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Identification of Root Cause for Lining Thickness Variation Defect in Brake Shoe Using Six Sigma

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Abstract: *The aim of the project is to reduce rejection level of brake shoe assembly using six sigma technique. Six sigma is a quality improvement tool for product. It reduces the defects, minimizes the variation and improves the capability of the manufacturing process. The main objective of Six Sigma is to increase the profit margin, improve financial condition through minimizing the defects rate of product. Further it increases the customer satisfaction, retention and produces the best class product from the best process performance. The brake shoe has more Lining Thickness Variation (LTV) defect in the production line. The current rejection level of lining thickness variation defect is very high which leads to consumption of money in the form of rework and rejection of the job. The aim of the project is to identify the causes for lining thickness variation defect in brake shoe.*
Key words *- Six sigma, Lining Thickness Variation, Brake shoe.*

I. Introduction

The Six Sigma is a financial improvement strategy for an organization and now a day it is being used in many industries. Basically it is a quality improving process of final product by reducing the defects, minimize the variation and improve capability in the manufacturing process. In order to use the Six Sigma in an organization, there are many things that are needed to achieve the financial goals in the organization. The main thing of Six Sigma is taking the existing product, process and improves them in a better way. Six Sigma provides a structured approach to solving problems through the Implementation of five phases, Define, Measure, Analyze, Improve and Control (DMAIC). The DMAIC methodology is simple, applicable to all environments and each phase has clear objectives, actions and outputs. Six Sigma focuses on the quality rather than the quantity of data on which it applies statistical techniques in a practical format [1].

Lars Krogstiea (2013) conducted the application of Six Sigma in improvement of tolerances and process variation in casting. The process variation leads to make tolerance defect in the product. The author has found that the root cause of the problem using the six sigma. After implementing six sigma the problem has been overcome and the product has been reached current tolerance level [2].

Keki R. Bhote (2007) using Six Sigma for the Business Excellence. Also he advises that ultimate goal shall be customer satisfaction and also gives importance to employee involvement. Giving reference to Maslow’s theory he suggests that employees will get motivated if all their needs get satisfied. Though the Author gives reasons for 64 failure of Six Sigma Implementation in an organization, he doesn’t give any plan for successful implementation [3].

Amit Kumar Singha (2010) conducted the application of Six sigma in head lamp manufacturing company. In that, the author have found that the current level of rejection is 12%. After implementation of six sigma, rejection level has been reduced to 6% [4].

II. Project Methodology

The manufacturer needs to produce high quality products with minimum amount of defects level. In a company, if defect level of brake shoe production increases, it will lead to more defective products in shop floor. It needs rework and rejection activity, which will consume more money, time, human effort and affect the productivity. Six sigma is a technique which is used for process improvement. It is the method used to identify the causes and eliminate the identified causes which would result in defects. So that the rejection level is reduced in the production of brake shoe. In six sigma, various tools are used to find out the root cause of the problem. The tools are catenaries under the different phases. Various factors like man, machine, material, measurement system, method may be the reason for making defects.

The Fig.1 shows the systematic approach for six sigma to reduce LTV rejection level in brake shoe.

Figure 1. Six Sigma Methodology

2.1 Process Flow

The brake shoe consists of three major components. They are rim, web and lining. The brake shoe should be manufactured by following processes which is shown below in Fig 2:

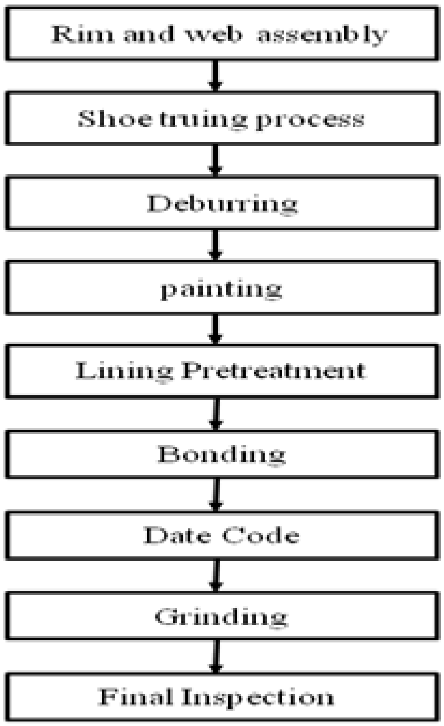

Figure 2. Process Flow

2.2 Define

This is the first phase of the six sigma which is used to define the problem statement. The various tools used in this phase are as follows:

2.2.1 Voice of Customer

The VOC helps to understand feedback from current and future customers. A sub-assembly team meets with their assembly plant customer to understand recurring problems and opportunities for improvement. Customer call centers are an excellent source of information for Voice of the Customer information, and customer service representatives who are adept at collecting VOC information tend to be highly marketable in the customer service field

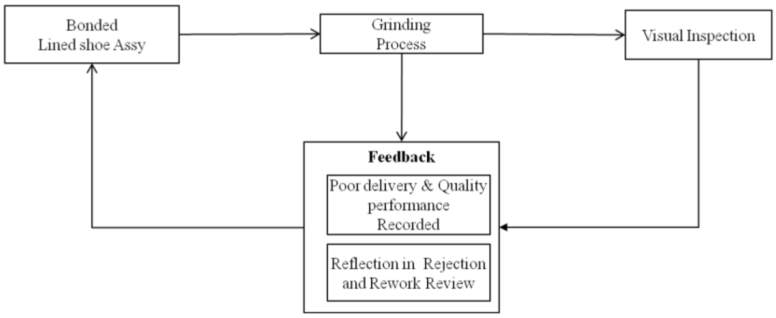

Figure 3. **Voice of Customer**

From the Fig 3, customer feedback is send to customer call centers which is useful to find out the location of the problem in the process.

2.2.2 SIPOC

This is the tool that summarizes the inputs and outputs of one or more processes in table form. The acronym SIPOC stands for suppliers, inputs, process, outputs, and customers which form the columns of the table 1. Suppliers and customers may be internal or external to the organization that performs the process. Inputs and outputs may be materials, services, or information. The focus is on capturing the set of inputs and outputs rather than the individual steps in the process. This Table1 gives overview idea about the production of the product from supplier to customer.

Table 1. SIPOC

Supplier	Input	Process	Output	Customer
Pretreated Shoe	Bonded Lined Shoes after Date coding	Grinding of Bonded Lined shoes	Ground Lined shoe	Final Inspection
Pretreated Lining			Shoes moved to Visual Inspection	Packing
				Warehouse

2.3 Measure

The measure phase is focusing the data gather from current process for improvement. There are different methods to analysis data by sampling, MSA **(**Measurement System Analysis), process capability and Gauge R&R. The measure phase are as follows:

2.3.1 Data collection plan and Data collection

A data collection plan is prepared to collect required data. This plan includes what type of data to be collected, what are the sources of data etc. The reason to collect data is to identify areas current processes need to be improved**.**

2.3.2 Production Volume

The last six months data is collected for finding out the sigma level of the process which is helpful to know the status of the defects level in the process. The volume of production of brake shoe from March 2014 to August 2014 is shown in Table 2 which provides last six month rejection of the product which is used to find out the sigma level of the process.

Table 2. Production volume

Month	Production volume	Lining Thickness Variation
March 14	86982	336
April 14	75873	269
May 14	98398	371
June 14	107214	386
July 14	115340	408
August 14	98919	298

The volume of production of brake shoe from March 2014 to August 2014 is shown in the form of bar chart in Fig 4

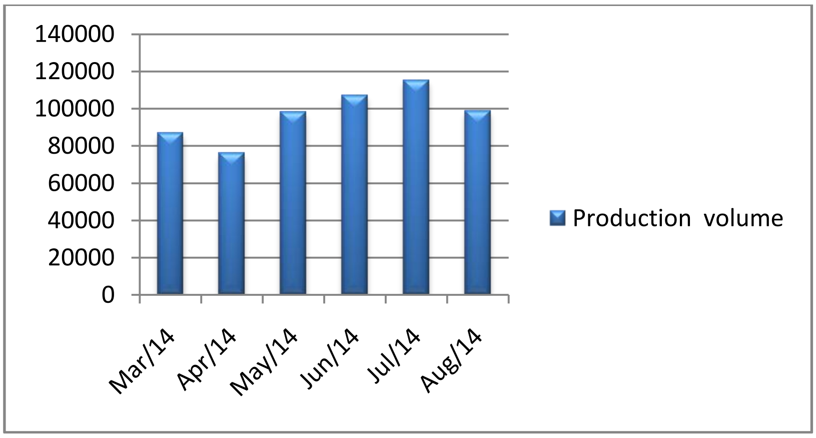

Figure 4. Production volume

2.3.3 Cost of poor quality

In this, the incurred cost will be calculated due to rejected quantity of the product. The scrap cost per product is 120 rupees. It is shown below**.**

Table 3. Cost of poor quality

Rejections due lining thickness variation Mar'14 to August'14	2068 nos.
Scrap cost/piece	Rs.120
Total scrap cost from Mar'14 to August'14	Rs.248160

From Table 3 total scrap cost of brake shoe should be calculated for March 2014 to August 2014 which is Rs.248160.

2.3.4 Data evaluation

At this stage, collected data evaluated and sigma calculated. It gives approximate number defects**.** We calculate Defects Per Million Opportunities (DPMO) and based on that we can fix the current sigma level. The following data gathered from table 2 as shown below.

Number of defects = 2068
Number of Units = 582726
Number of opportunities = 10

$$\text{DPMO} = \frac{\text{Number of defects} * 1{,}000{,}000}{(\text{Number of Units} * \text{Number of opportunities})} \longrightarrow \quad \text{Equation (1)}$$

= 2068/ (582726*10) * 1, 000, 000
= 354.88.

The DPMO value for 5 sigma is 233. So it is under 4 sigma level.

III. Result And Analysis

3.1 Ishikawa Diagram

Ishikawa diagram are used to identify potential factors causing an overall effect in product design and quality defect prevention. This each cause or reason for imperfection is a source of variation. Causes are usually grouped into major categories to identify these sources of variation. The categories typically include Men, Methods, Machines, Materials, and Measurements. The following Fig 5 shows the overview of the various possible causes for making the LTV defect. The factors may or may not be contribute for making of defect. So in further we check whether the factors making the defect or not using various tools.

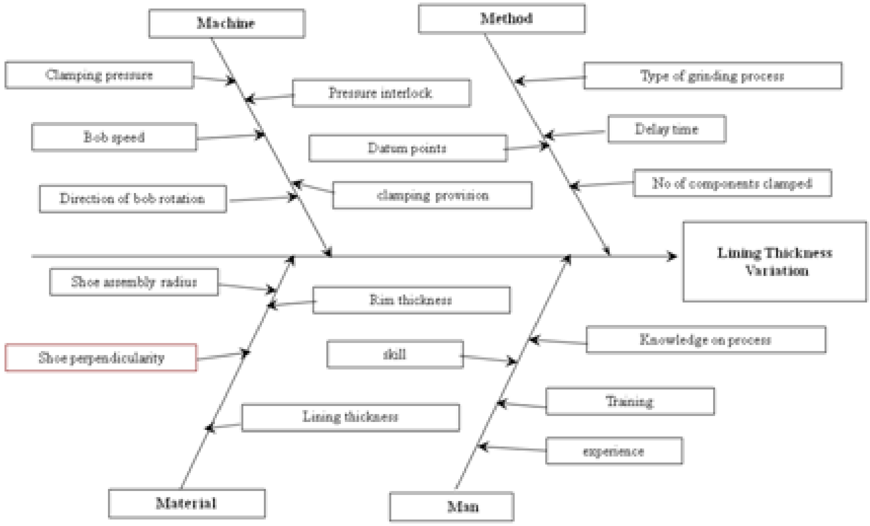

Figure 5. Ishawka Diagram

3.2 Measurement System Analysis

MSA (Measurement Systems Analysis) encompasses all aspects of measurement system planning and analysis. The Gage R&R (Repeatability and Reproducibility) is the most commonly discussed MSA topic which is used to find out the Men and Measurement system are the root cause for the problem or not. The Gage R&R is conducted for lining thickness is shown in Table 4.

Table 4. Gauge R&R

GAUGE REPEATABILITY AND REPRODUCIBILITY STUDY

(FOR VARIABLE TYPE OF GAUGE)

Part Number : 15618201	Gauge name : vernier caliper	Repor : 66 RR 10
part name : DC-DIH	gauge no : 66VC15	Date : 26.09.2014
Characteristics : Lining Thicknees	Gauge type :0 - 200 mm LC .001	Unit : 66
Specification : 4.77-4.37	Perfomed By : P.Prakash	

APPRAISER	TRIAL	PART 1	2	3	4	5	6	7	8	9	10	AVERAGE
M.Prakasu pandi	1	4.57	4.6	4.59	4.55	4.55	4.54	4.49	4.58	4.52	4.53	**4.552**
	2	4.57	4.61	4.58	4.56	4.56	4.53	4.51	4.59	4.52	4.53	**4.556**
	3	4.58	4.62	4.59	4.56	4.56	4.55	4.5	4.58	4.54	4.54	**4.562**
	Average	**4.573333**	**4.61**	**4.586667**	**4.556667**	**4.556667**	**4.54**	**4.5**	**4.583333**	**4.526667**	**4.533333**	***4.55667***
	Range	**0.01**	**0.02**	**0.01**	**0.01**	**0.01**	**0.02**	**0.02**	**0.01**	**0.02**	**0.01**	***0.014***
P.Ramesh	1	4.59	4.61	4.59	4.54	4.57	4.56	4.48	4.59	4.55	4.55	**4.563**
	2	4.6	4.6	4.58	4.53	4.55	4.56	4.49	4.57	4.56	4.56	**4.56**
	3	4.58	4.59	4.57	4.54	4.57	4.57	4.48	4.59	4.55	4.55	***4.559***
	Average	**4.59**	**4.6**	**4.58**	**4.536667**	**4.563333**	**4.563333**	**4.483333**	**4.583333**	**4.553333**	**4.553333**	***4.56067***
	Range	**0.02**	**0.02**	**0.02**	**0.01**	**0.02**	**0.01**	**0.01**	**0.02**	**0.01**	**0.01**	**0.015**
N.Senthilmurugan	1	4.58	4.6	4.55	4.54	4.57	4.58	4.48	4.57	4.54	4.56	**4.557**
	2	4.57	4.61	4.54	4.52	4.56	4.58	4.48	4.56	4.53	4.55	**4.55**
	3	4.58	4.6	4.55	4.54	4.57	4.56	4.47	4.57	4.53	4.55	**4.552**
	Average	**4.576667**	**4.603333**	**4.546667**	**4.533333**	**4.566667**	**4.573333**	**4.476667**	**4.566667**	**4.533333**	**4.553333**	***4.553***
	Range	**0.01**	**0.01**	**0.01**	**0.02**	**0.01**	**0.02**	**0.01**	**0.01**	**0.01**	**0.01**	***0.012***
Part Average		**4.58**	**4.604444**	**4.571111**	**4.542222**	**4.562222**	**4.558889**	**4.486667**	**4.577778**	**4.537778**	**4.546667**	***4.55678***

Average of range(R) =	0.013667	Part average range (Rp) =	**0.117778**
Difference of Average (X)=	0.007667		

Measurement Unit Analysis	**% Total Tolerance**
Repeatability equipment variation=R*k1= 0.008074	% repeatability = (EV/TT) ×100 =(.00807/.4) × 100 =2.01% 0.020186
Reproducibility Appraiser Variation(AV) AV=√(.007667×.5231)2 - (.00807/10×3) =.00373	% reproducibility = (AV/TT) ×100 =(.00373/.4) × 100 =.93%
GRR = √(EV2+AV2) = √(.00807 + .00373) =.00889	% GRR = (GRR/TT) ×100 =(.008894/.4) × 100 = 2.22%
part variation PV = RP × K3 =.11778 × .3146 = .03705	% PV = (PV/TT) ×100 =(.03705/.4) × 100 = 9.26%
Total talerance TT = 0.4	NDC = 1.41(PV/GRR) = 1.41 × (.03705/.00889) =5.8734

From the MSA (Gauge R &R) Study, the % of GRR should be less than 20%.It concluded that there is less variation in our current measurements which is found Satisfactory. Hence the Measurement System and Men are not the cause for this problem.

3.3 Concentration chart

The concentration chart has to give clear graphical representation of LTV concentration in the brake shoe. It will helpful to understand the severity of the defect on the product.

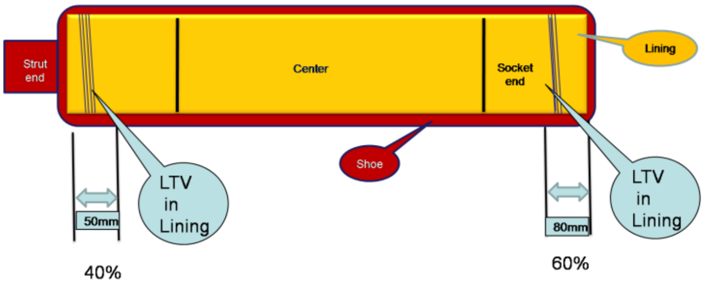

Figure 6. Concentration Chart

From the Fig 6, LTV in socket end (60%) is high when compare to stud end (40%). This gives distribution of defect in brake shoe.

3.4 Suspected Source of Variation (SSV)

The material related parameters may be the reason for this defect. We can relate the material factors with the LTV defect. The relationship between lining thickness variation and suspected source of variation are as follows in the form of mathematical representation

Y= f(X)

Where,

Y = Lining Thickness Variation (Response)

f(X) =Suspected Source of Variation (SSV)

The Suspected source of variation for LTV is shown in Table 5

Table 5. Suspected source of variation

	SSV'S Identified in Input Material f(X)	
	Specification	**Description**
(Y) Lining Thickness Variation	98.50~99.50	Shoe radius
	0.45 mm	Shoe perpendicularity
	2.5~2.85	Rim Thickness
	0.1mm Max	Shoe Tip Perpendicularity

The above source of suspected variations which are related to the incoming material may cause the defect. The paired comparison analysis used to conclude whether the SSV contribute the problem or not

3.5 Paired Comparison Analysis

The paired comparison analysis is the approach used to conclude whether the SSV contribute the problem or not. From the production line, Good and Bad parts are selected based on the response defined in the Cause definition. 8 BOB (Best Of Best) and 8 WOW (Worst Of Worst) parts are selected and the SSV's are measured. The analysis carried out which is shown below.

3.5.1 Paired comparison for radius

The paired comparison analysis for radius is shown in Table 6

Table 6. Paired comparison for radius

Sample	Radius (98.50~99.50)	G/B
10	98.994	B
12	99.034	B
3	99.064	G
11	99.084	B
16	99.094	B
13	99.114	B
8	99.124	G
9	99.124	B
1	99.134	G

4	99.134	G
14	99.134	B
5	99.144	G
15	99.154	B
2	99.174	G
6	99.174	G
7	99.204	G

From the paired comparison analysis of Shoe Radius, Minimum and Maximum value (specification) contains both good and bad category. Hence the SSV's identified is not the reason for the problem.

3.5.2 Paired comparison for Rim thickness

The paired comparison analysis for rim thickness is shown in Table 7

Table 7. Paired comparison for Rim thickness

Sample	Rim Thickness (2.5-2.85 mm)	G/B
12	2.51	B
14	2.57	B
15	2.58	B
3	2.59	G
13	2.6	B
1	2.61	G
9	2.61	B
16	2.61	B
2	2.62	G
8	2.62	G
10	2.62	B
11	2.62	B
5	2.64	G
4	2.65	G
6	2.66	G
7	2.66	G

From paired comparison analysis Rim Thickness minimum and maximum value (specification) contains both good and bad category. Hence the SSV's identified is not the reason for the Problem.

3.5.3 Paired comparison for perpendicularity

The Paired comparison for perpendicularity is shown in Table 8

Table 8. Paired comparison for perpendicularity

Sample	Perpendicularity (45 mm max)	G/B
1	0.05	G
5	0.06	G
4	0.09	G
8	0.09	G
11	0.09	B
10	0.11	B
7	0.12	G
13	0.12	B
9	0.13	B
6	0.14	G
16	0.14	B
3	0.15	G
12	0.16	B
15	0.16	B
2	0.17	G
14	0.24	B

From the paired comparison analysis Shoe Perpendicularity – minimum and maximum value (specification) contains both good and bad category. Hence the SSV's identified is not the reason for the problem.

3.5.4 Product and process search

After completion of grinding, 20 numbers samples have been taken. Similarly After completion of grinding and date code, 20 numbers samples have been taken. Then shoe tip perpendicularity has been measured which is shown in the Table 9

Table 9. Product and process search

Nos	With date code		Without date code	
	Stud end	Soc end	Stud end	Soc end
1	6.14	6.39	6.09	6.37
2	6.18	6.2	6.15	6.26
3	6.29	6.28	6.3	6.32
4	6.15	6.3	6.09	6.28
5	6.23	6.27	6.23	6.25
6	6.13	6.37	6.2	6.23
7	6.09	6.3	6.17	6.25
8	6.15	6.26	6.13	6.26
9	6.19	6.28	6.26	6.2
10	6.15	6.15	6.22	6.16
11	6.07	6.28	6.23	6.31
12	6.23	6.32	6.24	6.25
13	6.2	6.26	6.35	6.22
14	6.2	6.37	6.24	6.28
15	6.13	6.38	6.09	6.35
16	6.14	6.29	6.17	6.41
17	6.14	6.23	6.16	6.23
18	6.23	6.3	6.28	6.32
19	6.28	6.36	6.3	6.35
20	6.32	6.2	6.36	6.09
Min	6.07	6.15	6.09	6.09
Max	6.32	6.39	6.36	6.41
	0.25	0.24	0.27	0.32

From 20 numbers taken for analysis of Shoe tip perpendicularity. All are within specification. Hence the material related SSV is not the Reason for the Problem.

3.6 Why Why Analysis

Why Why analysis is a simple approach for exploring root causes and instilling a fix the root cause, not the symptom culture at all levels of a company. The idea is to keep asking why until the root cause is arrived at. The number five is a general guideline for the number of Why required to reach the root cause level. The why why analysis is shown in the Fig 7

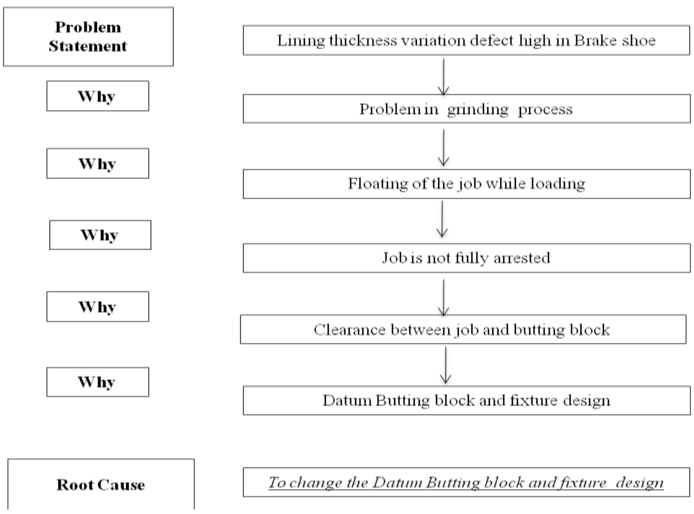

Figure 7. Why Why Analysis technique

From the why why analysis technique, the final root cause of the problem is butting block Fluctuation of job during clamping causes the defects in the job, due to improper budding block design and fixture design. Budding block design and fixture design is to be changed and implementation to be carried out.

IV. Conclusion

Lining thickness variation causes more amount of rejection in brake shoe assembly. The root cause has been identified using six sigma. The factors Man, Machine, Method, Material and Measurement system are the root causes, which have been shown in the Ishikawa diagram. Paired comparison analysis and gauge R & R are conducted which result Suspected Source of Variation and measurement system are not the causes of the LTV defect. But the major problem which causes the defects has been identified in the method of loading in grinding fixture. Fluctuation of the job during clamping causes the defects in the job, due to datum resting in butting block not ensured during process which is analyzing through why why analysis. The root cause of LTV defect in brake shoe has been identified that improper budding block design and grinding fixture design.

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