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Defect Analysis and Implementation of DMAIC Methodology for Defect Reduction in Tyre Manufacturing

Prof. Pankaj B. Ranade
Mechanical Deapartment
K K Wagh Institute of Engineering Education and Research
Nashik, India
pbranade@kkwagh.edu.in

Pooja J. Ugale
Mechanical Deapartment
K K Wagh Institute of Engineering Education and Research
Nashik, India
poojauagale269@gmail.com

Shreyash C. Pagare
Mechanical Deapartment
K K Wagh Institute of Engineering Education and Research
Nashik, India
shreyashpagare28@gmail.com

Tushar R. Pathade
Mechanical Deapartment
K K Wagh Institute of Engineering Education and Research
Nashik, India
tusharpathade108@gmail.com

Dhananjay S. Shende
Mechanical Deapartment
K K Wagh Institute of Engineering Education and Research
Nashik, India
dhananjay.shende30@gmail.com

***Abstract*-For the development of automobile sector the manufacturing of automobile tyres has become an essential activity.As various parameters are there in manufacturing of automobile tyre, these industries are suffering from number of defects. This paper discusses the productivity and quality improvement in a production sectors by analysis of defects. In this paper DMAIC (Define Measure, Analyze, Improve and Control) six sigma is implemented as an methodology in tyre production plant. Taguchi methodology is used for design of experiments (DOE). DOE helps to investigate the effects of variousinputsand output parameters. It gives the relationship between these two.With addition to DOE, taguchioptimizationis done. In taguchi optimization initially orthogonal array finalized with their levels for process parameters. The signal to noise ratio calculated followed by Analysis of Variance (ANOVA). The two significant parameters such as cleaning frequency and tread identification painting system are used to optimize and reduce the rejections due to various tyre defects. The quality control tools like histogram, 20-80 analysis and cause and effect diagram are used to find the defects in tyres. Taguchi analysis gives reduction in no. of defectives when optimum values of parameters are selected. This approach results in significant financial impact on company quality expenses.**

Keywords- DMAIC, Taguchi Methodology, orthogonal array, S/N ratio, ANOVA, quality control tools.

I.INTRODUCTION

Manufacturing of Pneumatic tyres uses same standard processes and equipment's in different industries. There are different components in assembly of tyre which is built on drum. Heat and Pressure is applied with the help of press od curing. For creating elastic in rubber heat is used which gives polymerization reaction. Initial phase of tyre manufacturing process consists of raw rubber,sulphurand other materials to form compound of rubber. Manufacturing is layer by layer to ensure proper adhesiveness between layers. Defects occur usually when any unwanted material get trap in this adhesiveness. These defects create problem while driving the car. The various failure modes for automobile tyres are bead failure, light side wall, side flow crack, side wall separation etc.

The foreign matter defect is one of the major defects faced by tyre manufacturing industries. It mainly occurs due to floor pickup, plastic on tread not removed while building green tyre, dry paint in tread identification painting system, inner gun of spray poking machine faulty and dust in the vicinity of press, etc. For this reason large numbers of tyres are rejected.

II. LITERATURE REVIEW

K. Srinivasan et al. [1] worked on shock absorber production. They reduce defects in paint section by implementing six sigma processes as DMAIC. MuminTutar et.al [2] worked on advanced manufacturing process which is friction stir welding. Aluminum alloy used as workspiece material to maximize tensile shear load. Ravi Butola et.al [3] worked on Abrasive flow machining. Taguchi optimization used to study impacting parameters in machining. Output parameter was to improve surface finish. Six sigma methodology implemented byT. Costa et al.[4] in extrusion process of tyre manufacturing. Their study improved the production system. SefikaKasman[5] worked on laser engraving using the taguchi orthogonal analysis to find the result of impacting parameters.

III. METHODOLOGY

Six Sigma projectis classified as DMAIC and DMADV.

- Application of DMAIC is to improvean present business practice.
- Application of DMADV is for creating differentmanufactured goods or design.

So here DMAIC methodology is used for current project work. With DMAIC or DMADV project, Six Sigma uses many quality improvement tools like Taguchi optimization, analysis of variance (ANOVA),etc. So after the experimentation or collecting the data by varying input, taguchi optimization is done.

Table 1: DMAIC methodology

Process	Description	Technique
Define	1. Data collection from industry. 2.Define problem 3. Createproject objectives.	Histogram
Measure	Collection of data and comparing it to define major issues.	Pareto Chart
Analyse	Analyse causes of variation.	Cause and Effect Diagram
Improve	1. Implementation of Design of Experiment. 2. Developalternatives and implement enhanced plan.	Taguchi method
Control	1. Implement the process control system 2. Implement the improvements of systems.	Statistical Process Control

IV. DEFINE PHASE

Data collection from industry is done for number of defectives for three months for three different types of tyres namely truck type, non-truck type and radial type. Out of the three types of tyre, a tyre which is having high rejection percentage is selected for project work.

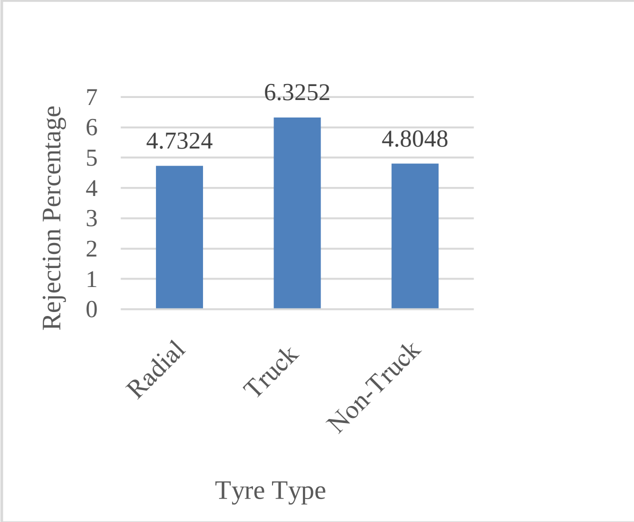

Fig 1. Histogram for Rejection

Histogram shows that Truck tyre has the highest percentage of rejection compared to radial non truck type. Histogram is plotted as tyre type versus percentage rejection.

V. MEASURE PHASE

The Pareto analysis shows that surface foreign material, light side wall and side flow crack are the three main defects which add nearly 72.55% of the total defects in truck tyre production.

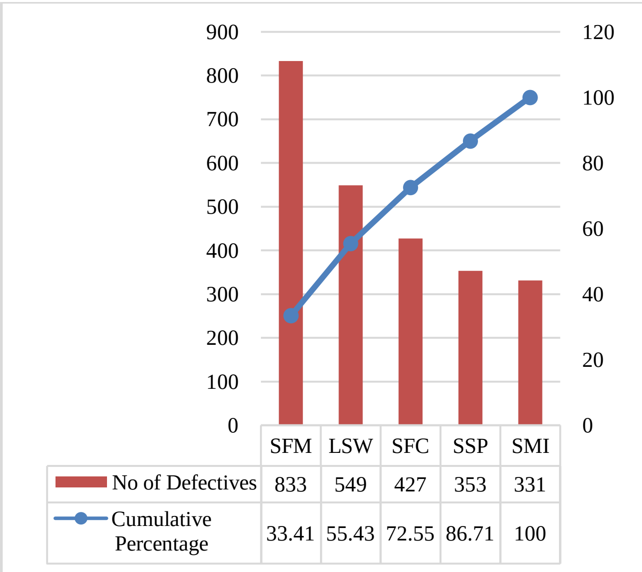

Fig 2. Pareto Analysis

The 80/20 principle of pareto analysis says that 80% of nonconformance parts are arising because of 20% defects. From theabove Pareto analysis, it can be seen that 72.55 % of nonconformanceare because of three types of defects which are surface foreign material, light side wall and side flow crack. So by working on surface foreign material defect which is the major one we can reduce the number of defectives, increase the productivity and ultimately improve the process capability.

VI. ANALYZE PHASE

After the pareto analysis next step is Analyze phase in which root causes of defect is identified. The analysis has given all possible root causes responsible for foreign matter defect but all of them are not important for this defect. Few show more impact and few less. So it is essential to select those parameters which have highimpacton occurrence of the defect. The parameters impacting more on defect are floor pick up by green tyre, dirty material handling equipment or press andthe faulty tread identification painting system which cause paint sticking to tread.

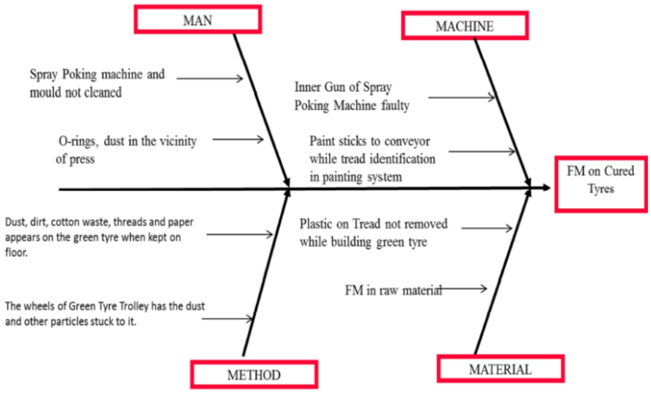

Fig 3. Cause and effect diagram

VII. IMPROVE PHASE

A] Selection of parameters for Taguchi Analysis

From the above analysis two major parameters are selected for experimentation which arefrequency of cleaning and tread identification painting system.

1) Cleaning frequency:There are many reasons for untidy vicinity and some of them are unavoidable. So the only thing that can be done is increase the cleaning frequency of shop floor, material handling equipment, press, etc. than the previous one so as to reduce the floor pick up.The experiments are conducted for both previous and present system.

2) Painting system: The tread identification painting system is changed from previous leather belt system to interlock belt system and experiments are conducted for both the systems.

B] Selection of signal levels for Taguchi Analysis

For performing the experiments following signal levels are selected in industry

Table 2: Signal Level for Experiments

Sr no.	Parameter	Level 1	Level 2
1	Cleaning Frequency	Once in a day	Thrice in a day
2	Painting system	Leather belt	Interlock belt

C] Selection of Orthogonal Array

L4 orthogonal array is selected for experimentation.

Table 3: L4 Orthogonal Arrangement

Expt. No.	Cleaning Frequency	Painting System
1	1	1
2	1	2
3	2	1
4	2	2

D] Experimentation

Experiment is performed according to Table No. 04. Number of defectives as output is noted.

Table 4: Experimentation Results

Expt. no.	Signal level of experiments		No. of defectives
	Cleaning Frequency	Painting System	
1	1	1	46
2	1	2	37
3	2	1	39
4	2	2	27

E] Optimization of parameters

In this research, the focus is on foreign matter defect so while inspection only this defect is considered in the results. For the present study, the lower number of defectives values is the target.

The Signal to Noise Ratio is shown for each experiment in table 5 which is calculated using the following equation:

$$S/N = -10\log\left(\frac{1}{n}\sum_{i=1}^{n} Y_i^2\right)$$

Where, n= Number of Experiments, and Y= No. of defective.

Table 5: S/N Ratio for the experiments

Expt. no.	No. of defectives	Signal to noise ratio
1	46	-33.255157
2	37	-31.364034
3	39	-31.821292
4	27	-28.627275

The factor which is having more delta value (considering magnitude only) is ranked first. Rank signifies which factor has a high impact onoutput i.e. decrease in no. of defectives.

Table 6: Response Table for S/N Ratio

Level	Cleaning Frequency	Painting System
1	-32.3096	-32.53822439
2	-30.22428	-29.99565488
Delta	-2.085312	-2.542569505
Rank	2	1

F] Results and Discussion:

The results are drawn in Minitab software and the plots are shown for S/N Ratio.The main effect plot for SN ratios for dissimilar factors with dissimilar levels is shown in figure 4. The Signal to noise ratio is plotted for the situation of smaller is better. For the lower value of number of defectives, the SN Ratio should be as low as possible.

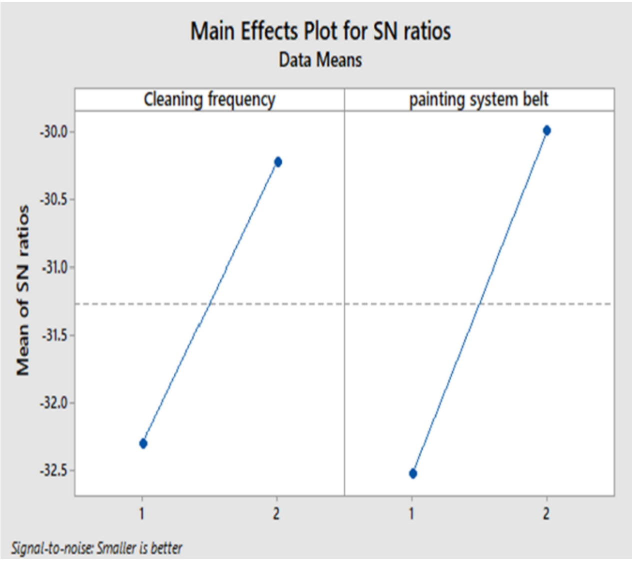

Fig 4: Main Effect Plot for SN Ratio

The optimized values of parameters for truck tyre production are shown in the following table:

Table 7: Optimum Value for Parameters

Parameters	Level	S/N Ratio	Optimum Value
Cleaning Frequency	2	-30.2243	Thrice in a day
Painting system	2	-29.9957	Interlock belt

VIII. CONTROL PHASE

The main aim of this stage is to implement and maintain the above results. So to sustain the gains from above process the industrial organization should concern about the cleaning of shop floor, material handling equipment, press, etc. so as to avoid dust, dirt, etc. and also about the painting system so as to avoid sticking of paint particles. By controlling these things Foreign Matter defect can be eliminated.

IX. CONCLUSION

1. The optimized value of parameters for truck tyres are Cleaning Frequency should be thrice in a day and Painting System should be changed from leather belt to interlock belt system.
2. The highest priority is for Painting system.
3. Process capability is increased from 3.02 to 3.26 after implementing optimized values of parameters.

Table 8: Summary stats of project results

Parameters	Before	After
Defects	2394	2827
Total Production	40784	71728
Percent defective	5.869949	3.9412782
DPMO	58699.49	39412.78
Process Capability	3.06	3.26

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