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Root Causes Analysis for Lean Maintenance Using Six Sigma Approach

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ABSTRACT

The aim of the project is to reduce rejection level of needle roller bearing assembly using six sigma techniques. 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 needle roller bearing has more Lining Thickness Variation (LTV) defect and bearing Fits like loose fit and tight fit 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 various assembly defect and its remedies to reduce rejection level in needle roller bearing.

Key words: *Six Sigma, Lining Thickness Variation, Needle Roller Bearing*

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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.

Roller bearings - Similar in appearance to cylindrical roller bearings, needle roller bearings have a much smaller diameter-to-length ratio. By controlling circumferential clearance between rollers, or needles, rolling elements are kept parallel to the shaft axis. A needle roller bearings capacity is higher than most single-row ball or roller bearings of comparable OD. The bearing permits use of a larger, stiffer shaft for a given OD, and provides a low friction rolling bearing in about the same space as a plain bearing. The basic needle roller bearing is the full-complement, drawn-cup bearing.

1.1Various defects or failure in assembly of Needle Roller Bearing are following:

1. Thickness variation
2. Loose fit
3. Tight fit
4. Outer Ring Fracture
5. Corrosion
6. Axial Cracks
7. Normal fatigue

II. PROJECT METHODOLOGY

The manufacturer needs to produce high quality products with minimum amount of defects level. In a company, if defect level of needle roller bearing 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 needle roller bearing. 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 defect.

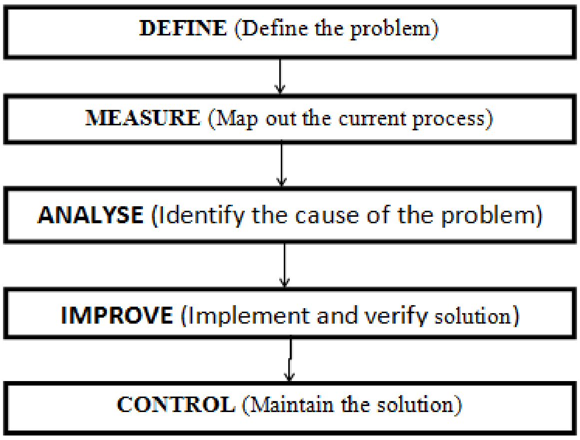

Figure 1.0 Project Methodology

III. PROCESS FLOW

The needle roller bearing consists of four major components. They are cage, shell, needle and roller; the needle roller bearing should be manufactured by following process which is shown below in Fig.2:

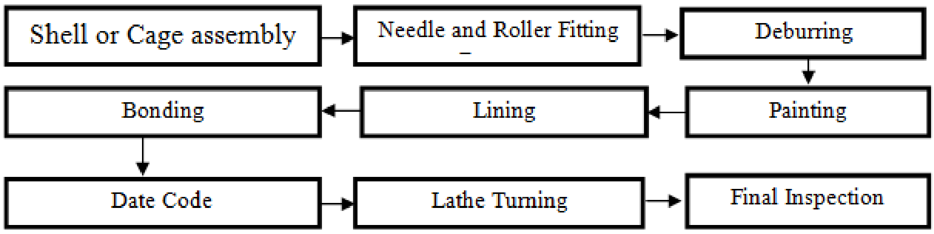

Figure 2.0 Process Flow

3.1 Define

During the define phase a specific problem statement is formulated and a team is assigned. Activities of the define phase include identifying the customers and CTQ characteristics or KPOV s, and identifying and documenting the business process. The various tools used in this phase are as follows:

3.2 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.

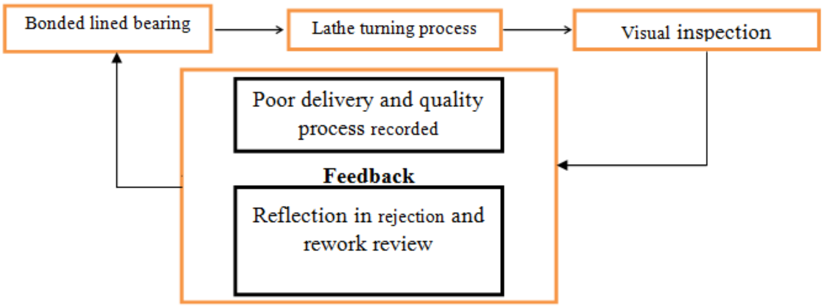

Figure 3.0 Voice of customer

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.

3.3 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 . 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 Table 2 gives over view idea about the production of the product from supplier to customer.

3.4 Measure

One objective of the measure phase is to develop a reliable and valid measurement system of the business process identified in the define phase. The measurement phase uses statistical tools to quantify and define the capabilities of the existing business process. It provides a baseline against which progress is to be measured.
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.

3.5 Analyse

During the analyse phase the team is focused on determining the root cause of the problem. Again, statistical tools are used to provide insight into the relationships between. Data collected during the measurement phase can be used to find patterns, trends, and other differences that can suggest, support, or reject theories about the causes of defects Hypotheses and experiments are formulated and tested to verify or eliminate possible causes of defects.

3.6 Improve

During the improve phase a solution is selected and tested prior to full implementation Several solutions may need to be tested before a final one is selected for implementation. Design of experiments is a key tool used in the improve phase.

3.7 Control

Once improvements have been made and results documented, the control phase begins without the control phase, the improved process may very well revert to its previous state, undermining the gains achieved in the Six Sigma process. The control phase provides an operation that is stable, predictable, and meets customer requirements. On-going process measurements are established and methods are put in place to monitor those measurements**.**

IV. PRODUCTION VOLUME AND REJECTION DUE TO DEFECTS IN ASSEMBLY LINE

The last six months data is collected for finding out the sigma level of process which is helpful to know the status of the defects level in the process. The volume of production of needle roller bearing from January 2015 to June 2015 is shown in Table which provides last six month rejection of the product which is used to find out the sigma level of the process.

Month	**Production volume**	**Lining thickness variation**	**Bearing fits**
Jan 15	96982	436	268
Feb 15	85873	369	242
March 15	98698	481	296
April 15	101121	508	311
May 15	115340	528	329
June 15	98990	486	299

Table 1

V. 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 60 rupees. It is shown below.

Table 2. Cost of poor quality

Rejection due to lining thickness variation from Jan. 15 to June 15	2808nos.
Rejection due to bearing fits from Jan. 15 to June 15	1745
Scrap cost /piece	Rs.60
Total scrap cost from jan.15 to June 15	Rs.273180

Table 2

From Table 2 total scrap cost of needle roller bearing should be calculated for Jan. 15 to June 15 which is Rs.273180.

Data evaluation for LTV

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.

Number of defects = 2808

Number of units = 597004

Number of opportunities = 10

$$\text{DPMO} = \frac{(\text{Number of Defects X 1,000,000})}{(\text{Number of Units X Number of opportunities})}$$

= (2808 *1,000,000)/ (597004 * 10)

= 470.33

The DPMO value for 5 sigma is 354, so it is under 4 sigma level.

VI. 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 3.

In this Table all Measurement are taken and the below value comes from the Table.

From the MSA (Gauge R &R) Study, the % of GRR and part variation should be Always less than 10%.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. in our measurement:

% GRR =2.22% ,% PART VARIATION = 9.26 %

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

Table 3.Gauge R&R

GAUGE REPEATABILITY AND REPRODUCTIVITY STUDY

(For variable type of GAUGE)

Gauge name: Digital calliper Characteristics: Lining Thickness Gauge type: 0-200 mm, LC .001

Performed by: Kumar Gaurav gauge No: 69VC18 Date :26.06.2015

Appraiser	Trial	Part										Average
		1	2	3	4	5	6	7	8	9	10	
	4.67	4.70	4.69	4.65	4.65	4.64	4.59	4.68	4.62	4.63	**4.652**	
	2	4.67	4.71	4.68	4.66	4.66	4.63	4.61	4.69	4.62	4.63	**4.656**
	3	4.68	4.73	4.69	4.66	4.66	4.65	4.60	4.68	4.64	4.64	**4.663**
Technician 1	**Average**	**4.67333**	**4.71333**	**4.68666**	**4.65666**	**4.65666**	**4.64**	**4.60**	**4.68333**	**4.62666**	**4.63333**	**4.65667**
	Range	0.01	0.03	0.01	0.01	0.01	0.02	0.02	0.01	0.02	0.01	**0.014**
	1	4.69	4.71	4.69	4.64	4.67	4.66	4.58	4.69	4.65	4.65	**4.663**

Technician II.	2	4.70	4.70	4.68	4.63	4.65	4.66	4.59	4.67	4.66	4.66	**4.66**
	3	4.68	4.69	4.67	4.64	4.67	4.67	4.58	4.69	4.66	4.66	**4.669**
	Average	**4.69**	**4.70**	**4.68**	**4.63666**	**4.66333**	**4.66333**	**4.58333**	**4.68333**	**4.65333**	**4.65333**	**4.66067**
	Range	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.02	0.01	0.01	**0.015**
Technician III.	1	4.68	4.70	4.65	4.64	4.67	4.68	4.58	4.67	4.64	4.66	**4.657**
	2	4.67	4.71	4.64	4.62	4.66	4.68	4.58	4.66	4.63	4.65	**4.65**
	3	4.68	4.70	4.65	4.64	4.67	4.66	4.57	4.67	4.63	4.65	**4.652**
	Average	**4.67**	**4.70**	**4.64**	**4.63**	**4.66**	**4.67**	**4.57**	**4.66**	**4.63**	**4.63**	**4.653**
	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		**4.68**	**4.70**	**4.67**	**4.64**	**4.66**	**4.65**	**4.58**	**4.67**	**4.63**	**4.64**	**4.6567**

VII. 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 4.

Table 4. Suspected source of variation

	SSV' Identified in input Material f(X)	
	Specification	**Description**
(Y) Lining Thickness Variation	18.50-19.50	Bearing internal diameter
	19.50-20.50	Bearing outer diameter
	0.55 mm	Needle roller perpendicularity
	2.60-2.95	Cage Thickness
	2.20-2.35	Shell Thickness
	0.1 mm Max.	Needle Tip perpendicularity

Table 3

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.

VIII. 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. 6 BOB (Best of Best) and 6 WOW (Worst of Worst) parts are selected and the SSV's are measured. The analysis carried out which is shown below.

8.1 Paired comparison for internal diameter (ID) of bearing

The paired comparison analysis for internal diameter is shown in Table 4

Table 4 paired comparison for internal diameter

Sample	**Diameter (18.50-19.50)**	**G/B**
10	18.994	B
12	19.034	G
9	19.064	B
1	19.084	B
3	19.094	G
2	19.114	B
5	19.124	B
7	19.124	G
4	19.134	B
8	19.135	G
6	19.136	G
11	19.204	G

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

8.2 Paired comparison for Outer diameter (OD) of bearing

The paired comparison analysis for outer diameter is shown in Table 5

Table 5 paired comparison for outer diameter

Sample	Diameter (19.50-20.50)	G/B
10	19.550	B
12	19.569	B
3	19.990	G
11	19.999	B
8	20.150	G
9	20.220	B
1	20.250	G
4	20.251	G
5	20.255	G
2	20.259	G
6	20.260	G
7	20.260	G

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

8.3 Paired comparison for Cage Thickness

The paired comparison analysis for cage thickness is shown in Table 6

Table 6 paired comparison for cage Thickness

Sample	Cage Thickness (2.60-2.95)	G/B
12	2.61	B
3	2.69	G
1	2.71	G
9	2.71	B
2	2.72	G
8	2.72	G
10	2.73	B
11	2.74	B
5	2.75	G
4	2.76	G
6	2.78	G
7	2.79	G

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

8.4 Paired comparison for Shell Thickness

The paired comparison analysis for shell thickness is shown in Table 7.

Table 7 Paired comparison for shell Thickness

Sample	Shell Thickness (2.20-2.35)	G/B
7	2.201	B
6	2.202	G
4	2.202	B
5	2.203	G
11	2.203	B
10	2.205	G
8	2.225	G
2	2.229	B
9	2.303	B

1	2.310	G
3	2.311	B
12	2.320	G

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

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

8.5 Product and process search

After completion of Lathe turning, 20 numbers samples have been taken. Similarly After completion of Lathe turning and date code, 20 numbers samples have been taken.

From 20 numbers taken for analysis of needle tip perpendicularity .All are within specification, Hence the material related SSV is not the reason for problem.

IX. 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. 4

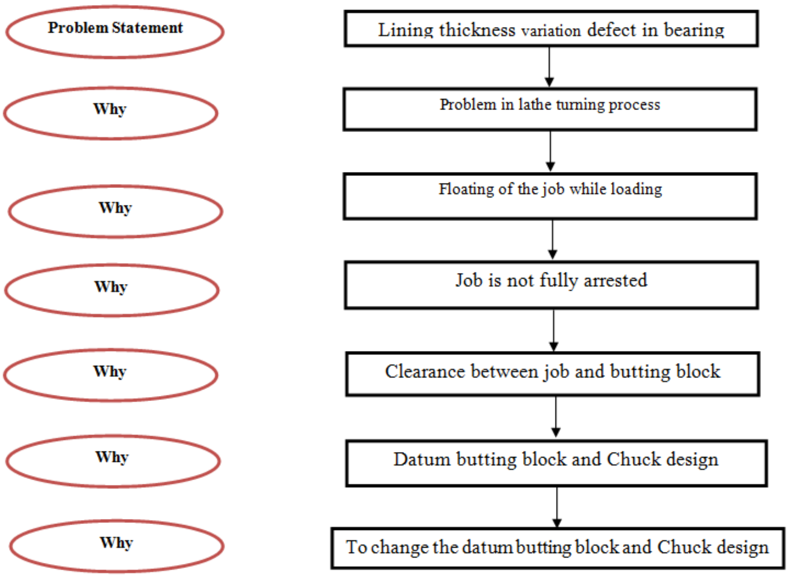

Figure4. Why Why Analysis technique

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 Holding device like chuck or mandrels. Budding block design and holding device of job is to be changed and implementation to be carried out.

X. CONCLUSION

The various defects in assembly of needle roller bearings are shown above in my thesis in which Lining thickness variation causes more amount of rejection in Needle roller bearing 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 lathe turning fixture. Fluctuation of the job during clamping causes and holding device the defects in the job, due to datum resting in butting block not ensured during process which is analysing through why why analysis. The root cause of LTV defect in needle roller bearing has been identified that improper budding block design and holding device (chuck/mandrels) design.

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