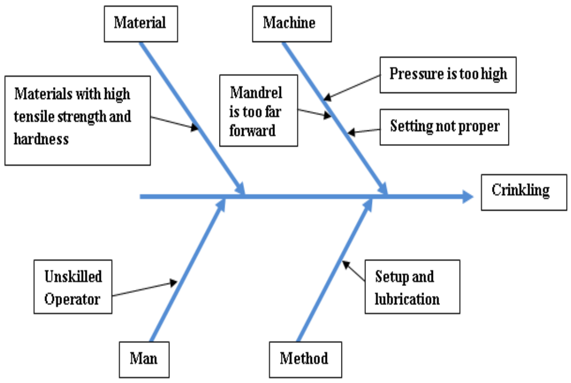

Fig. 4 Cause and Effect diagram Analysis for Crinkling.

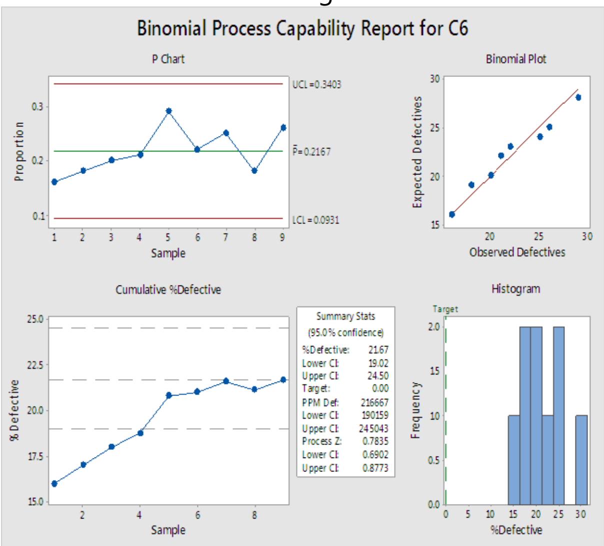

Fig 5 Binomial capability analysis for flattening before study

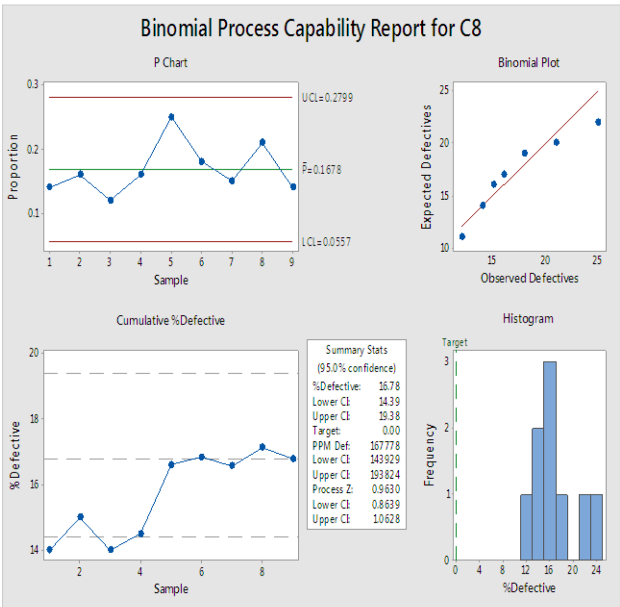

Fig. 6 Binomial capability analysis for crinkling before study

3. Improve Phase

This phase of the Six Sigma project is aimed at identifying solutions for all the root causes identified during the Analyse phase, implementing them after studying the risk involved in implementation and observing the results. At this stage, as decided earlier, a DOE was planned for optimizing the process/machine parameters. The team along with the production supervisor and operators of the process conducted a series of brain storming sessions to identify the important parameters for experimentation. The parameters selected through these discussions were outer diameter, mandrel gap and clamping pressure.

4. Data collection for flattening defect

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.

Table 3 Parameter and level selection for experiment

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

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 six parameters and three interactions, L9 orthogonal array was selected. As per the design layout given in Table 4, 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.

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Table 4 L9 orthogonal array sequence

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

The experiment is carried out as per the factor settings in each test condition and 900 components are produced in 9 batches. The number of defected components is recorded as response for each test. Since the experiment response is number of defected components, 'Smaller the better' S/N ratio characteristic selected and calculated using the below equation and recorded as shown in Table 5.

Table 5 SN ratio for flattening defect

Outer Diameter	Gap	Clamping Pressure	N0. 0f 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

Data Collection For Crinkling Defect:

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 6.

Table 6 Parameter and level selection for experiment

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

As per the design layout given in Table 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 7 SN ratio for flattening defect

Outer Diameter	Gap	Clamping Pressure	N0. 0f Defect items out of 100	SN ratio of Defect Items out of 100
114.3	2.5	4.9	25	27.95
114.3	2.65	5.6	11	20.82
114.3	2.85	7.4	18	25.1
150.7	2.5	5.6	21	26.44
150.7	2.65	7.4	23	27.23
150.7	2.85	4.9	9	19.08
190.4	2.5	7.4	14	22.92
190.4	2.65	4.9	6	15.56
190.4	2.85	5.6	4	12.04

Main effect plots for flattening are shown in the figure 7. Main effect plot shows the variation of no. of defected item with respect to outer diameter, mandrel gap and clamping pressure. X axis represents change in level of the variable and y axis represents the change in the resultant response.

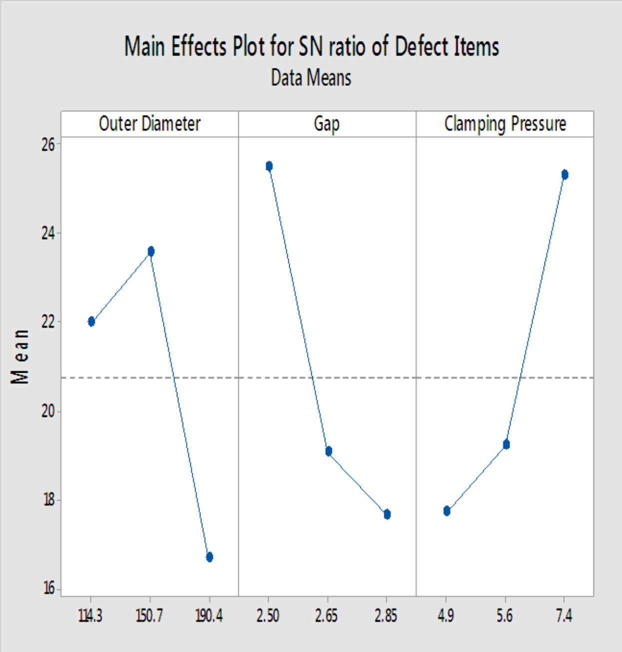

Fig. 7 Main effects plot for S/N ratios for flattening

Main effect plots for crinkling are shown in the figure 8. Main effect plot shows the variation of no. of defected item with respect to outer diameter, mandrel gap and clamping pressure. X axis represents change in level of the variable and y axis represents the change in the resultant response.

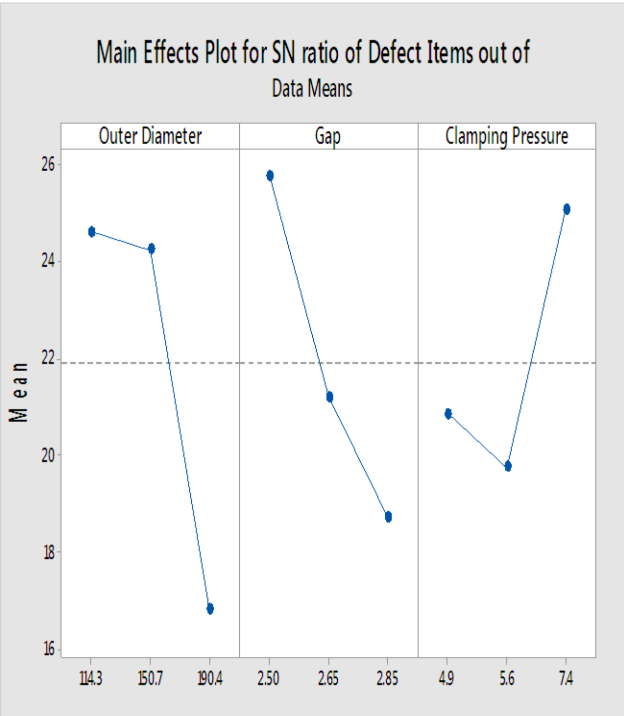

Fig 8 Main effects plot for S/N ratios for crinkling

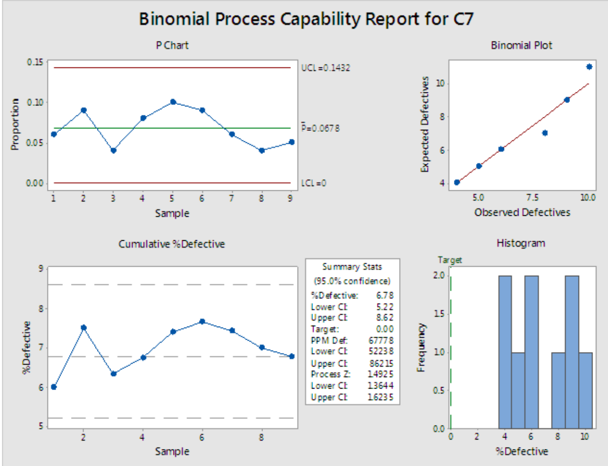

Fig 9 Binomial capability analysis for flattening after study

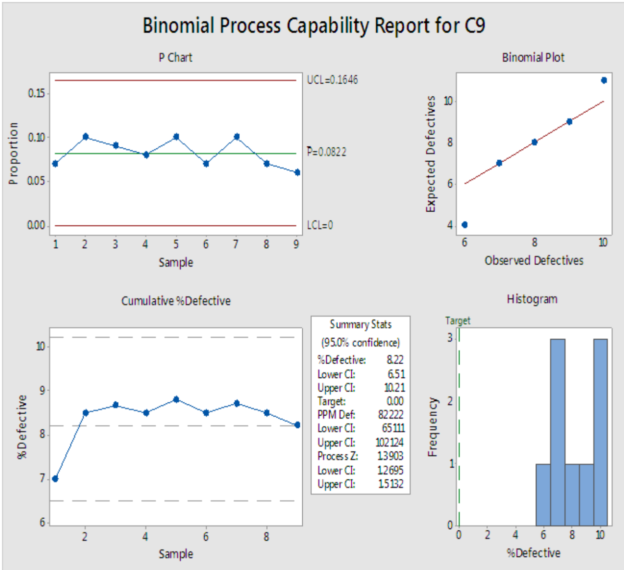

Fig 10 Binomial capability analysis for flattening after study

IV. 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.

1.Confirmation test for Flattening

Confirmation test have been done with settings i.e. Outer Diameter= 190.4 mm, Gap = 2.85 mm and clamping pressure= 4.9 MPa on 9 Batches, consists of 100 unit per batch. Results are shown in below table 8.

Table 8 Defect percentage level for flattening.

S. No	Good Items	Defected Items	Defect Percentage %
1	94	6	6
2	91	9	9
3	96	4	4
4	92	8	8
5	90	10	10
6	91	9	9
7	94	6	6
8	96	4	4
9	95	5	5
Avg. Defect level			6.77

1.Confirmation test for Crinkling

Confirmation test have been done with settings i.e. Outer Diameter= 190.4 mm, Gap = 2.85 mm and clamping pressure= 5.6 MPa on 9 Batches, consists of 100 unit per batch. Results are shown in below table 9.

Table 9 Defect percentage level for crinkling

S. No	Good Items	Defected Items	Defect Percentage %
1	93	7	7
2	90	10	10
3	91	9	9
4	92	8	8
5	90	10	10
6	93	7	7
7	90	10	10
8	93	7	7
9	94	6	6
Avg. Defect level			8.22 %

V. 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. Sustainability of the results requires standardization of the improved methods and introduction of monitoring mechanisms for the key results achieved. It also requires bringing awareness among the personnel performing the activities.

Standardization of the solutions was ensured by affecting necessary changes in the process procedures that was a part of the quality management system of the organization. The quality plans and control plans were revised as per the solutions implemented and issued to the corresponding users. As a part of ISO 9001 implementation, once in three months internal audits were carried out in the process. After implementation, the data were compiled with respect to the defects for one month and the rejection percentage was found to be 6.77 % and 8.22 %. Hence, as a result of this project, the rejection percentage reduced from 21.66 to 16.77 % in case of flattening and 16.77 to 8.22 % in case of crinkling.

VI. CONCLUSION

A. conclusions from flattening defect

- It has been found that mandrel gap is found to be the most significant factor & its contribution to flattening defect is 47.51 %. The best results for flattening (lower is better) would be achieved with optimum parameter= Outer Diameter= 190.4 mm, Mandrel Gap = 2.85 mm and clamping pressure= 4.9 MPa. With 95% confidence interval, the mandrel gap effects the flattening defect most significantly.
- The flattening defect is mainly affected by outer Diameter, mandrel gap and clamping pressure. With the increase in outer diameter the flattening defect first increase and decrease, as the mandrel gap increases the flattening defect decrease and as the clamping pressure increase flattening defect increases.
- Optimal parameters were determined. The percentage of rejection decreases from 21.66% to 6.77%.
- Number of defective items was also decreases from 195 to 61.
- Number of good items was also increases from 705 to 839.
- Productivity increases from 78.33% to 93.22%.

2. Conclusions from crinkling defect

- It has been found that clamping pressure is found to be the most significant factor & its contribution to crinkling defect is 85.05 %. The best results for crinkling (lower is better) would be achieved with optimum parameter= Outer Diameter= 190.4 mm, Mandrel Gap = 2.85 mm and clamping pressure= 5.6 MPa. With 95% confidence interval, the clamping pressure effects the crinkling defect most significantly.

- The crinkling defect is mainly affected by outer Diameter, mandrel gap and clamping pressure. With the increase in outer diameter the crinkling defect decrease, as the mandrel gap increases the crinkling defect decrease and as the clamping pressure increase crinkling defect first decrease and then increase.
- Optimal parameters were determined. The percentage of rejection decreases from 16.77 % to 8.22 % as shown below.
- Number of defective items was also decreases from 151 to 74.
- Number of good items was also increases from 749 to 826.
- Productivity increases from 83.22 % to 91.77 %.

REFERCENCES

[1] Fursule, N. V., Bansod, S. V. & Fursule, S. N., "Understanding the Benefits and limitations of Six Sigma Methodolgy", International Journal of Scientific and Research publications,(2012).

[2] Kumar M., Antony J., Singh R. K., Tiwari, M. K., and & Perry, D. "Implementing the Lean Sigma framework in an Indian SME: a case study", Production Planning & Control: The Management of Operations, Vol. 17, No. 4. (2006).

[3] Antony, J. & Banuelas, R., Six Sigma: A Business Strategy for Manufacturing Organization. Manufacturing Engineering,pp 119-121(2001).

[4] Tushar N.Desai & Shrivastava, R.L.," Six Sigma – A New Direction to Quality and Productivity Management", World Congress on Engineering and Computer Science WCECS,(2008).

[5] Ina Sitit Hasanah, Bdi Hermana, Hani Hastiyani, "Application of six sigma method using define-measure-analyze-improve control (DMAIC) method on string production". Proceedings of the International Seminar on Industrial Engineering and Management, Jakarta,(2007).

[6]Sachidanand S. More, Dr. Maruti S. Pawar.,"Performance Improvement of Textile Sector by Implementation Quality Six Sigma", International Journal of Application or Innovation in Engineering & Management, Vol.2, Iss: 12 ,pp 352-357,(2013).

[7] Chethan Kumar, Dr. N V R Naidu, Dr. K Ravindranath, "Performance improvement of manufacturing industry by reducing the Defectives using Six Sigma Methodologies ",IOSR Journal of Engineering , Vol. 1, Issue 1, pp. 001-009.

[8] Senthil, R. and Sundaresan, S. (2010), "Six Sigma in textile industry", The Indian Textile Journal, July issue (2010).

[9] Chen, S., Chen, K. and Hsia, T. (2005), "Promoting customer satisfaction by applying Six Sigma: an example from the automobile industry", The Quality Management Journal, Vol.12, No. 4, pp. 21-33.(2005).

[10] Desai, D. (2006), "Improving customer delivery commitments the Six Sigma way: case study of an Indian small scale industry", International Journal of Six Sigma and Competitive Advantage, Vol. 2 No. 1, pp. 23-47. (2006)

[11] Tong, J.,Tsung, F. and Yen, B. (2004), "A DMAIC approach to printed circuit board quality improvement", The International Journal of Advanced Manufacturing Technology, Vol. 23, No. 7-8, pp. 523-31.(2004).

[12] Dreachslin, J. and Lee, P. (2007), "Applying Six Sigma and DMAIC to diversity initiatives", Journal of Healthcare Management, Vol. 52, No. 6, pp. 361-7.(2007)

[13] Pranay s. Parmar, vivek a. Deshpande "implementation of statistical process control techniques in industry: a review" journal of emerging technologies and innovative research (jetir) volume 1 issue 6 (issn-2349-5162) pp 583-587, 2014, india.