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Increase in Sigma Level Using DMAIC Approach to Reduce Rejection in Production Environment: A Case Study of Large Scale Jaipur Based Bearing Manufacturing Company

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Abstract
The aim of this paper is to determine the importance of Six Sigma DMAIC methodology to reduce the rejection which in turn increases the productivity in large scale bearing manufacturing company. For identification of root cause and fact verification, different hypothesis tested on the basis of Cause & Effect Matrix diagram after collection of data. Visual rejection becomes the main cause of rejection which affects the productivity in company. On analysis, thin section bearings will increase the cause of visual rejection i.e. Mark on OD & Rehoning.

Keywords: *Thin section bearing, DMAIC Methodology, Visual Rejection*

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I. INTRODUCTION

Six Sigma help organization in improving customer values and efficiency and thus increase in profit of organization. Quality level also increases with first time right in organization which implemented Six Sigma methodology. There are two types of quality i.e. Potential quality and Actual quality. Potential quality is maximum possible value added per unit of input while actual quality is current value added per unit of input. Difference in both qualities i.e. potential and actual known as waste. Six sigma helps to reduce the waste. The steps required to successfully implement Six Sigma as follows:

1. Six sigma implementation starts with senior leadership in organization. Involvement of senior leadership reduces the barriers to implement six sigma and provide opportunity to experiment and change without fear.
2. Base line study done in advance by keeping view on customer requirements i.e. internal as well as external, process owners, employee and supplier. Base line helps to determine the starting point.
3. Training needs identified for different hierarchy levels of organization.
4. Six sigma is a continuous process improvement which focuses over strategic goals, drivers & business processes.
5. Business processed need to be improved are decided on the basis of some key process indicators or where we need some productivity improvement without adding any extra resources.

The aim of present study is to reduce the visual rejection on grinding lines of Jaipur based large scale bearing manufacturing company (NEI Ltd). Visual rejections are mainly Mark on OD and Rehoning based on Pareto Chart formed where approximate 80% of visual faults related to Mark on OD & Rehoning. DMAIC methodology utilised for reducing the rejection and increase in the sigma level of the process.

II. DEFINE PHASE

2.1 Problem Statement

NEIL Tapered Roller Bearing division facing issue of visual defects in Outer or cup component of bearing which has several consequences i.e. decrease in line availability, increase in rework, increase in waiting time to clear rejection from grinding line, increase in scrap, increase in manpower cost etc. which impacted the profitability of TRB Division of NEI. Post this a complete analysis of the bearing production and assembling process was carried out and the issue was identified.

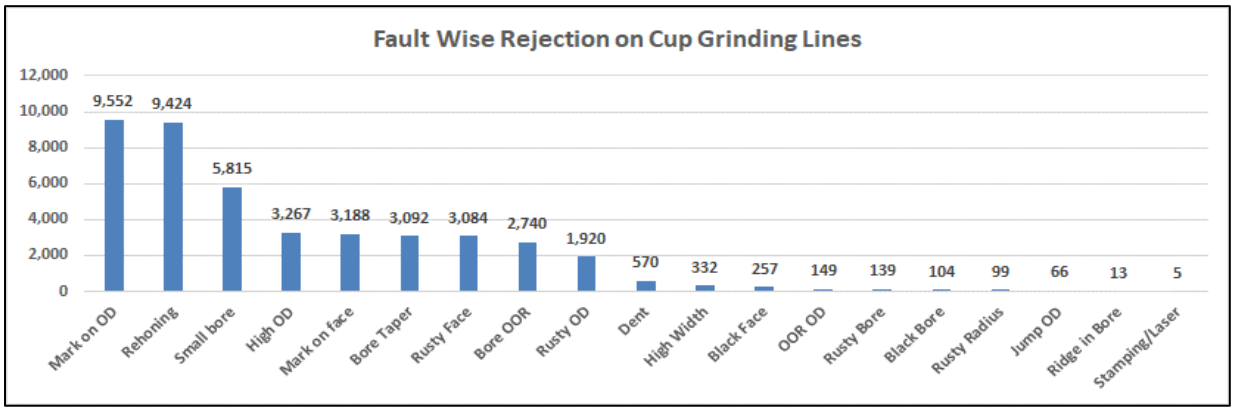


Fig: 2.1 Pareto Graph for fault wise rejection on cup grinding lines of TRB Division for the period 2020~21.

INFERENCE: "Mark on OD & Rehoning" rejection is contributing the highest loss on cup grinding lines. Both rejections are fall under category of Visual defects.

2.2 Identification of Business Opportunity

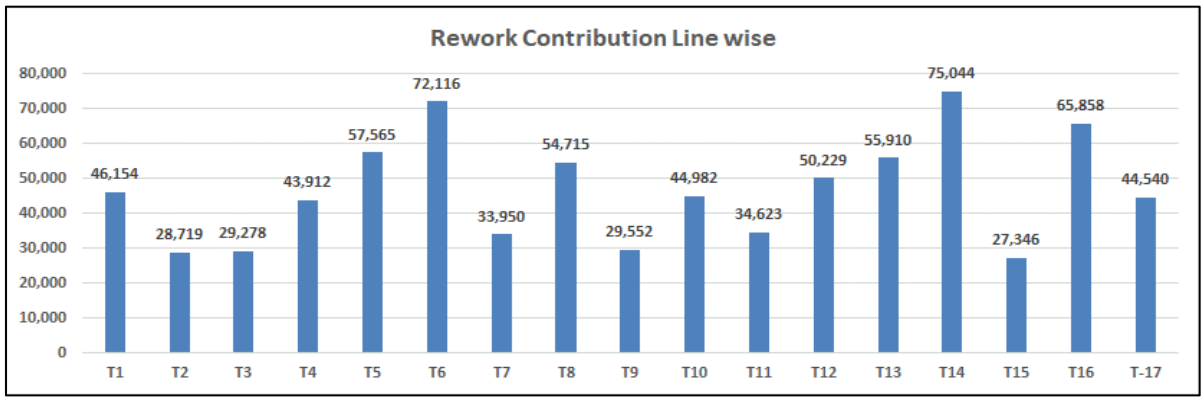


Fig: 2.2 Pareto Graph for fault wise rejection on cup grinding lines of TRB Division for the period 2020~21.

INFERENCE: "T-14" Grinding line is the top contributor for rejection generated from all cup grinding lines.

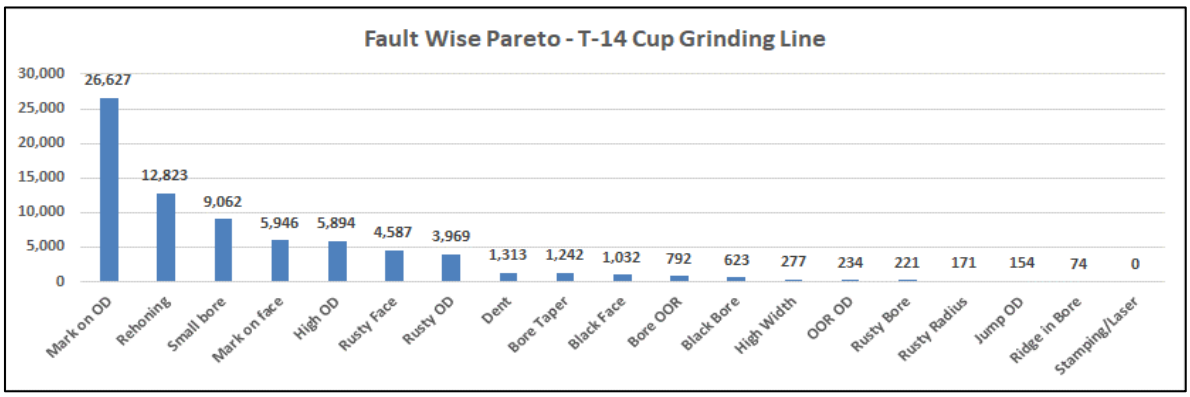


Fig 2.3: Pareto Graph for identification of top contributor fault on T-14 Cup Grinding Line of TRB Division for the period 2020~21.

INFERENCE: On "T-14" Grinding line also Visual Fault i.e. "Mark on OD" & "Rehoning" are the major contributor for rework generation.

2.3 Taper Roller Bearing Manufacturing Process

Below is the process flow chart which shows the different stages of manufacturing process of Taper Roller Bearing in NEI Ltd, Jaipur. Taper roller bearing mainly comprises of 4 components i.e. Cup or Outer, Cone or Inner, Roller i.e. rolling element and Retainer or cage. Out of these 4 components Cup and cone are

manufactured over grinding lines. Roller manufacturing section is different while Cage or retainer is outsourced to supplier.

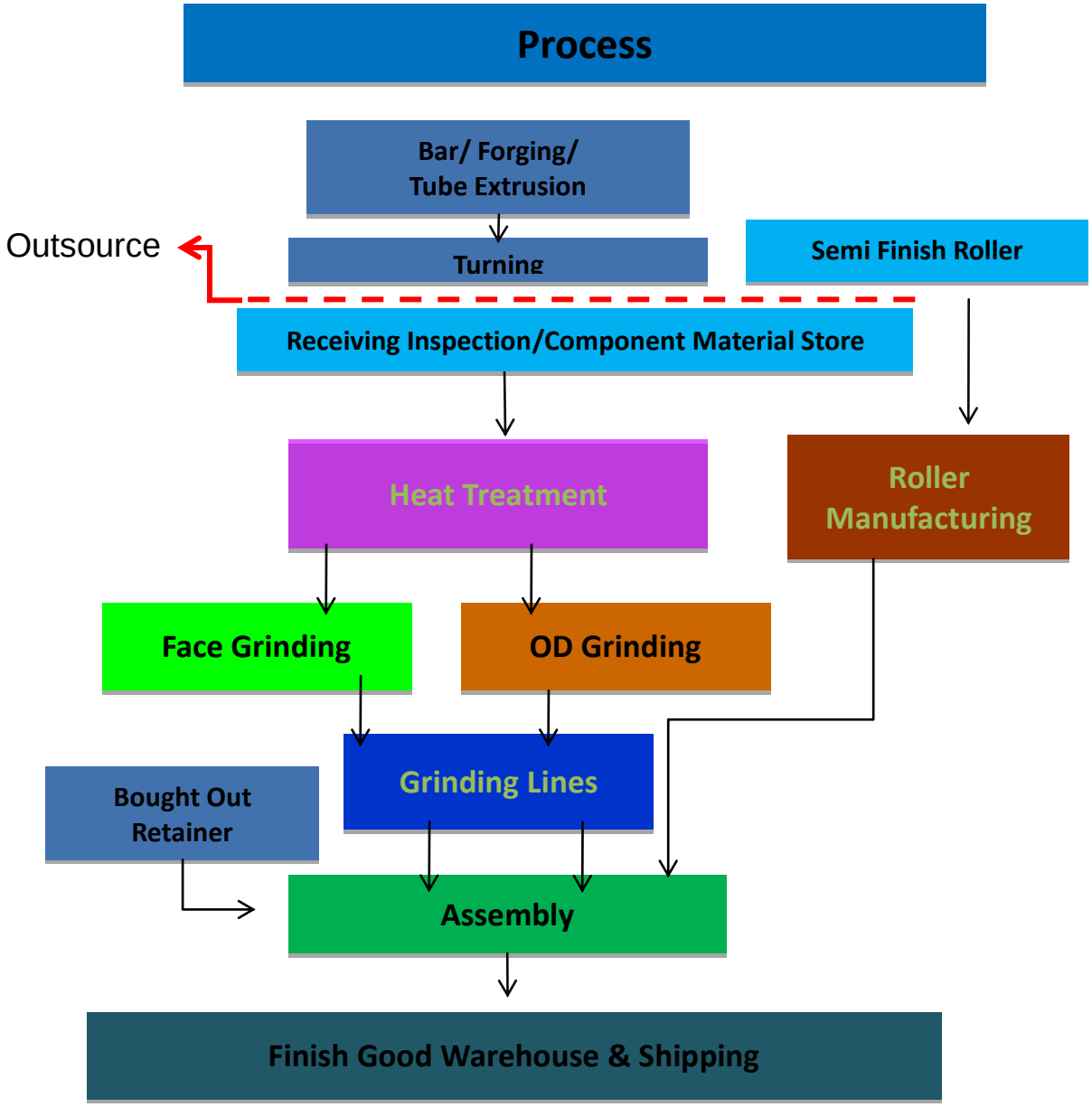


Fig 2.4: Taper Roller Bearing Manufacturing Process Flow Chart

2.4 Component Manufacturing Process

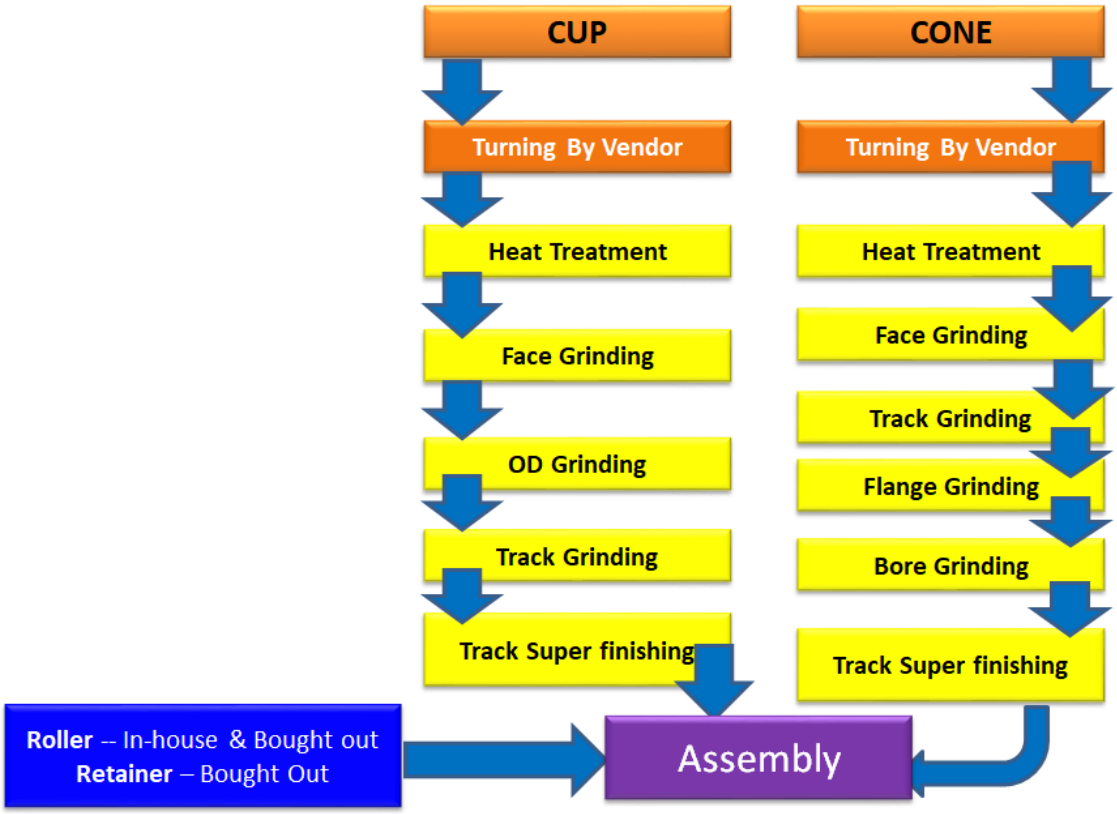
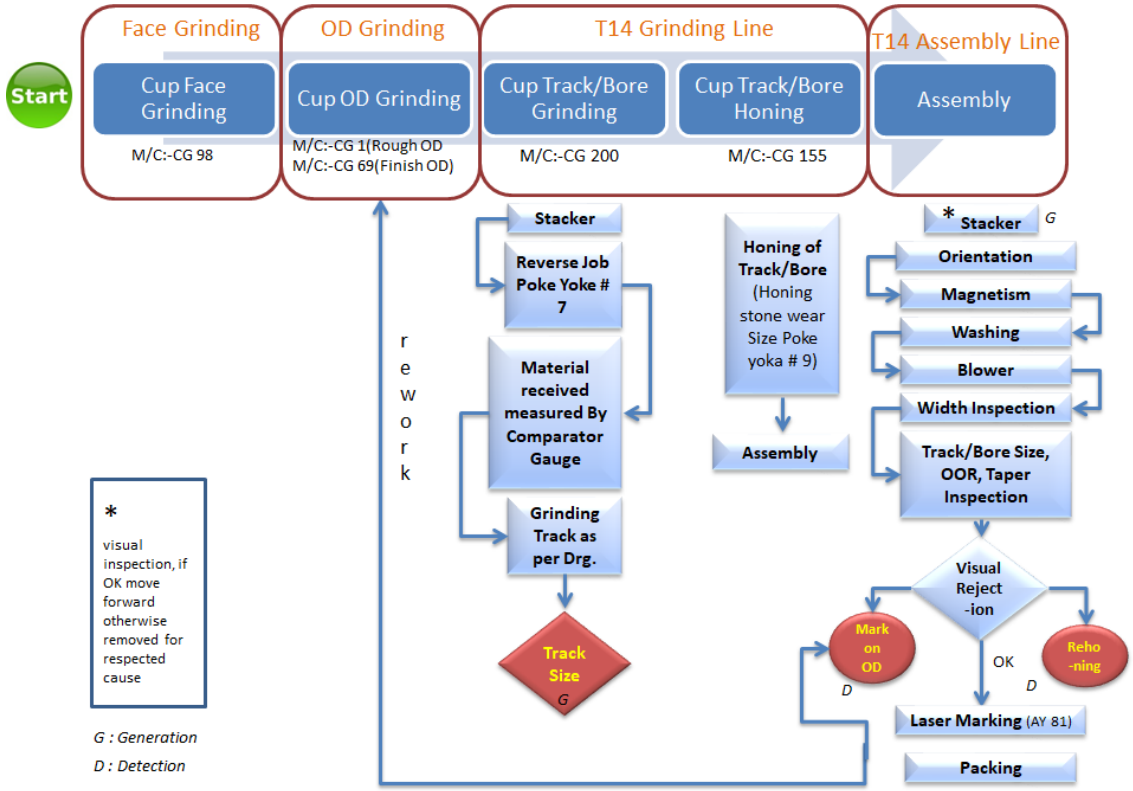


Fig 2.5: Cup and Cone Manufacturing Process Flow Chart

2.5 Project Charter:

Project Title: To increase the Sigma Level of T14 Line by reducing Visual Defects.		
Opportunity	**Customer Impact**	**Business impact**
To improve capability of process in order to ensure first time right	Probability of supplying NG part to customer will be reduced which enhance reliability	Reduce in visual defect i.e. Mark on OD & Rehoning rework PPM of T14 Grinding line by increasing sigma level to 3.8 from 3.25.

2.6 Process Mapping:



2.7 Potential Cause & its Operational Definition for Visual Defects:

Based on the brainstorming activity, all possible causes listed down based on which cause and effect matrix diagram prepared. All members present in brainstorming group done marking against each possible cause on the scale of 1 to 10. (In brainstorming activity, operators, setters, supervisors, cell managers also included i.e. all hierarchy levels covered on shop floor). Cause and effect diagram matrix used for prioritization of factors.

S.No.		Performance Indicator (Y)	Operational Definition
Y		Visual Fault	When Shoe mark observed on Cup or Outer periphery and Rehoning rejection observed.
S.No.		Process/Input Indicators (X)	Operational Definition
X	X1	No air gap b/w job & GW	As per std. there should be gap in between job & GW of minimum 200µm to avoid direct grinding start position. (When GW touches the job from that position GW took back for 200µm.)
	X2	High grinding allowance in job	Input material GA is 400µm Max. (Tol : 350±50µm)
	X3	High play in dressing arm	By putting the dressing arm in dressing position, there should not be any play in dressing arm in upward movement.
	X4	High run out on face of adopter of work head	By putting dial indicator on the face of adopter, move the work head motor slowly through belts and check the reading of dial indicator. It should not be more than 2µm.
	X5	Thin section jobs	Thin section jobs are jobs having l/d ratio less than 0.8 where l is width & d is diameter of the cup.

Table 1: Potential Cause & its Operational Definition for "Mark on OD" rejection

III. MEASURE PHASE

3.1 Data Collection Plan

Data Collection Plan – Visual Rejection						
S.No.	Process/Input Factor	Operational Definition	Source & Place of Data	Who will Collect	Frequency	Disposition
Y	Visual Rejection	When Shoe mark observed on Cup or Outer periphery and Rehoning rejection	T-14/ A-14	LPE	Daily	Rejection/ Production Qty

		observed.				
X1	No air gap b/w job & GW	As per std. there should be gap in between job & GW of minimum 200µm to avoid direct grinding start position. (When GW touch the job from that position GW took back for 200µm.)	T-14	Production	Daily	Dimension
X2	High grinding allowance in job	Input material GA is 400µm Max. (Tol : 350±50µm)	T-14	LPE	Daily	Dimension
X3	High play in dressing arm	By putting the dressing arm in dressing position, there should not be any play in dressing arm in upward movement.	T-14	Maintenance	Daily	OK/Not OK
X4	High run out on face of adopter of work head	By putting dial indicator on the face of adopter, move the work head motor slowly through belts and check the reading of dial indicator. It should not be more than 2µm.	T-14	Production	At the time of New Set Up	Dimension
X5	Thin section jobs	Thin section jobs are jobs having l/d ratio less than 0.8 where l is width & d is diameter of the cup.	T-14	LPE	One Time	Y/N

Table 2 Data collection plan for Visual Rejection

3. ANALYZE PHASE

The factors mentioned X1, X2, X3, X4 & X5 analysed against Y through Minitab for identification of main cause.

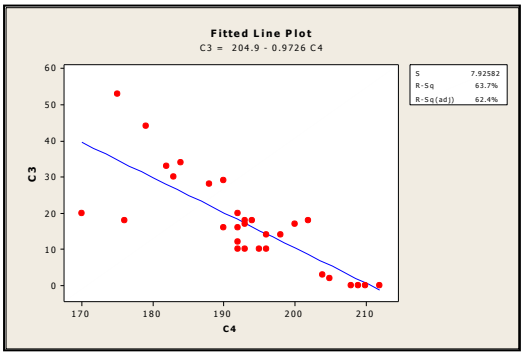


Fig 3.1: Fitted line plot between Visual Rejection v/s No air gap between job & GW

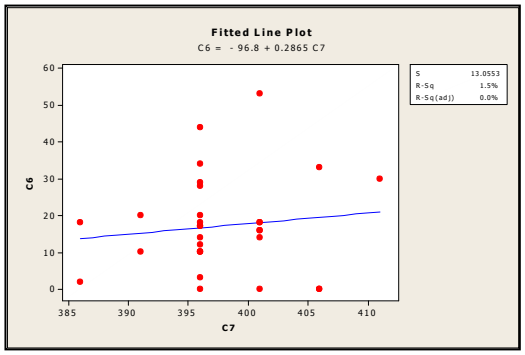


Fig 3.2 : Fitted Line Plot between Visual Rejection v/s High Grinding Allowance in job

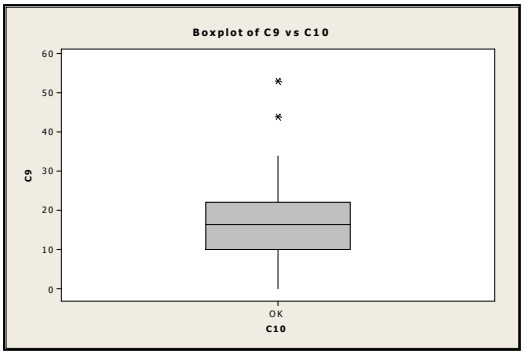


Fig 3.3: Box plot between Visual Rejection v/s High Play in Dressing Arm

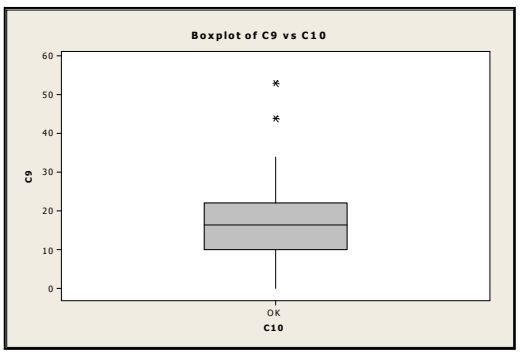


Fig 3.4 : Box Plot between Visual Rejection v/s High run out on face of adopter of work head

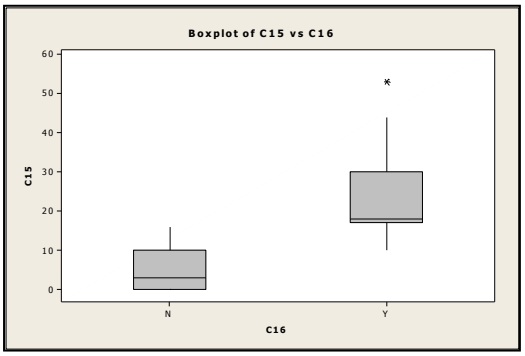
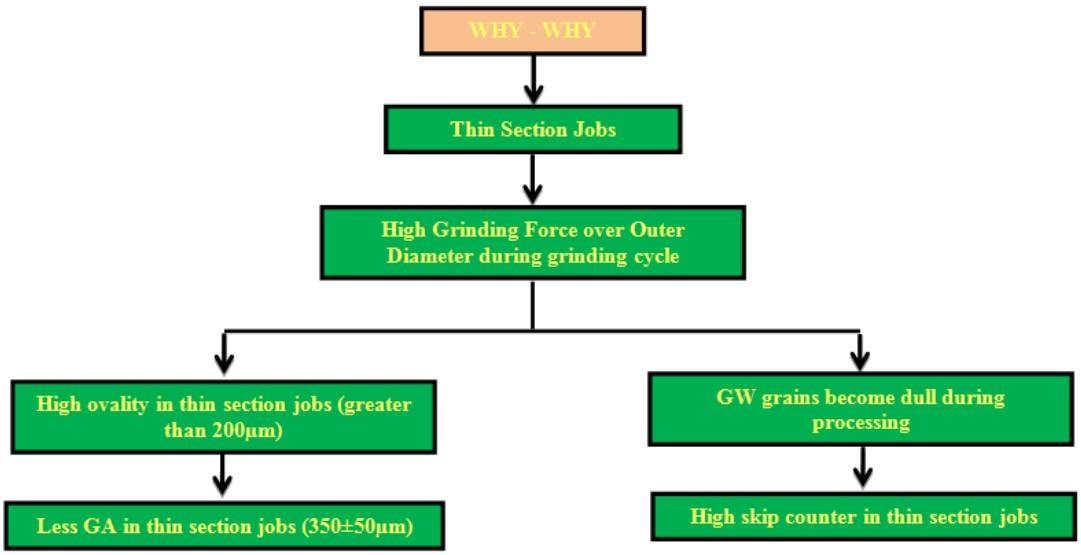


Fig 3.5: Box plot between Visual Rejection v/s Thin Section Jobs

INFERENCE: Based on the above Minitab plots and hypothesis used, Visual rejection changes with thin section jobs. Visual rejection increases with thin section job running on machine.

IV. IMPROVE PHASE

4.1 Why – Why Analysis for "Visual Rejection"



Based on the Why-Why analysis done for the Thin Section Jobs. Following two issues discussed with top management:

1. Grinding allowance to increase in job as countermeasure of high ovality generated during heat treatment operation. Due to this productivity will suffer as with increase in grinding allowance, cycle time also increase which in turn affect productivity.
2. Skip counters i.e. grinding wheel dress count after certain number of jobs, are too high or similar to all jobs as per machine model or as per process which impact the grinding process badly in thin section of bearings. Due to this also cycle time will increase and management wants solution without impacting the productivity.

With further discussion, we trial lot on T-14 Line with increase in Outer diameter size with +100 micron so that strength of the job will improve and job easily sustain the grinding force without impacting the dimension. Based on trial result, we get approval for bulk trial which remain quite successful and become our final solution for reducing the rejection in visual category.

V. CONTROL PHASE

In Control phase, we further strengthen the solution through review in documents. For the same Standard Operating Procedure made to run thin section jobs on grinding line with OD Size at "+100 micron". Flow chart modified through "Process Design Change Request Approval" process. Following documents updated for the same:

- Flow Chart

- Standard Operating Procedure for Running Thin Section Jobs over grinding lines
- Process Failure Mode & Effect Analysis
- Horizontal Deployment Sheet to implement same on other grinding lines also.

Graph also attached to show the improvement observed over T-14 Grinding Line after implement the same from the month of Nov'21 and after observing 3 month data, process change from temporary to permanent.

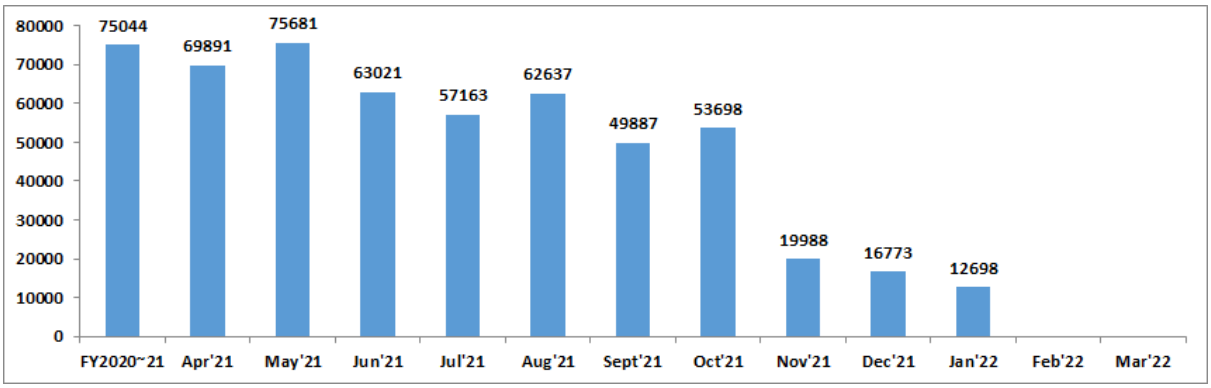


Fig 5.1: Month Wise Rejection Graph (PPM) on T-14 Grinding Line

Comparison of Sigma Level:

Before (May'21):	**After (Jan'22)**
No. of Units Processed: 53429	No. of units processed: 58316
Total number of defects made: 4043	Total number of defects made: 740
No. of defect opportunities per unit = 2	No. of defect opportunities per unit =2
DPMO = (1000000*4043) / (53429*2)	DPMO = (1000000*740) / (58316*2)
= 37835	= 6344
Sigma Level = **3.25**	Sigma Level = **4.00**

VI. CONCLUSION

It was observed that the thin section bearing impact the visual rejection level badly. But after increasing the outer diameter size to +100 micron from finish size provide the extra strength to the job to withstand the grinding force during grinding which will reduce the rejection on T-14 grinding line. Sigma level also increase with this DMAIC approach for the complete process to 4.00 from 3.25 which significantly improve the productivity of organization.