QUALITY FOR EVERYONE. IN EVERYTHING.

LEAN SIX SIGMA

Lean Six Sigma – Project Presentation

Project Title	**To Reduce flange coupling dimensional variation in taper boring and final grinding**		
Process / Product	Machining Process		
GB Name	Balaji D	Champion / Sponsor Name	R.Sethuraman (CQ-SQ, AL)
GB Project No	GB/Ennore/2011/A	BB / MBB Name	V. Rajagopal (LSS, CQ-TQM, AL)
Unit	Chennai Machining unit Supplier Code 3262	Function / Dept.	Quality dept
Start Date	01.08.2011	End Date	15.03.2012
Team Members	Sukumar (General Manager, CFL Chennai), Rakkumuthu (Production Head, CFL, Chenna), SenthilKumar (Quality, CFL, Chennai),		

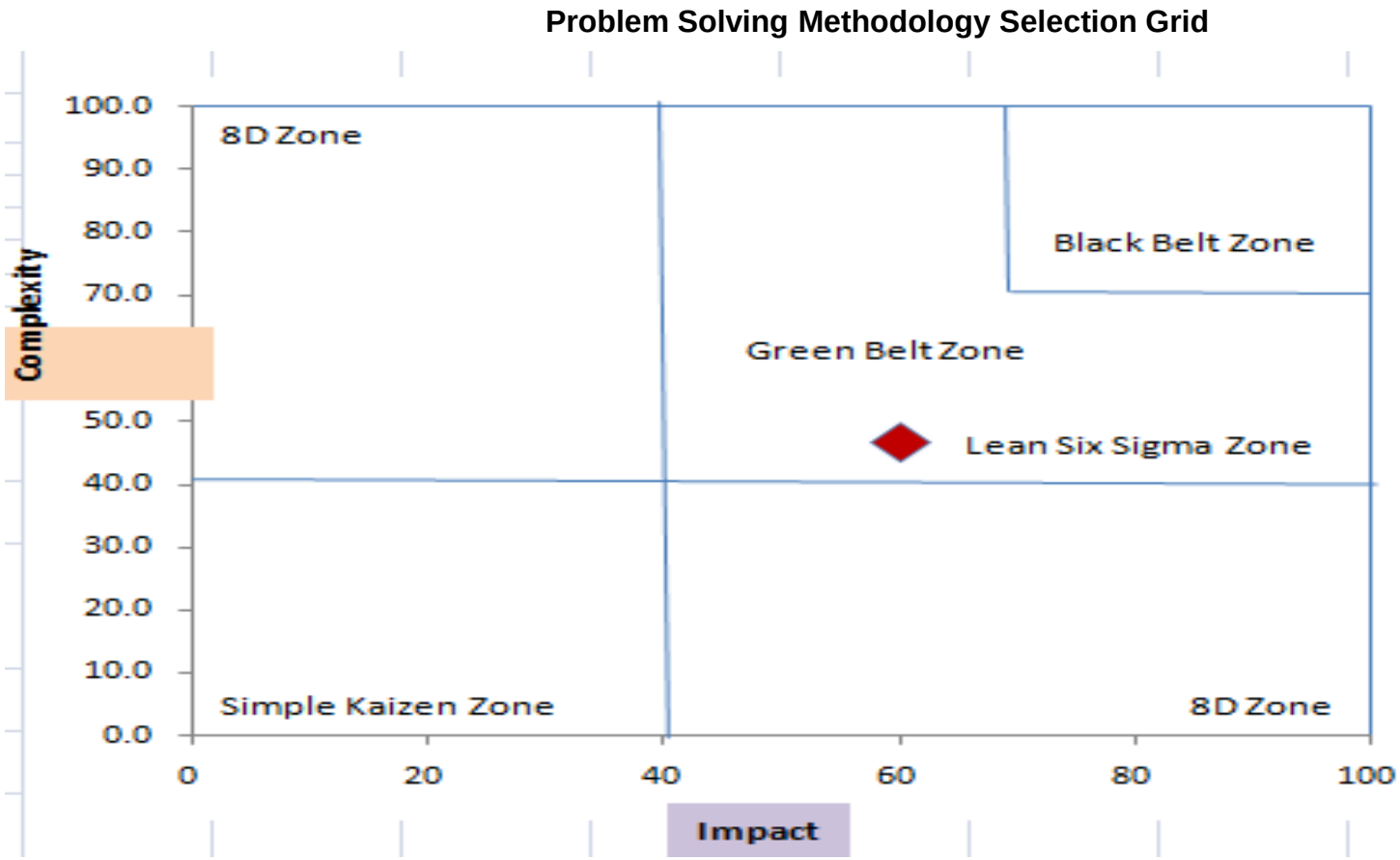
ASHOK LEYLAND

HINDUJA GROUP

Project Selection Matrix

#	Aspect	Weightage	Rating (1, 3, 9)	Score (Weight X Rating)	Rating Guidelines		
					1	3	9
Impact							
1	Impact on the Customer	0.3	3	0.9	No Effect or No Direct Effect	Impacts the Internal Customers but only Indirect impact on the final customer.	Direct Effect on the Final Customer / Internal Customer
2	Money Saving Potential	0.3	3	0.9	Less Than 10 Lakhs	Between 10 to 50 lakhs	More Than 50 lakhs
3	Frequency of the Problem	0.2	9	1.8	Less than 1000 PPM	Between 1000 to 5000 PPM	More than 5000 PPM
4	Linkage to the Business Goals	0.2	9	1.8	No Direct Linkage	Very Weak Linkage	Direct Linkage to Company's Business Goals
		1		5.4			
	Impact Score			60			
Complexity							
1	Knowledge about the Solution	0.3	3	0.9	Solution is Known, requires only Implementation	Solution is known for a similar situation, but needs to be tried out for the current situation.	Solution is Not Known , to be found out.
2	Data Availability	0.3	3	0.9	All Data is readily available	Requires Little effort	No data is available, we need to put up a process for data collection
3	Manpower Required	0.2	9	1.8	Concerned Executive is sufficient for Implementation	Requires help from one more function	Requires support from more than one function.
4	Time Required	0.2	3	0.6	Can be implemented within a Month	Upto 3 months is required	Min 6 Months is required
		1		4.2			
	Complexity Score			46.7			

Project Selection Matrix




Define

Project Charter

Project Code	GB/Ennore/ 2011/A	**Green Belt**	Balaji D	**Unit / Function**	Machining / Quality
Mentor / Sponsor	AL CQE-R. Sethuraman / P. Dakshinamurthy			**Gemba**	Machining Unit

Project Definition

Project Title	To reduce Flange Coupling dimensional variations							
Problem Definition	Repeated issues (during March 2011 – Aug 2011) arising out of dimensional variations with Flange Coupling component at the customer end.							
Scope	Finishing Operation 1 and Operation 2 done in CNC in Machining unit							
Goal Statement	**Metric**	PPM	**From**	2,303 PPM	**To**	100 PPM	Target (Entitlement)	0 PPM
Tangible Benefits	**Money Savings / ECU**	1. Reducing Rejections and there by reducing loss from it			**Other Tangibles**	1. Customer satisfaction will be improved 2. Self morale will be improved		
Customers	Ashok Leyland							
Linkage to Company Objective	Linked to the Objective of SQMI rating of 93%							

Time Lines	**Define**	24/08/2011	**Measure**	10/09/2011	**Analyze**	30/09/2011	**Improve**	31/10/2011	**Control**	19/11/2011
Support Required	CFFPL - Sukumar (General Manager), Rakkumuthu (Production head), SenthilKumar (Quality), Balaji (General Manager) AL CQE – R. Sethuraman									
Approvals	Mentor: R. Sethuraman		Unit Head: D.Balaji			AL Knowledge Academy: V. Rajagopal				

One Page Executive Summary

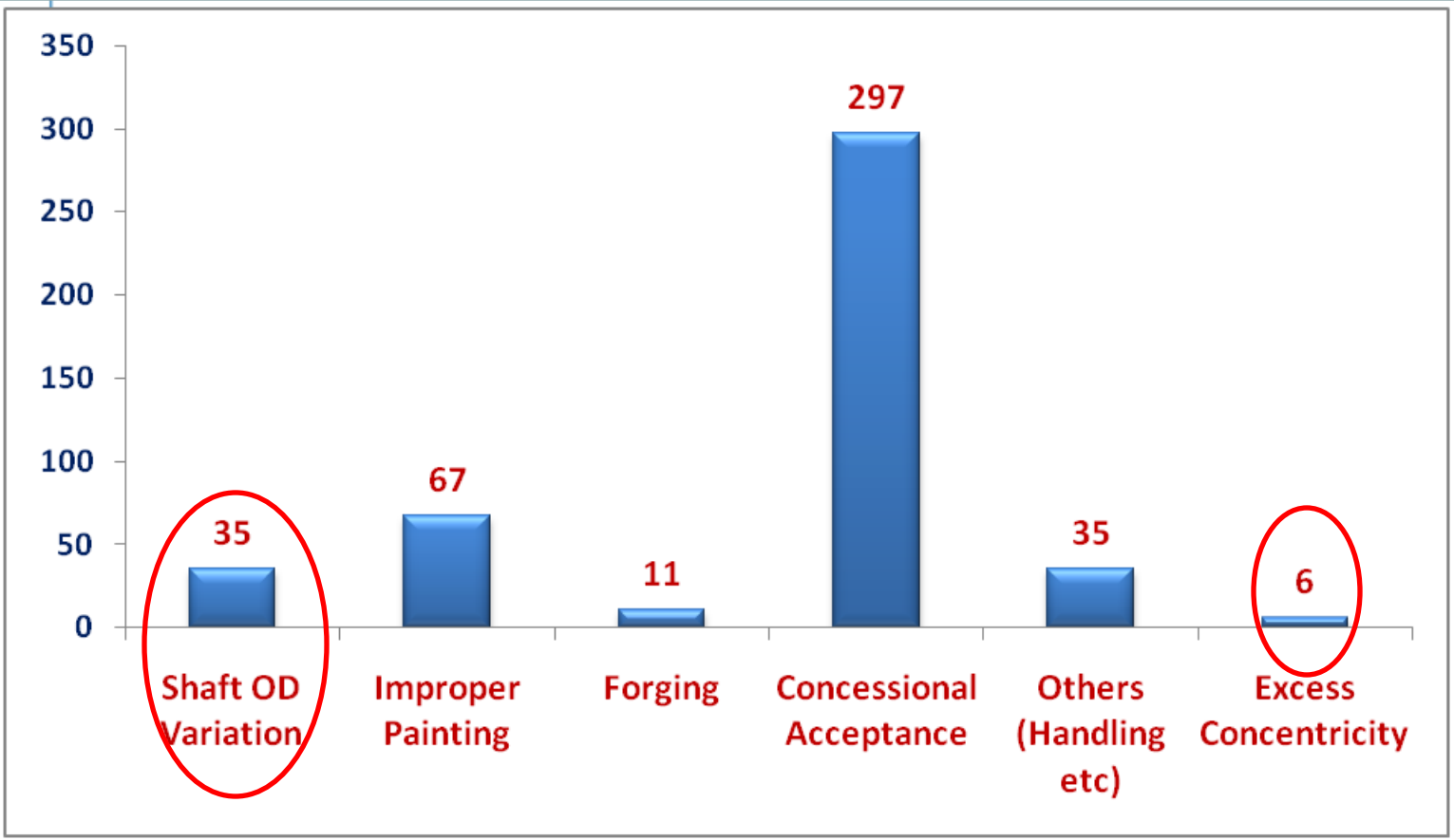
Reason for selection at this juncture	**To reduce frequent customer complaint's, and to improve customer satisfaction levels**	
Goal / Objective	To reduce Flange Coupling dimensional variations from 29,950 PPM to 100 PPM	
Benefits	Tangible	Intangible
	• Uninterrupted Customer line • Loss & Rejections will be reduced	• Customer satisfaction will be improved • In house morale will be improved
Results	Targets	Actual
	• PPM of less than 100 • 80% reduction of in process rejections due to shaft OD oversize / undersize	• Customer PPM: 0 as of Jan 2013 • 100% reduction in, in-process rejections due to Shaft OD o/s or u/s • 80% reduction in overall in in-process rejections.

Business Case

Period	**Threats** *(Negative aspects if we don't take up this project now)*	**Opportunities** *(Positive aspects if we take up this project now)*
Short Term (3 to 6 Months)	-Customer dissatisfaction -Loss due to customer rejections (cost of poor quality)	- Improvement in customer satisfaction - Opportunities in new product development
Long Term (3 to 5 Yrs)	- Regular orders will be reduced - Loss of Credibility	- Improvements in in-house quality awareness - Use of learning's from this project to other components

Background Information

Data – Customer Rejections from April 2011 to August 2011



Inference / Conclusion from the Data

Dimensional variations is the topmost reason for rejections

Background Information

Data – Flange Coupling Customer Issues for the duration of April – Sep 2011

Defect Grouping	Defect Quantity	GRN Quantity	PPM	Remarks
Shaft OD Variation	35	15,196	2,303	Dimensional variation, needs to be controlled in the machining process
Improper Painting	67	15,196	4,409	
Forging	11	15,196	723	Segregation of components with excess material and control at Forging
Concessional Acceptance	297	15,196	19,544	Assign person to upload inspection reports regularly
Excess Concentricity	6	15,196	394	Dimensional variation, needs to be controlled in the machining process
Others (Handling etc)	35	15,196	2,303	Handling, Packing issues.

Inference / Conclusion from the Data

Dimensional variations is the topmost cause for rejections, while improper painting, handling are more of discipline related issues

Project Tracker

Phase	Activity		Jul'11	Aug'11	Sep'11	Oct'11	Nov'11	Dec'11	Jan ' 12	Feb '12	Mar '12	Apr '12	May '12
Define	Charter preparation	P											
		A											
Measure	Process Map	P											
		A											
	MSA	P											
		A											
	Attribute P-chart	P											
		A											
Analyze	Scatter, Box plots	P											
		A											
	Customer onsite Visit	P											
		A											
	Hypothesis tests	P											
		A											
Improve	Hypothesis Tests	P											
		A											
	Process Capability - New	P											
		A											
Control	Control Plans	P											
		A											
		P											
		A											

Project Reviews with AL

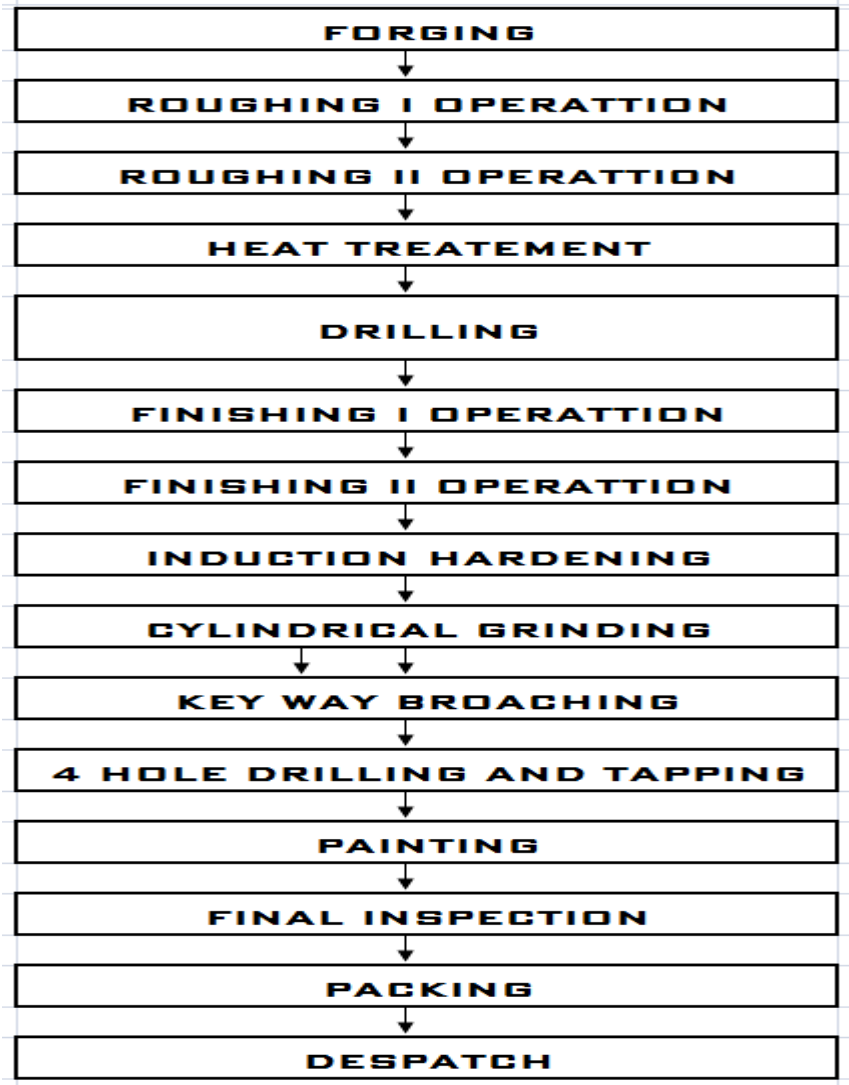
Date	Location	Discussion With	Members Participated	Remarks
20/12/11	CFL, Ambattur	CQ-SQ Vertical Head & BB	Balaji, Rakkumuthu, Premkarthik, Sukumar	Review up to Measure Phase (refer attached MOM)  Microsoft Excel Worksheet
24/02/12	CFL, Ambattur	CQ-SQ Vertical Head & BB	Balaji, Rakkumuthu	Review up to Improve Phase

Inference / Conclusion from the Data

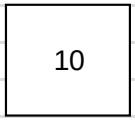
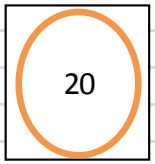
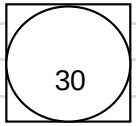
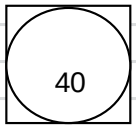
Visits undertaken to supplier Gemba for the project support was provided


Measure

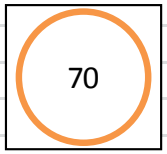
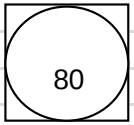
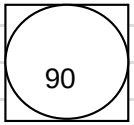
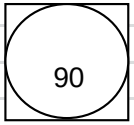
Flow Chart


FORGING
ROUGHING I OPERATTION
ROUGHING II OPERATTION
HEAT TREATEMENT
DRILLING
FINISHING I OPERATTION
FINISHING II OPERATTION
INDUCTION HARDENING
CYLINDRICAL GRINDING
KEY WAY BROACHING
4 HOLE DRILLING AND TAPPING
PAINTING
FINAL INSPECTION
PACKING
DESPATCH

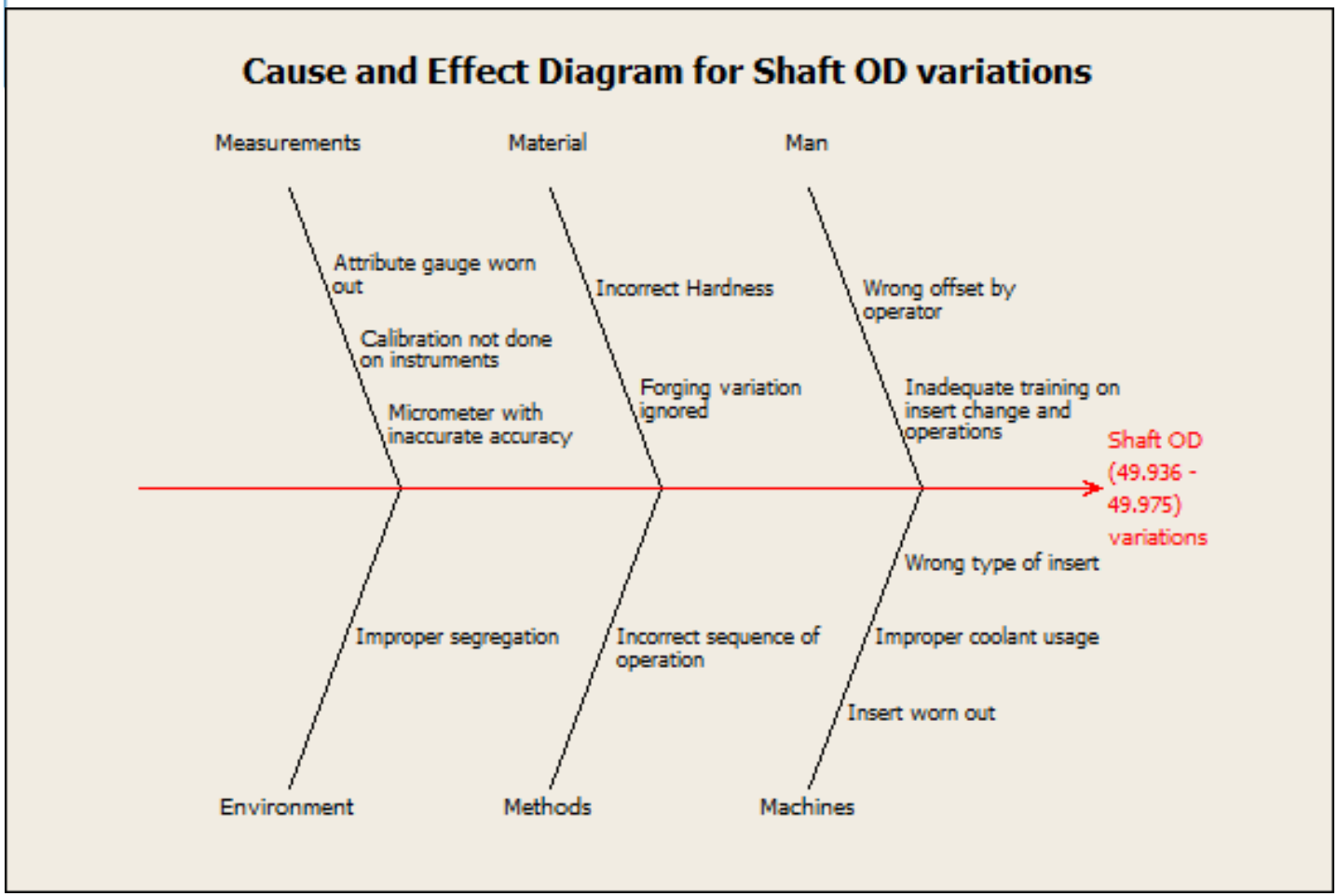
Process Flow Chart – Detailed - Sample

Operation No.	Brief Description.	Incoming source of variation.	Process flow Diagram	Output Characteristics
10	CNC I st Operation	Forging , Forging Mismatch Unfilling,Lap,Fitting,O/S,U/S M/c,Gauge,Speed,Feed,Tool, Coolant,R.P.M,Fixture Insert,Drill		DIAMETER - 39.80 / 40.20 DIAMETER - 15.90 / 16.10 CHAMFER - 2 × 45° LENGTH - 40.50 / 41.00 LENGTH - 110.20 / 110.80
20	CNC II nd Operation	Size U/S,O/S,Insert M/c,Gauge,Speed,Feed,Tool, Coolant,R.P.M,Fixture Insert		DIAMETER - 117.30 / 117.70 DIAMETER - 52.30 / 52.70 LENGTH - 14.80 / 15.20 CHAMFER - 1.5 × 45° CHAMFER - 1.5 × 45° DISTANCE - 25.80 / 26.20 DISTANCE - 108.20 / 108.80
30	Heat Treatement	Material,Furnace Temperature Quenching Media , Tempering Temperature , Time		HARDNESS
40	Ø 13.5 Drilling	Size U/S,O/S ,Drill Bit M/c,Gauge,Speed,Feed,Tool, Coolant,R.P.M,Fixture		CENTER OFFSET OD OVALITY DIAMETER - 13.30 / 13.70 DEPTH - 29.00 / 30.00

Process Flow Chart – Detailed (Contd…)

Operation No.	Brief Description.	Incoming source of variation.	Process flow Diagram	Output Characteristics
50	CNC Finishing I st Operation	Size U/S,O/S ,Insert M/c,Gauge,Speed,Feed,Tool, Coolant,R.P.M,Fixture U Drill,Thread Insert		RUNOUT,FACEOUT OD-49.936/49.975, DEPTH,THREAD,CHAMFER ID,LENGTH,RADIUS
60	CNC Finishing II nd Operation	Size U/S,O/S ,Insert M/c,Gauge,Speed,Feed,Tool, Coolant,R.P.M,Fixture		OD-49.90/50.10,TOTAL LENGTH TAPER FINISH,DEPTH,ANGLE LENGTH,RUNOUT,FACEOUT CHAMFER,RADIUS
70	Induction Hardening	Material,Induction Coil Quenching Ring,Anvil Indenter		HARDNESS-550 HV Min
80	Cylindrical Grinding	Size U/S,O/S ,Grinding Wheel M/c,Gauge,Speed,Feed,Tool, Coolant,R.P.M,Taper Mandrel Dresser		OD-34.936/34.975 CONCENTRICITY-0.1 DEPTH
90	Key Way Broaching	M/c,Gauge,Speed,Feed, Coolant,R.P.M,Fixture Broaching Tool,Sim		KEY WAY WIDTH,DEPTH
100	4 Hole Drilling and Tapping	Size U/S,O/S ,Drill Bit M/c,Gauge,Speed,Feed,Tool, Coolant,R.P.M,Fixture		CENTER OFFSET THREAD,PCD,DEPTH

Fish Bone Diagram



Inference / Conclusion from the Data

Multiple factors could lead to dimensional variations with Flange Coupling

FMEA - Before

Process Function / Requirements	Potential Failure Mode	Potential Effect(s) of Failure	S E V	C L A	Potential Cause(s) / Mechanism(s) of Failure	O C C	Current Process Controls Prevention	Current Process Controls Detection	D E T	R. P. N.
10.RECEIVING INSPECTION	Outer Dia 122 Over Size	Extra material to be removed in next operation	5		Process problem at Supplier end	3		Receiving Inspection Report	2	30
	Outer Dia 122 Under Size	Unclear	5		Process problem at Supplier end	3		Receiving Inspection Report	2	30
	Length 110 over size	Extra material to be removed in next operation	5		Process problem at Supplier end	3		Receiving Inspection Report	2	30
	Length 110 under size	Unclear	5		Process problem at Supplier end	3		Receiving Inspection Report	2	30
20. CNC FINISHING 1st OPERATION	Outer diameter Ø35.32/35.37 Over Size	Assembly Fitment Problem at customer end	6		Insert Worn out	2	Tool life fixed & Insert changed	Line Inspection Report	3	36
	Outer diameter Ø35.32/35.37 Under Size	Assembly Fitment Problem at customer end	6		wrong Offset given	2	Trained setter	Line Inspection Report	3	36
	Outer diameter Ø49.936/49.975 Over Size	Assembly Fitment Problem at customer end	6		Insert Worn out	4	Tool life fixed & Insert changed	Line Inspection Report	2	48
	Outer diameter Ø49.936/49.975 Under Size	Assembly Fitment Problem at customer end	6		wrong Offset given	3	Trained setter	Line Inspection Report	3	54
30.CNC FINISHING 2nd OPERATION	Taper Bore 19.85/19.90 Under size	Assembly Fitment Problem at customer end	5		Taper Tool worn Out	3	Tool life fixed & Insert changed	Line Inspection Report	3	45
	Taper Bore 19.85/19.90 Over size	Assembly Fitment Problem at customer end	5		wrong Offset given	3	Trained setter	Line Inspection Report	3	45
	Run out 0.1 variation	Assembly Fitment Problem at customer end	6		Improper loading	4	Trained operator	Line Inspection Report	3	72

MSA Before Improvement - Set up

Category	Data
Number of Appraisers	3
Number of Parts	10
Number of Trails per Appraiser	3
Equipment under MSA study	MICROMETER (.01 accuracy)
Tolerance	0.039

MSA Results – Before Improvement

Gage R&R

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	0.0000685	27.37
Repeatability	0.0000408	16.31
Reproducibility	0.0000277	11.06
Operators	0.0000066	2.65
Operators*Parts	0.0000210	8.40
Part-To-Part	0.0001818	72.63
Total Variation	0.0002503	100.00

Process tolerance = 0.039

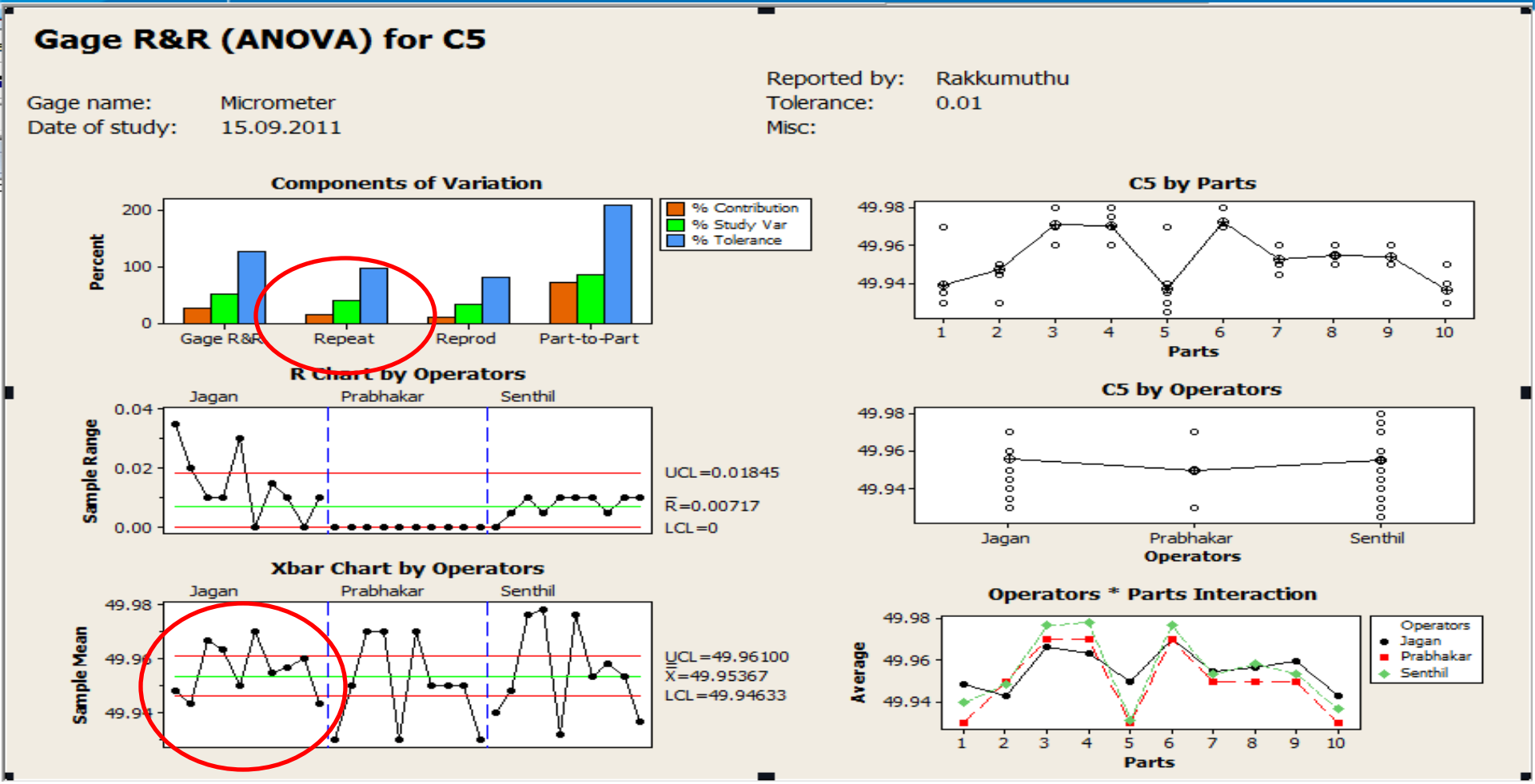
Source	StdDev (SD)	Study Var (6 * SD)	%Study Var (%SV)	%Tolerance (SV/Toler)
Total Gage R&R	0.0082776	0.0496655	52.32	127.35
Repeatability	0.0063901	0.0383406	40.39	98.31
Reproducibility	0.0052617	0.0315700	33.26	80.95
Operators	0.0025780	0.0154680	16.29	39.66
Operators*Parts	0.0045868	0.0275210	28.99	70.57
Part-To-Part	0.0134837	0.0809023	85.22	207.44
Total Variation	0.0158218	0.0949308	100.00	243.41

Number of Distinct Categories = 2

Inference / Conclusion from the Data

Total Gage R&R (52.32%) is > 30%, so measurement system is not accceptable. Micrometer with wrong accuracy used, and No of distinct categories is 2.

MSA Results – Before Improvement



Inference / Conclusion from the Data

Training to be given to Operators, and due to high repeatability score, equipment could be an issue

MSA Results – Before Improvement

Inference / Conclusion from the Data

Micrometer with least count .01 were regularly used, hence there is a need to change

Actions taken to Improve MSA

No	Actions taken
1	Digital Micrometer with improved least count used
2	Training on usage of Digital Micrometer given to all operators

Inference / Conclusion from the Data

Micrometer with least count .01 were regularly used, hence there is a need to change

MSA After Improvement - Set up

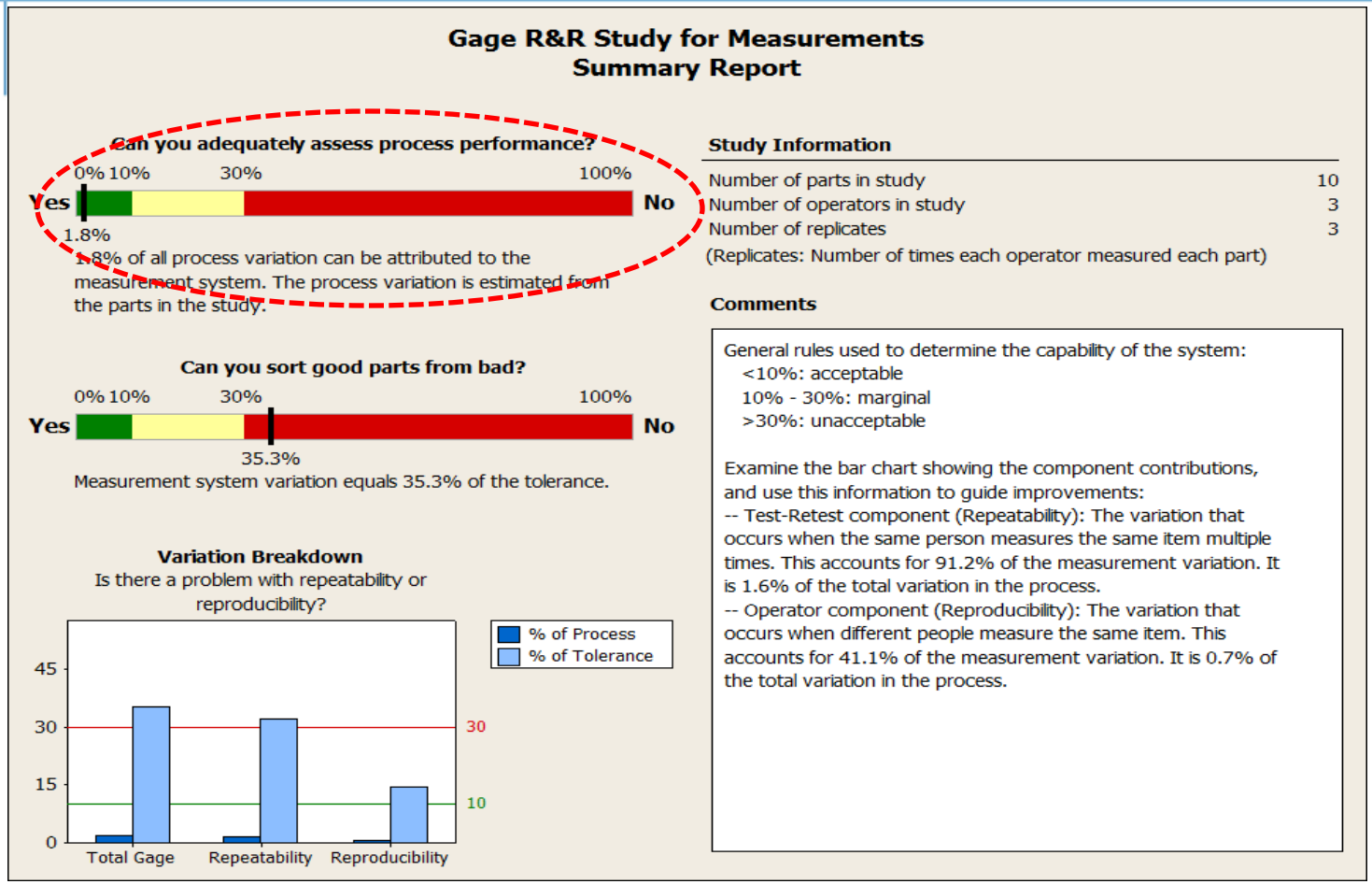
Category	Data
Number of Appraisers	3
Number of Parts	10
Number of Trails per Appraiser	3
Equipment under MSA study	Digital Micrometer 25-50 mm
Tolerance	0.039
Least Count	0.001

MSA Results – After Improvement

Inference / Conclusion from the Data

Digital Micrometer with 0.001 accuracy used.

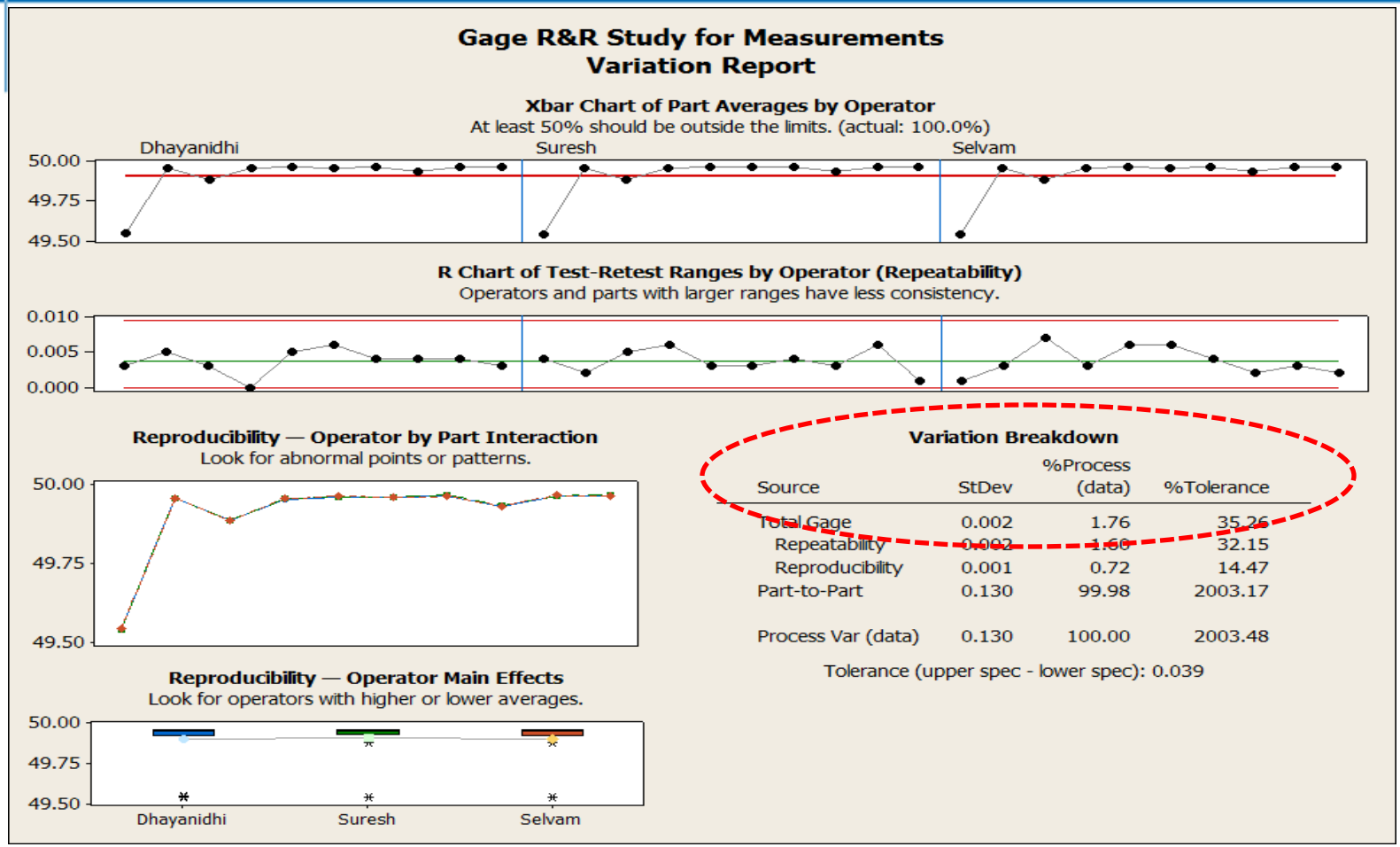
MSA Results – After Improvement – Round 1



Inference / Conclusion from the Data

Total Gage R&R (1.8%) is < 10%, so measurement system is ACCEPTABLE.

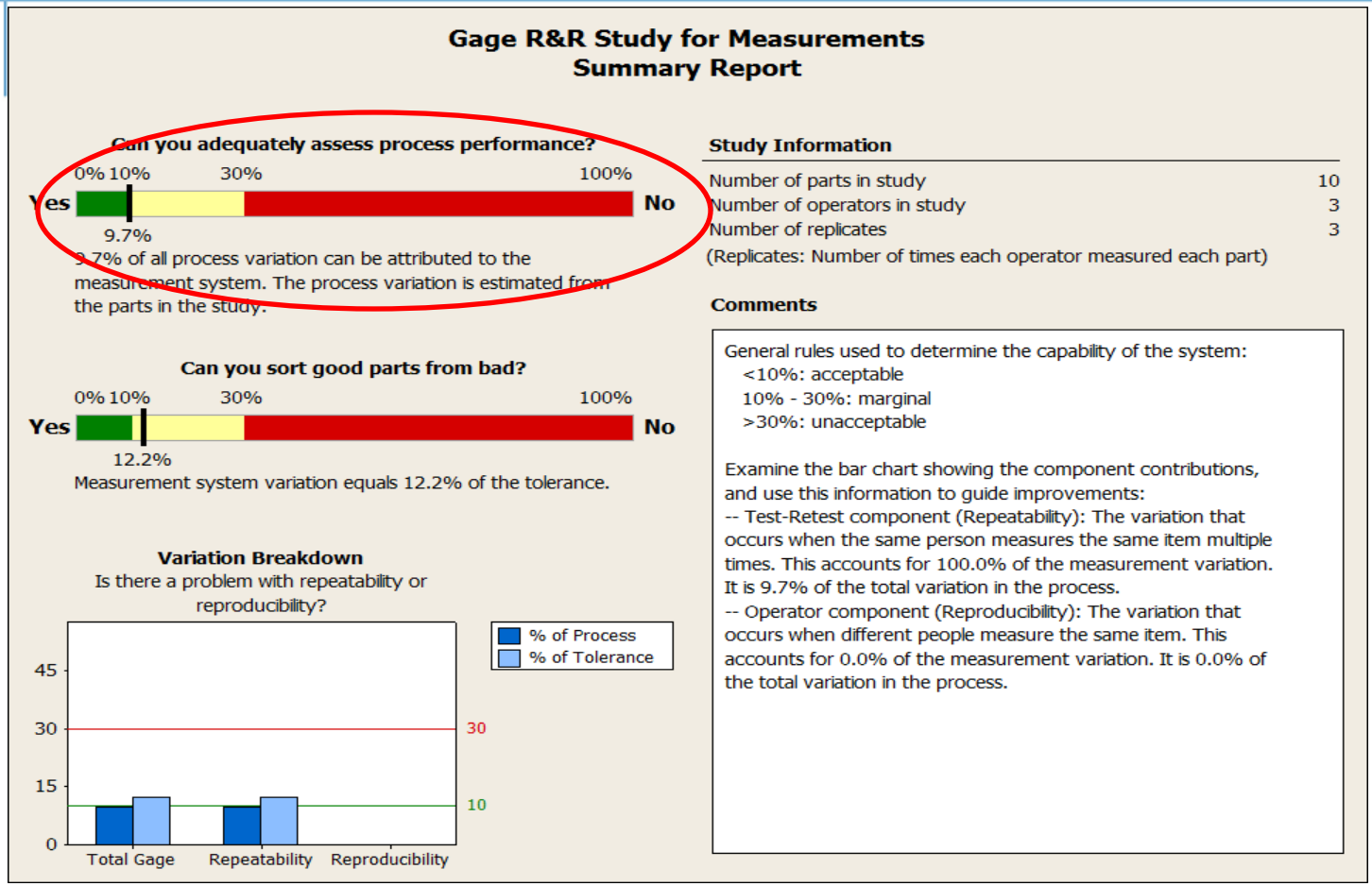
MSA Results – After Improvement – Round 1



Inference / Conclusion from the Data

Repeatability and Reproducibility is less than 10% - Measurement system is acceptable

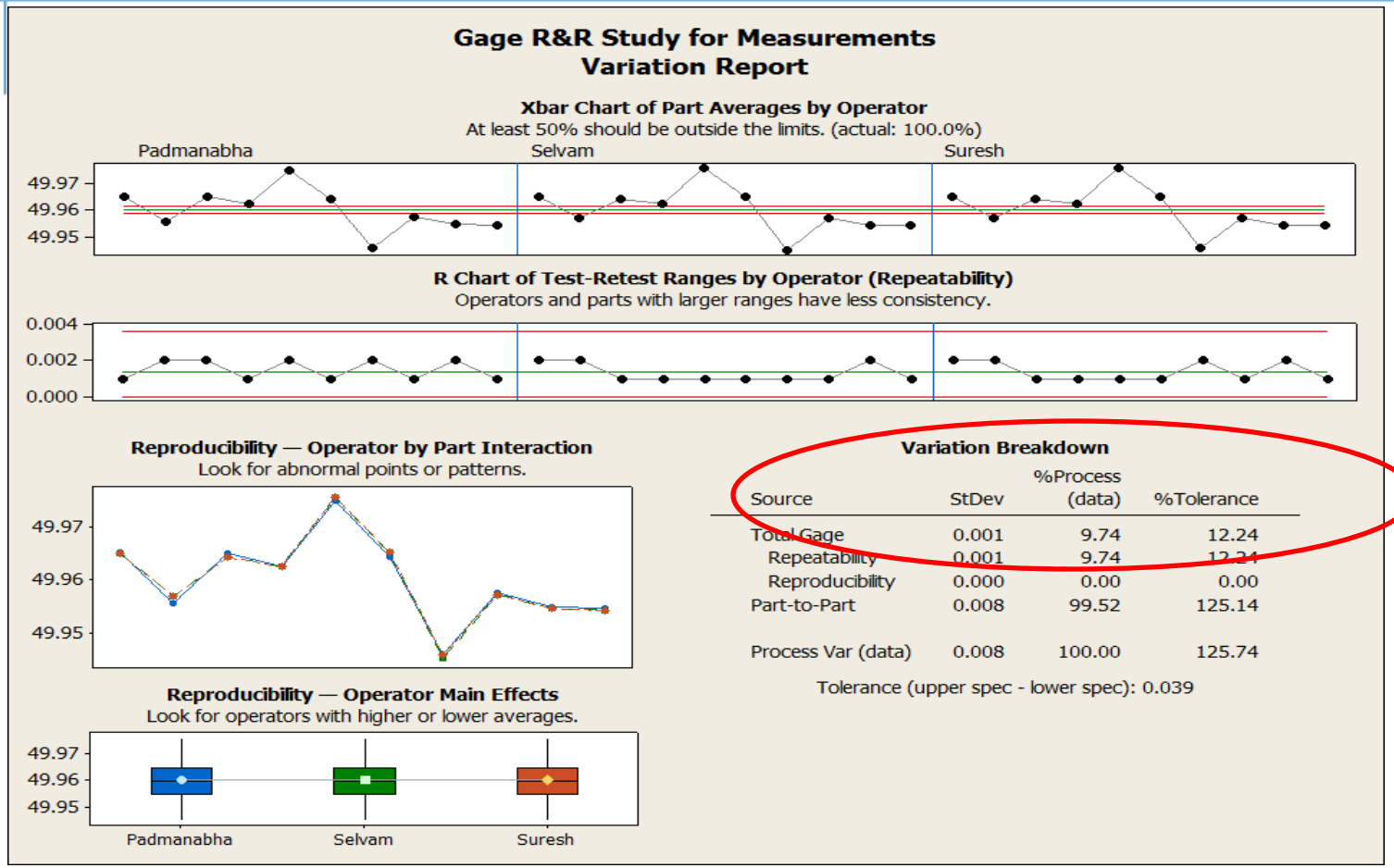
MSA Results – After Improvement – Round 2



Inference / Conclusion from the Data

Total Gage R&R (9.7%) is < 10%, so measurement system is ACCEPTABLE.

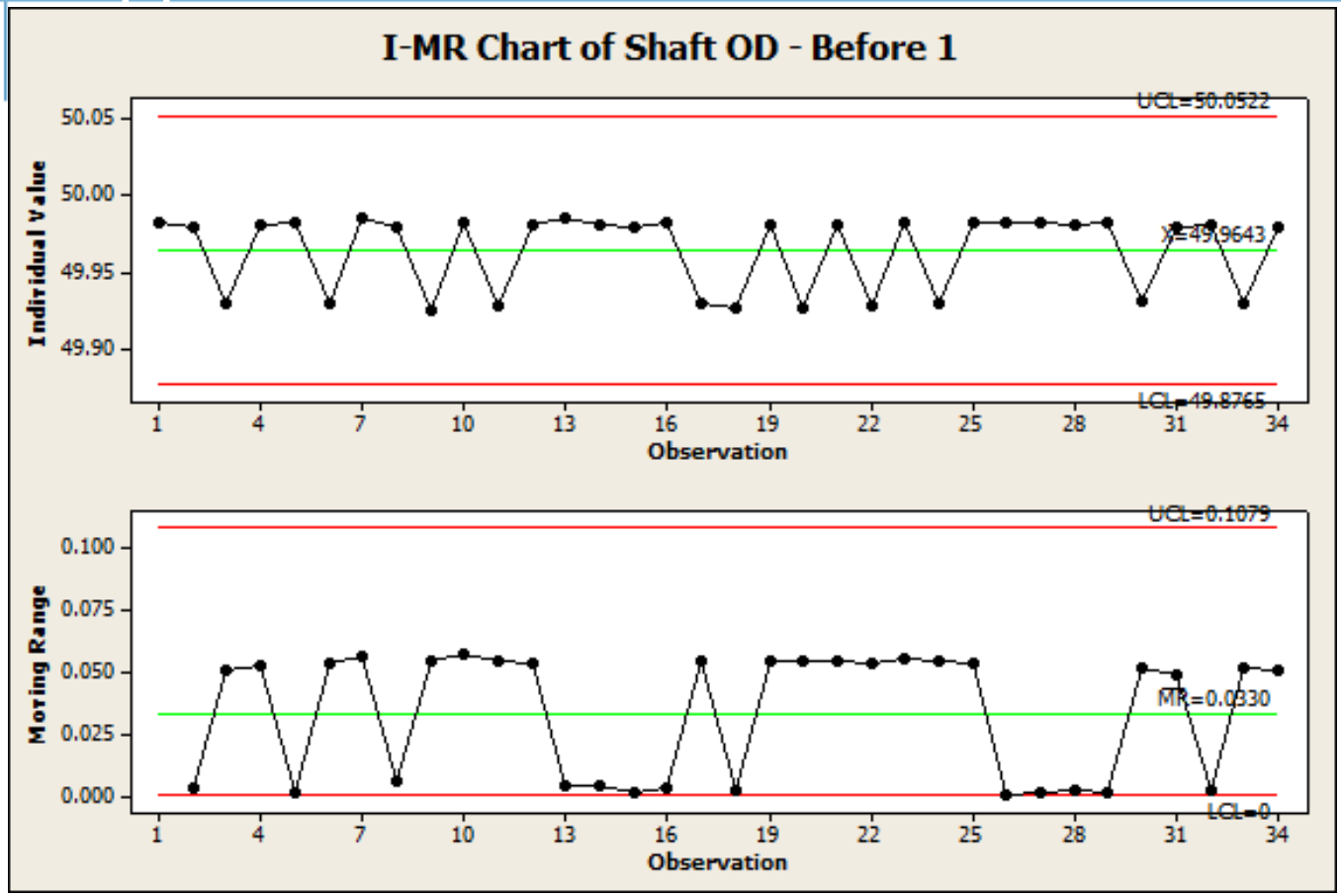
MSA Results – After Improvement – Round 2



Inference / Conclusion from the Data

Repeatability and Reproducibility is less than 10% - Measurement system is acceptable

I-MR Chart – Shaft OD Variations Supplier End



Inference / Conclusion from the Data

From the control chart, we can infer that the process is not stable, scope for improvement

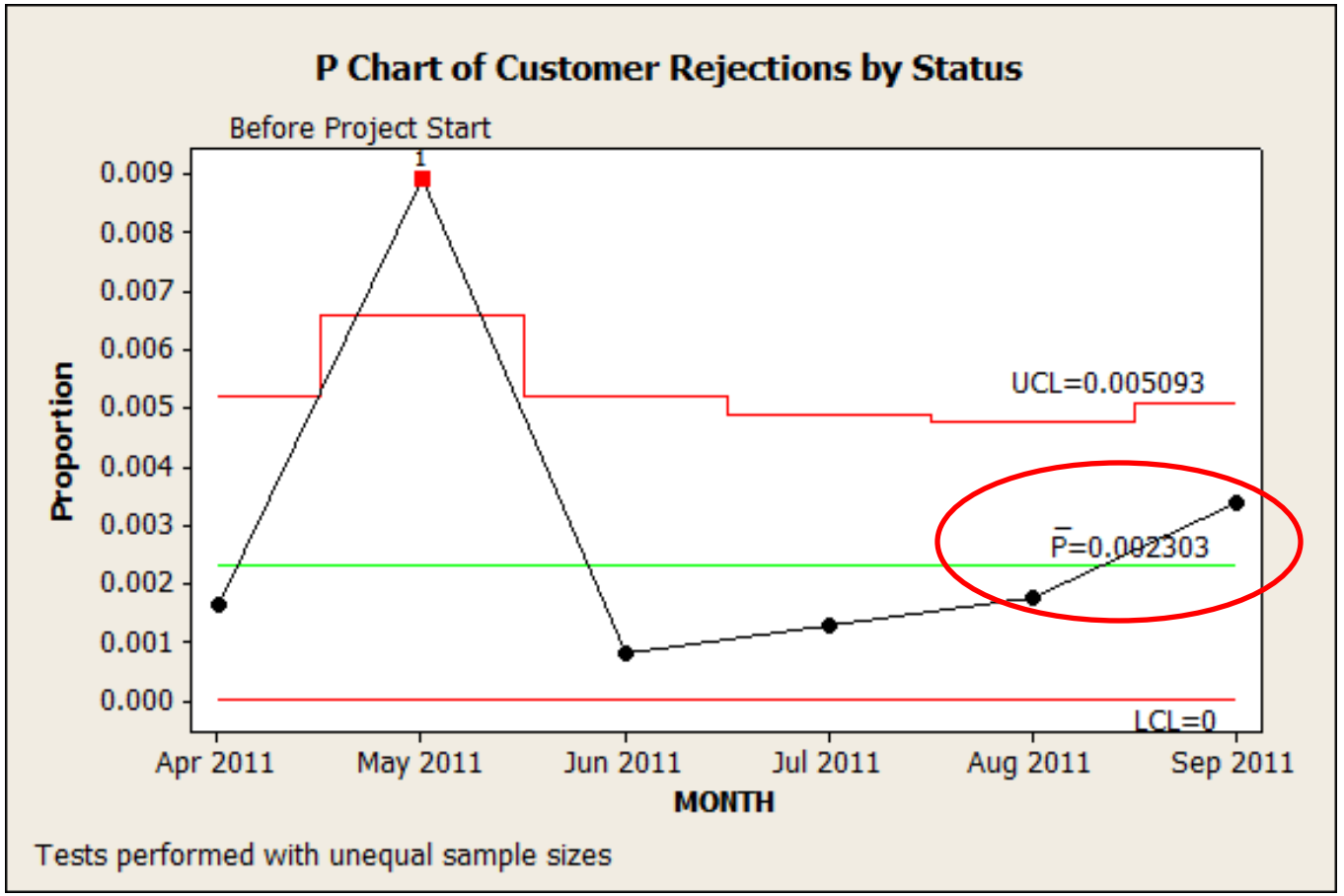
Project Base Line - Raw Data

Month	Received	Total rejection related to ID Oversize / Under size
11-Mar	3,000	56
11-Apr	2,803	4
11-May	2,405	5
11-Jun	2,114	5
11-Jul	2,579	7

Inference / Conclusion from the Data

Shaft OD variation is a consistent issue at the customer end

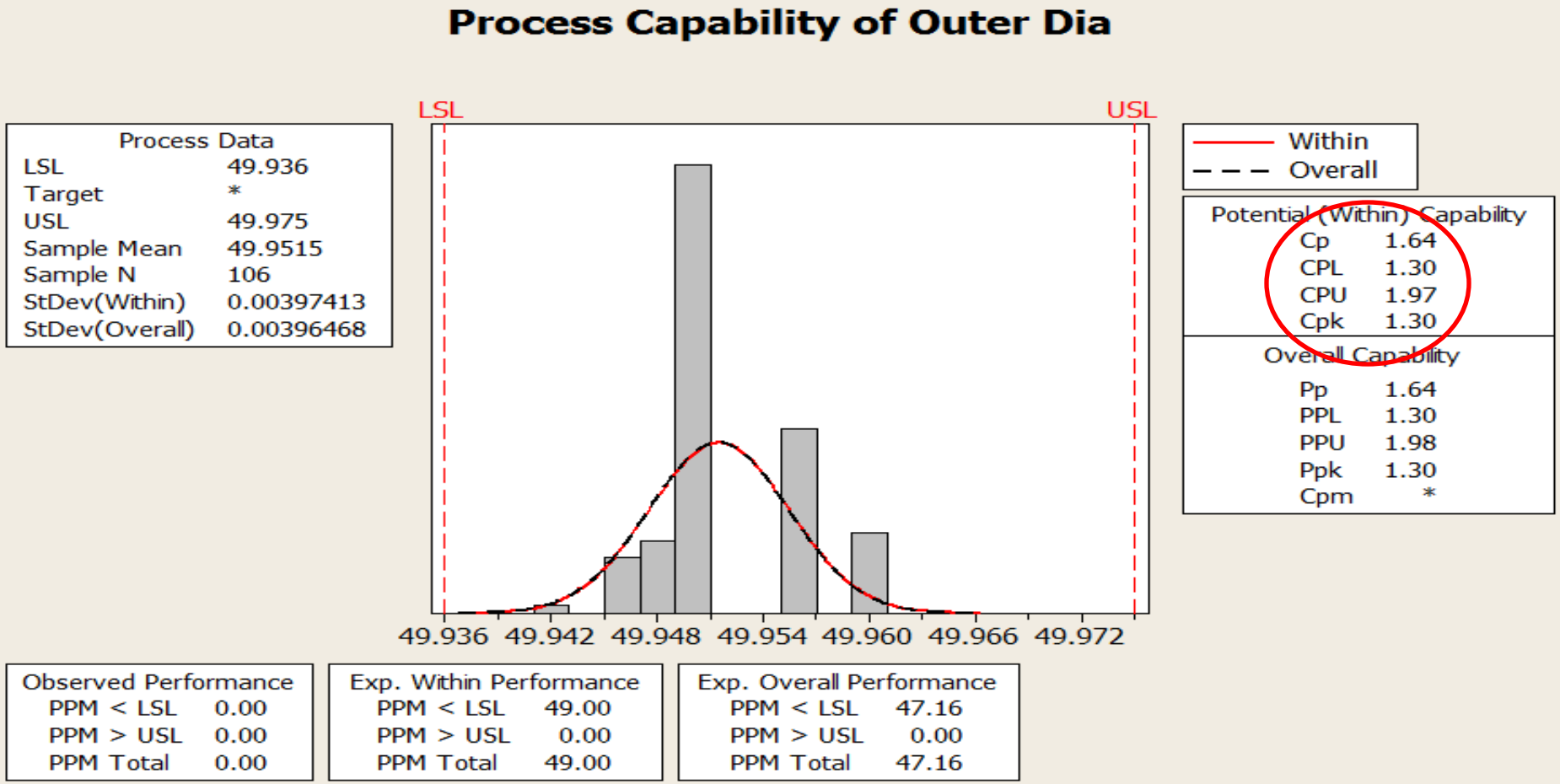
Project Base Line - Attribute P-Chart



Inference / Conclusion from the Data

Baseline PPM is 2303, May quantities were high as the process controls were revisited based on customer feedback

Project Base Line (Continuous data) – Initial Process Capability



Inference / Conclusion from the Data

Current Cpk - 1.30, there is scope for improvement

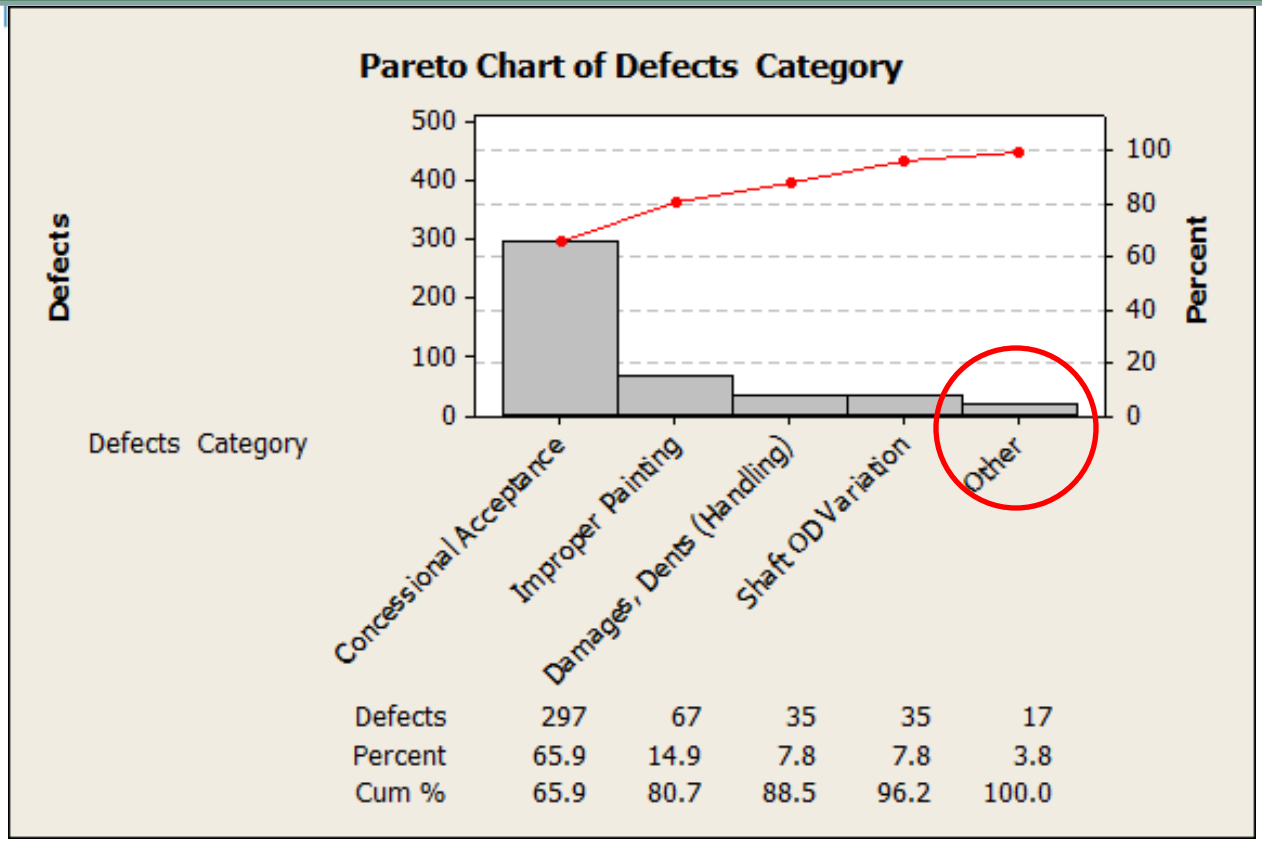
Data Collection Plan

KPIV / KPOV	Process	Type of Data (Variable / Discrete)	Data Source and Location	Sample Size	Who will Collect the Data?	Method of Collecting data	Is the Measurement System Capable?
OD (49.936 - 49.975)	Finishing 1st operation	Variable	Machining Unit - CNC Line	50	Line Inspector - Selvam	Micrometer 25-50 mm	Yes
OD (34.936 - 34.975)	Cylindrical Grinding	Variable	Machining Unit - CNC Line	50	Padmana bha	Micrometer 25-50 mm	Yes


Analyze

Pareto Analysis

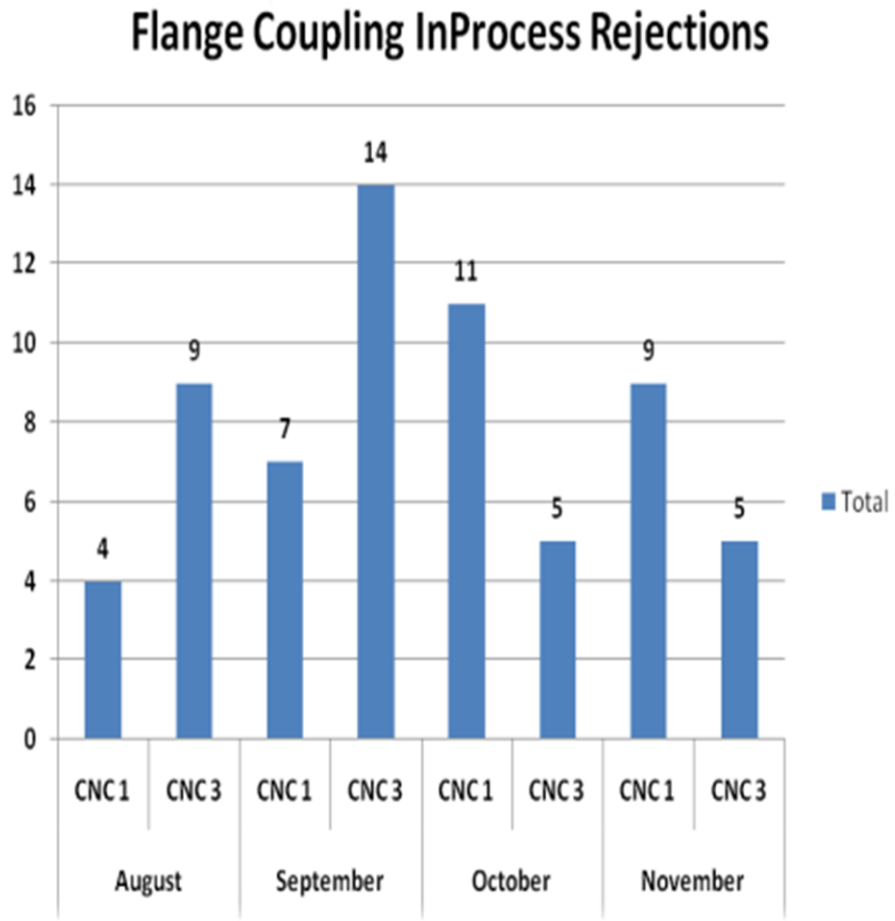
Customer Rejections Data from April – Sep 2011

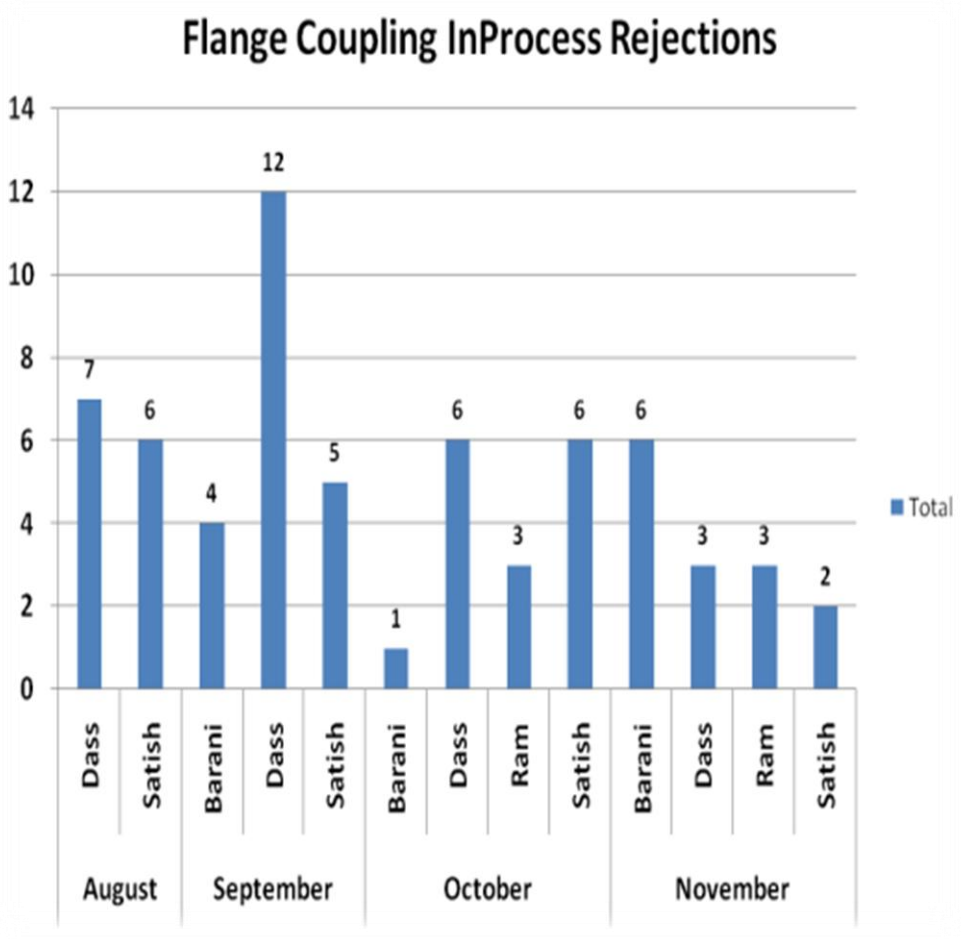


Inference / Conclusion from the Data

Shaft OD Variation contributes to about 8% of the total rejections, since improper painting, damages, dents were more of discipline issues, they were not considered

In Process Rejections (OD) Analysis

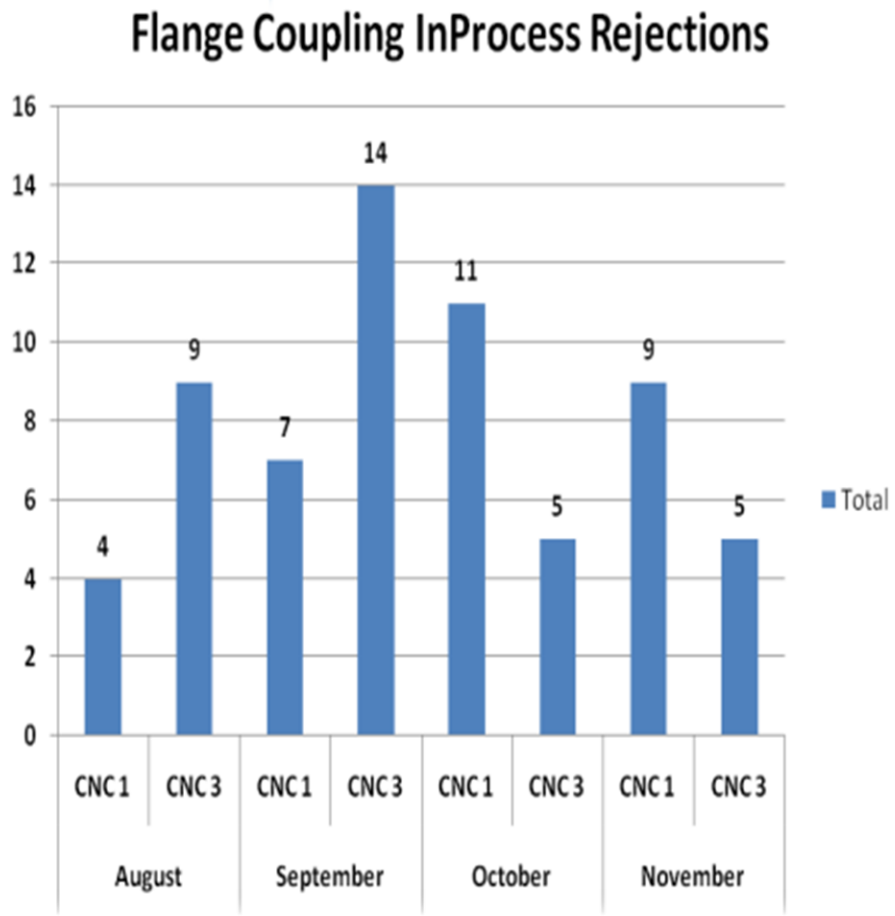


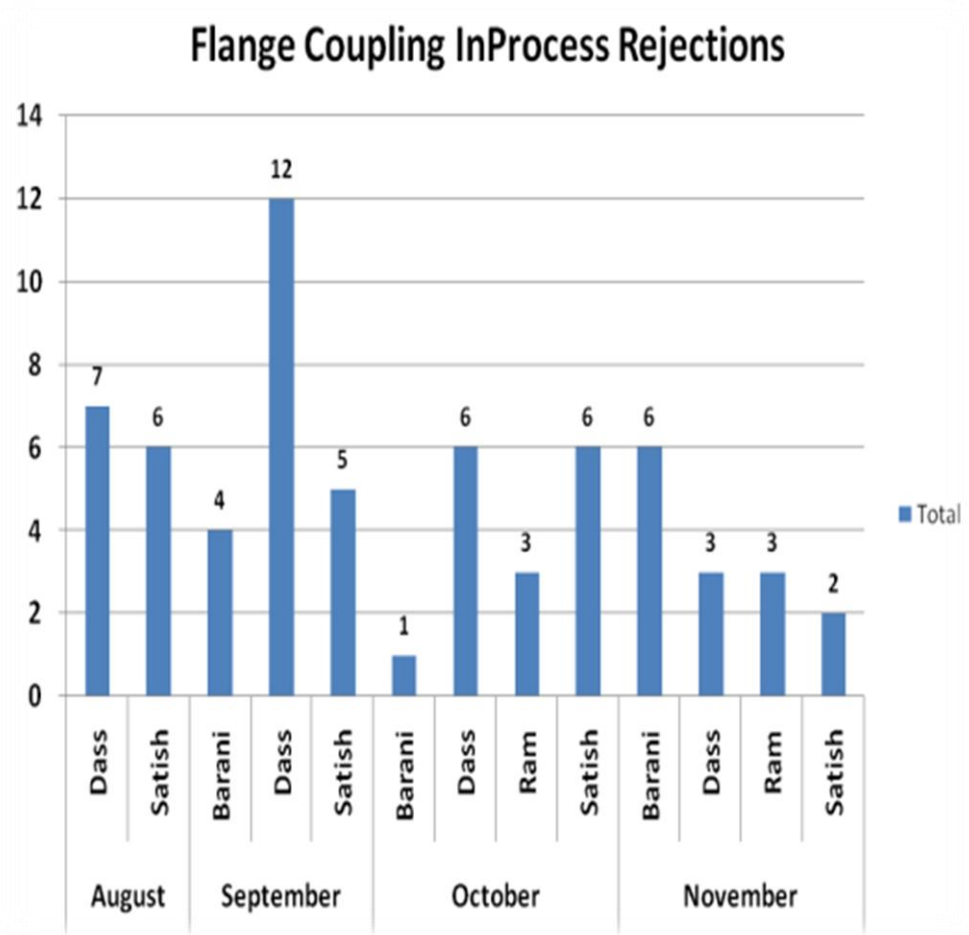


Inference / Conclusion from the Data

In Process rejections cannot be attributed solely due to operator /machine

In Process Rejections (OD) Analysis

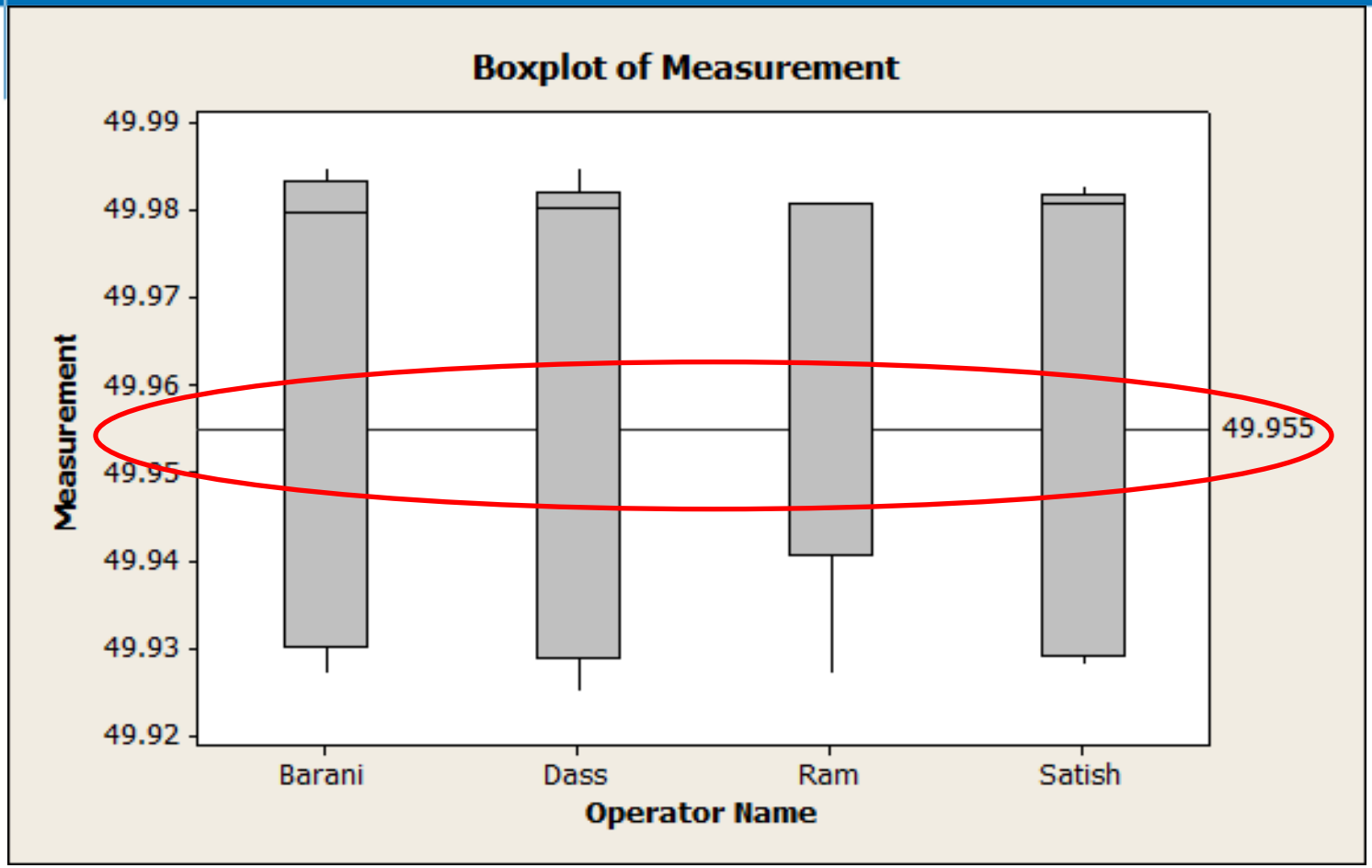




Inference / Conclusion from the Data

In Process rejections cannot be attributed solely due to operator /machine

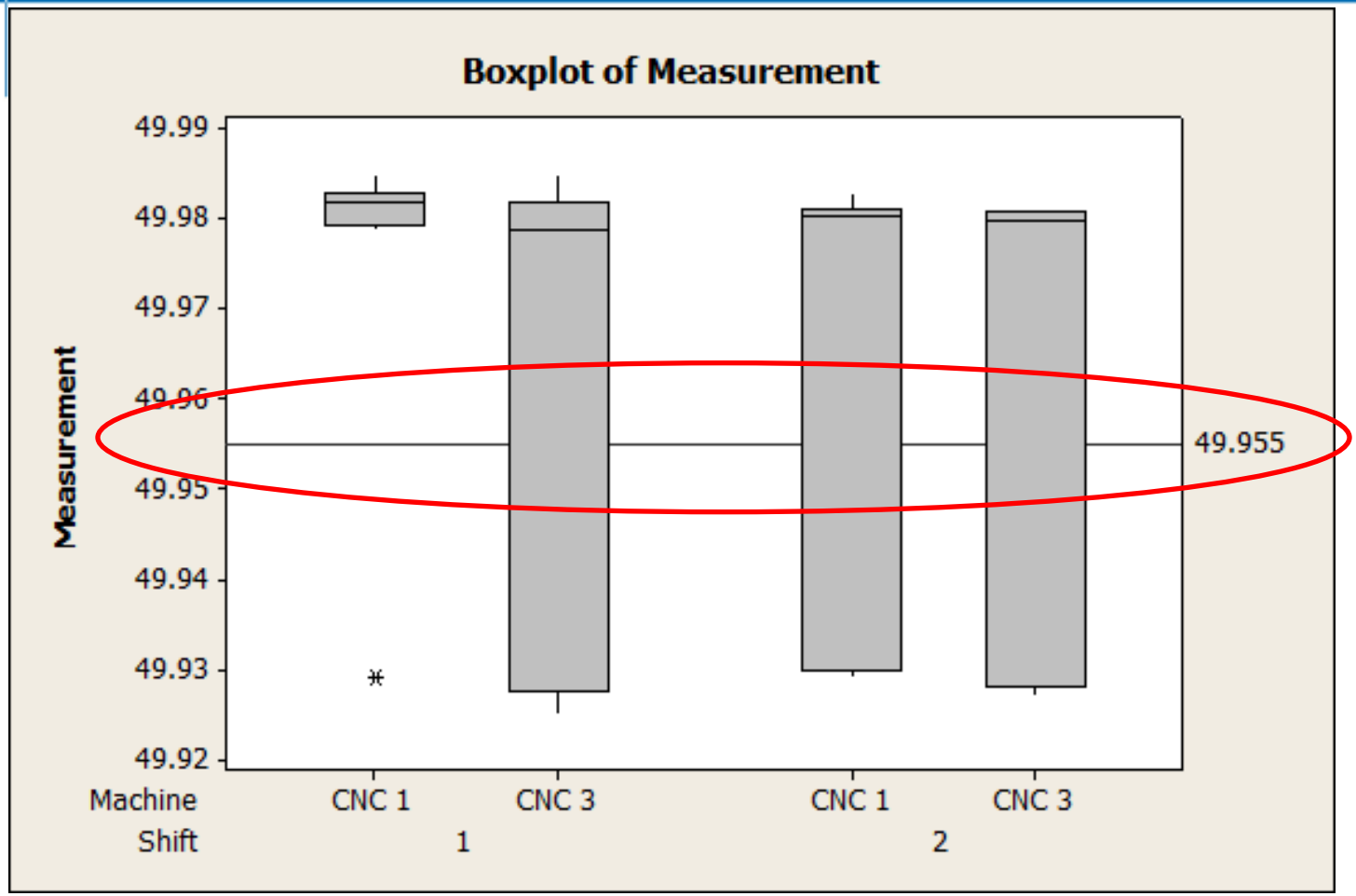
In Process Rejections (OD) Analysis



Inference / Conclusion from the Data

Consistent rejections across all the operators from the Spec 49.955. The problem is not solely with the operator.

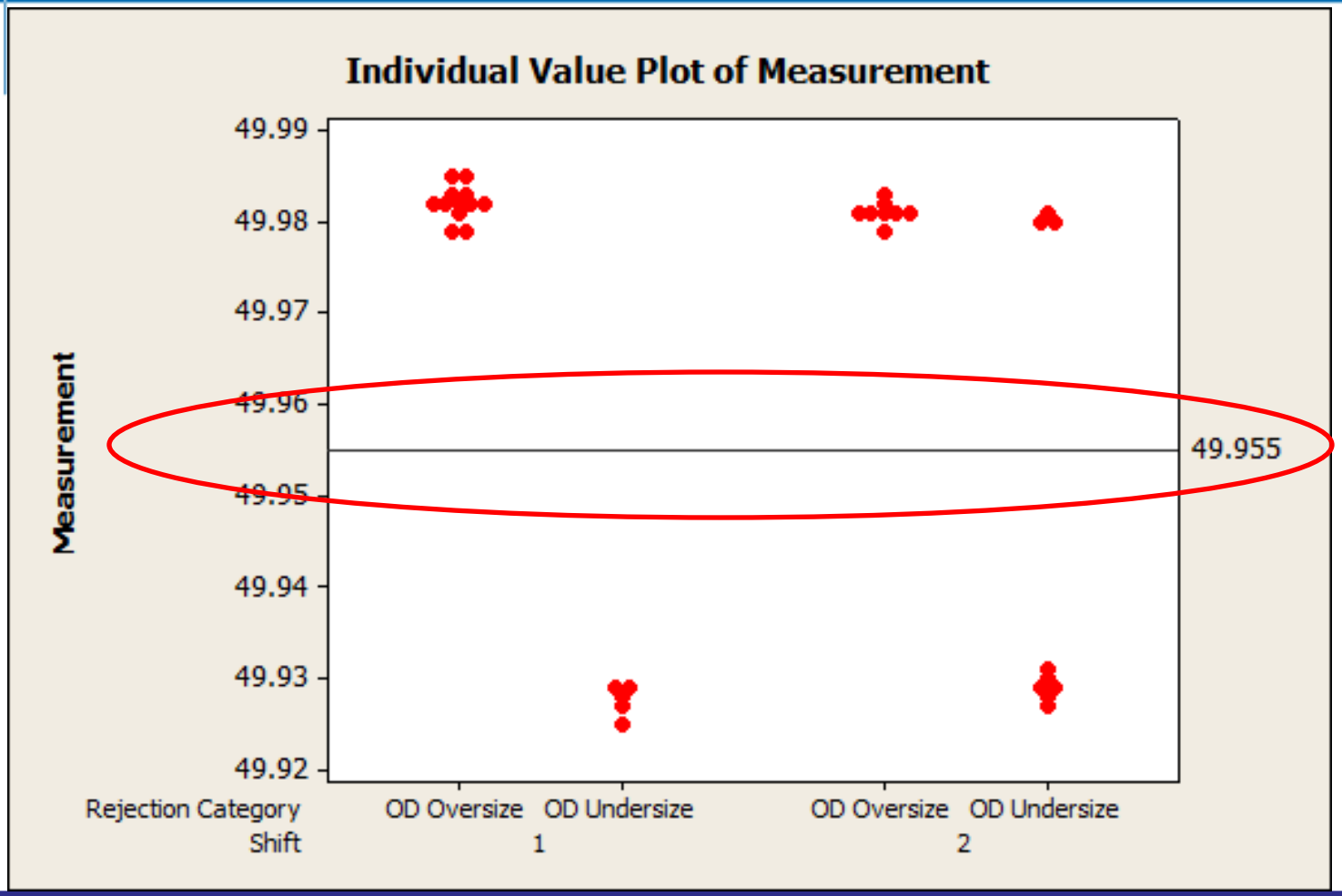
In Process Rejections (OD) Analysis



Inference / Conclusion from the Data

Both machines appears to have contributed to rejections across shifts, and data falls on eiither side of Spec 49.955.

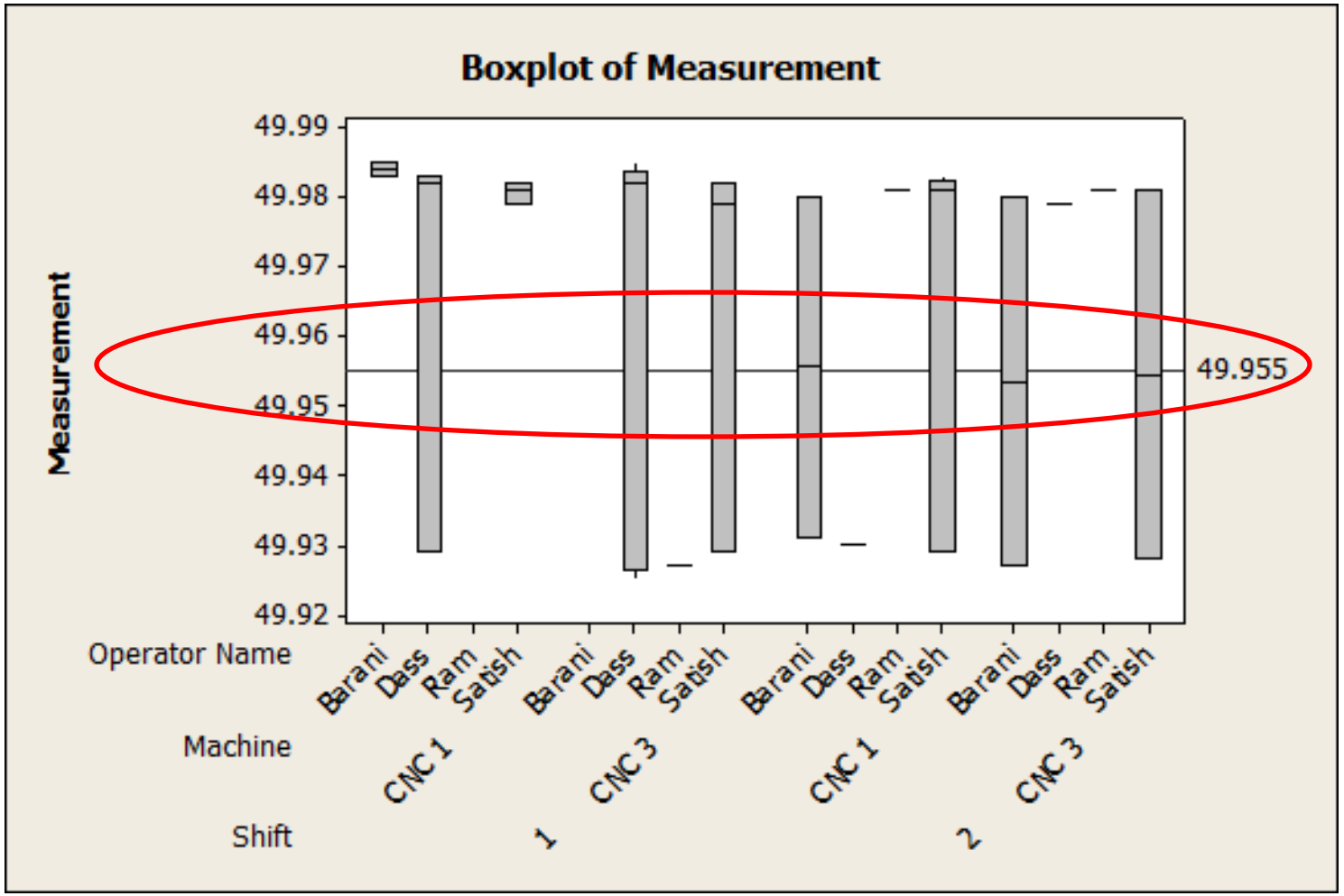
In Process Rejections (OD) Analysis



Inference / Conclusion from the Data

Across shifts, both oversize and undersize appears to exist

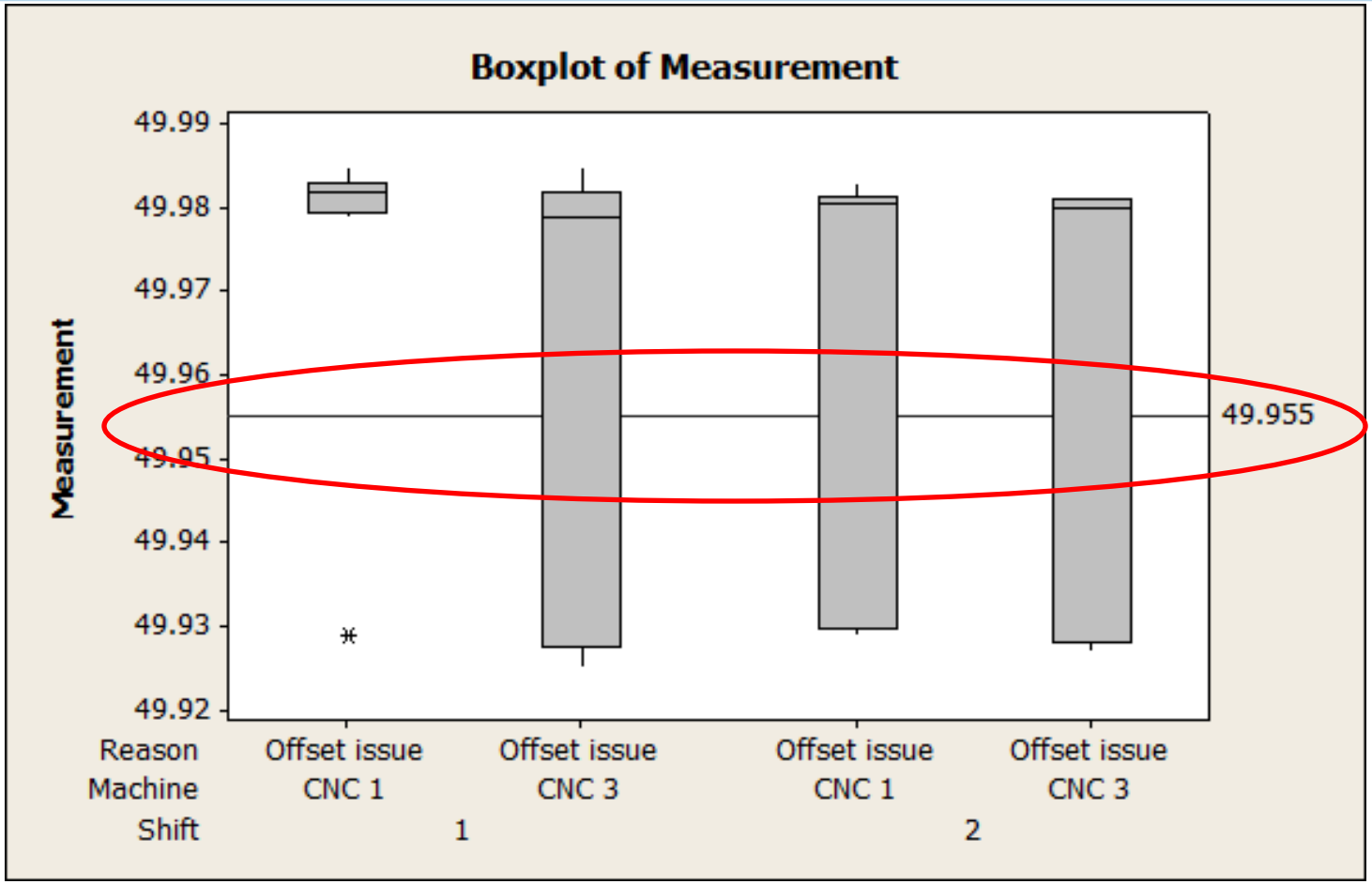
In Process Rejections (OD) Analysis



Inference / Conclusion from the Data

From the graph, it appears that we cannot narrow down the cause to any shift/operator/machine

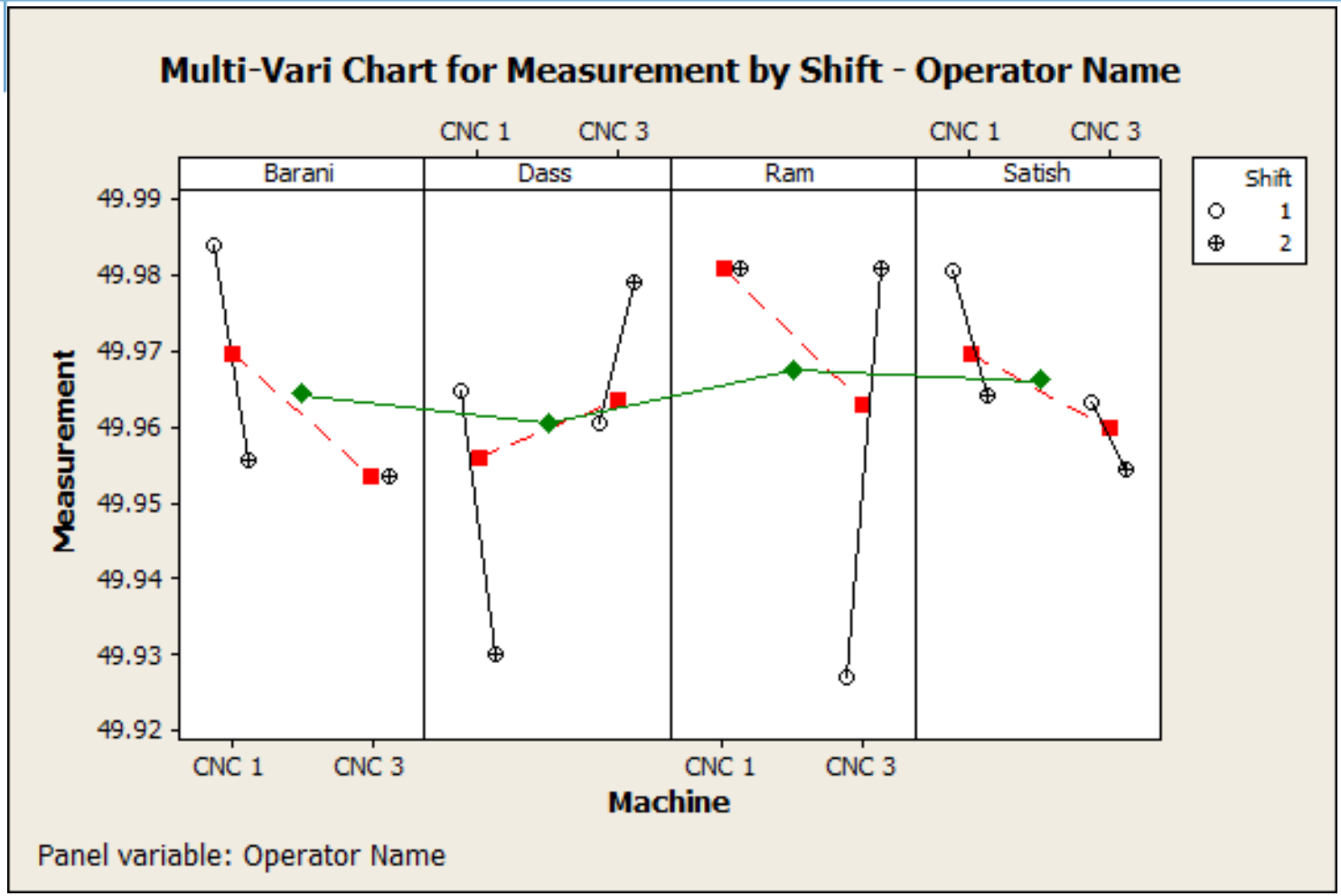
In Process Rejections (OD) Analysis



Inference / Conclusion from the Data

Offset issue seems to be primary reason for OD variation, and it appears to happen across shifts/machines.

In Process Rejections (OD) Analysis



Inference / Conclusion from the Data

From the graph, it appears that we cannot narrow down the cause to shift/operator/machine

Hypothesis test - ANOVA
To chk Impact of Machine, Operator, Shifts

General Linear Model: Measurement versus Shift, Machine, Operator Name

Factor	Type	Levels	Values
Shift	fixed	2	1, 2
Machine	fixed	2	CNC 1, CNC 3
Operator Name	fixed	4	Barani, Dass, Ram, Satish

Analysis of Variance for Measurement, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Shift	1	0.0001024	0.0003548	0.0003548	0.49	0.489
Machine	1	0.0003842	0.0003680	0.0003680	0.51	0.481
Operator Name	3	0.0004115	0.0004115	0.0001372	0.19	0.902
Error	28	0.0202134	0.0202134	0.0007219		
Total	33	0.0211114				

S = 0.0268683 R-Sq = 4.25% R-Sq(adj) = 0.00%

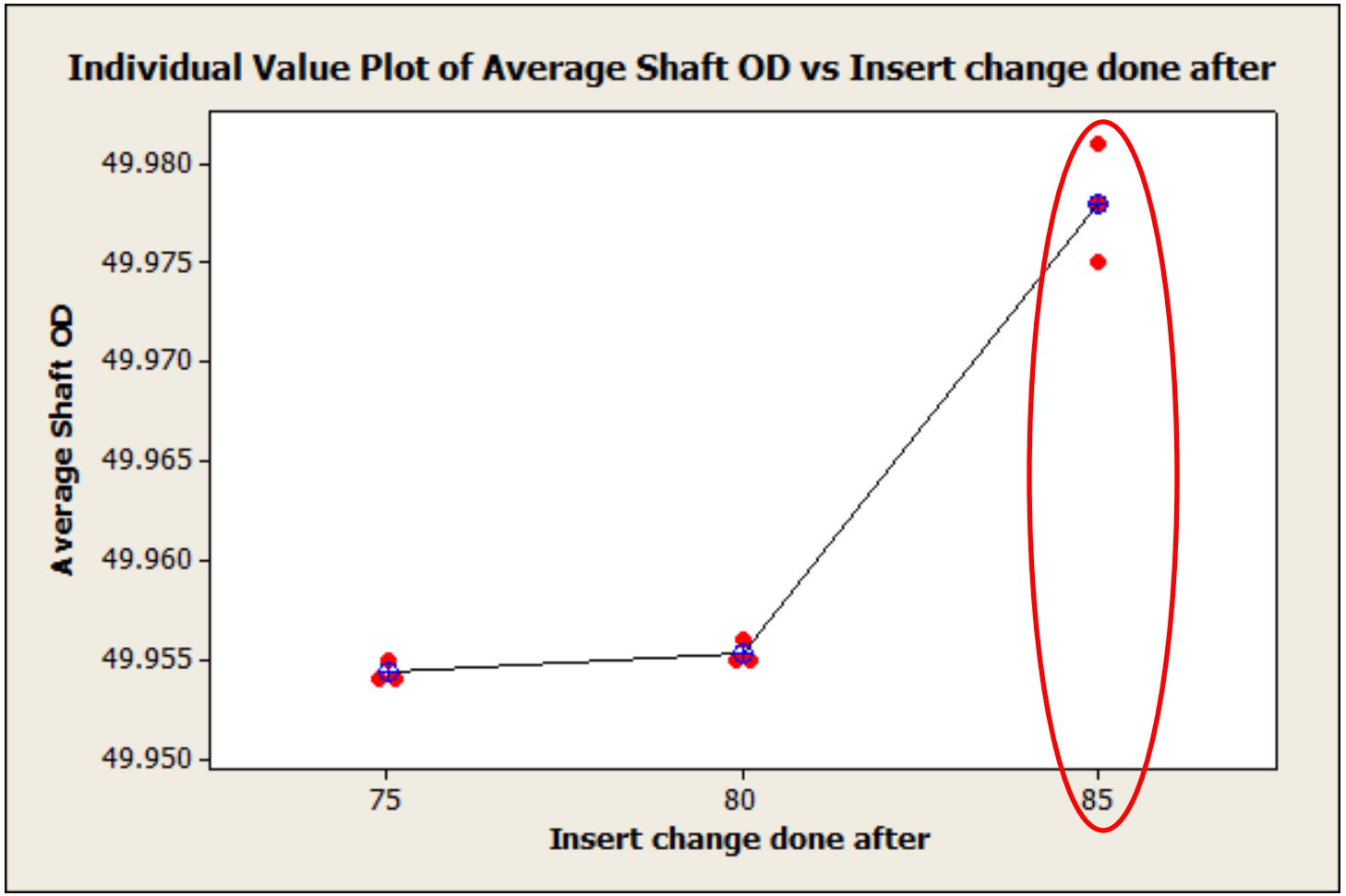
Inference / Conclusion from the Data

Cannot narrow down the cause to shift/operator/machine, since P-Value > 0.05, Accept Ho, there is no significant impact of Shift, Machine, Operator

Raw Data - One way Anova

Running Sequence of Components	Average Shaft OD
75-80	49.954
80-85	49.955
85-90	49.975
75-80	49.955
80-85	49.955
85-90	49.981
75-80	49.954
80-85	49.956
85-90	49.978

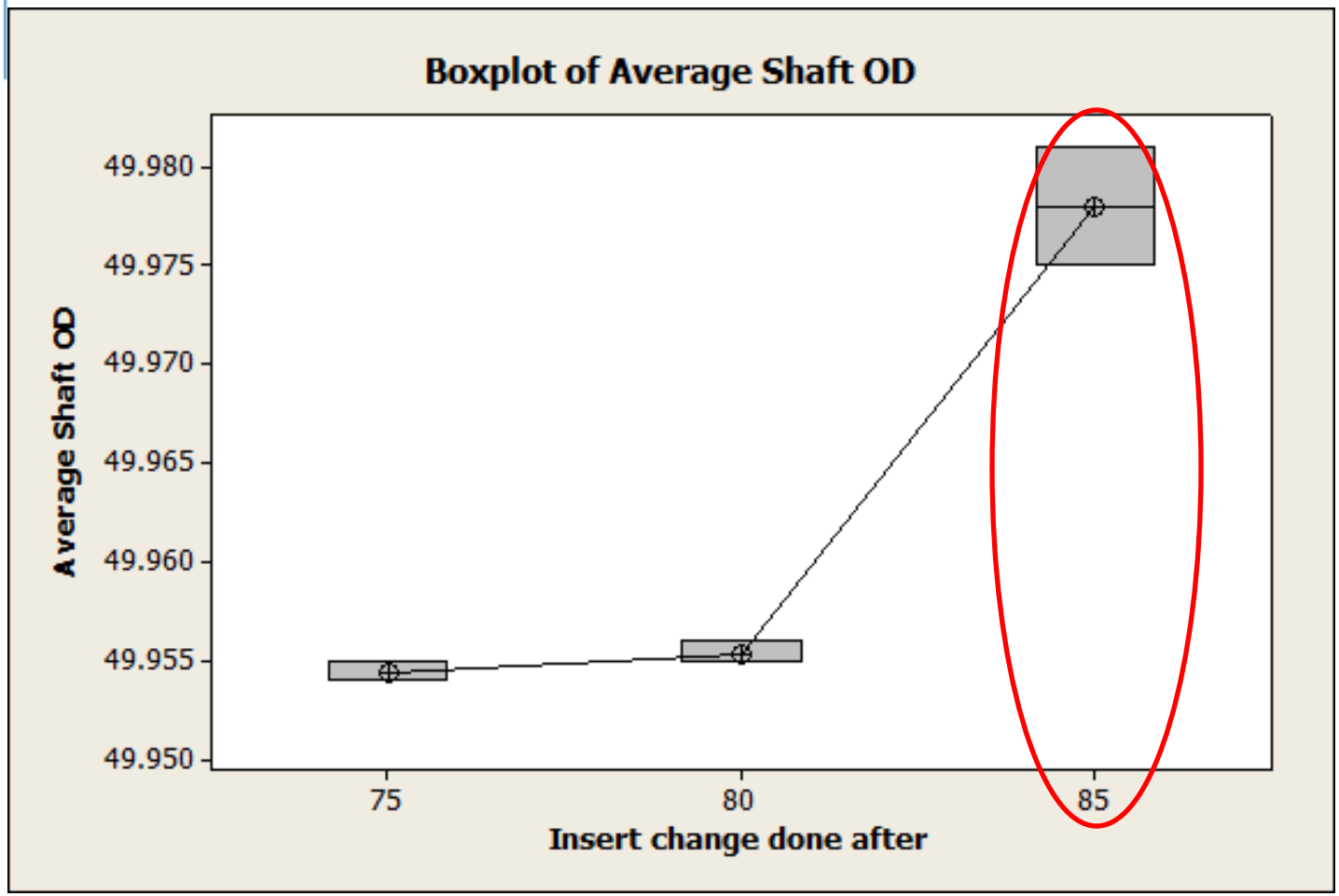
Individual Value Plot



Inference / Conclusion from the Data

There is significant shift in the average value between 80-85 component readings

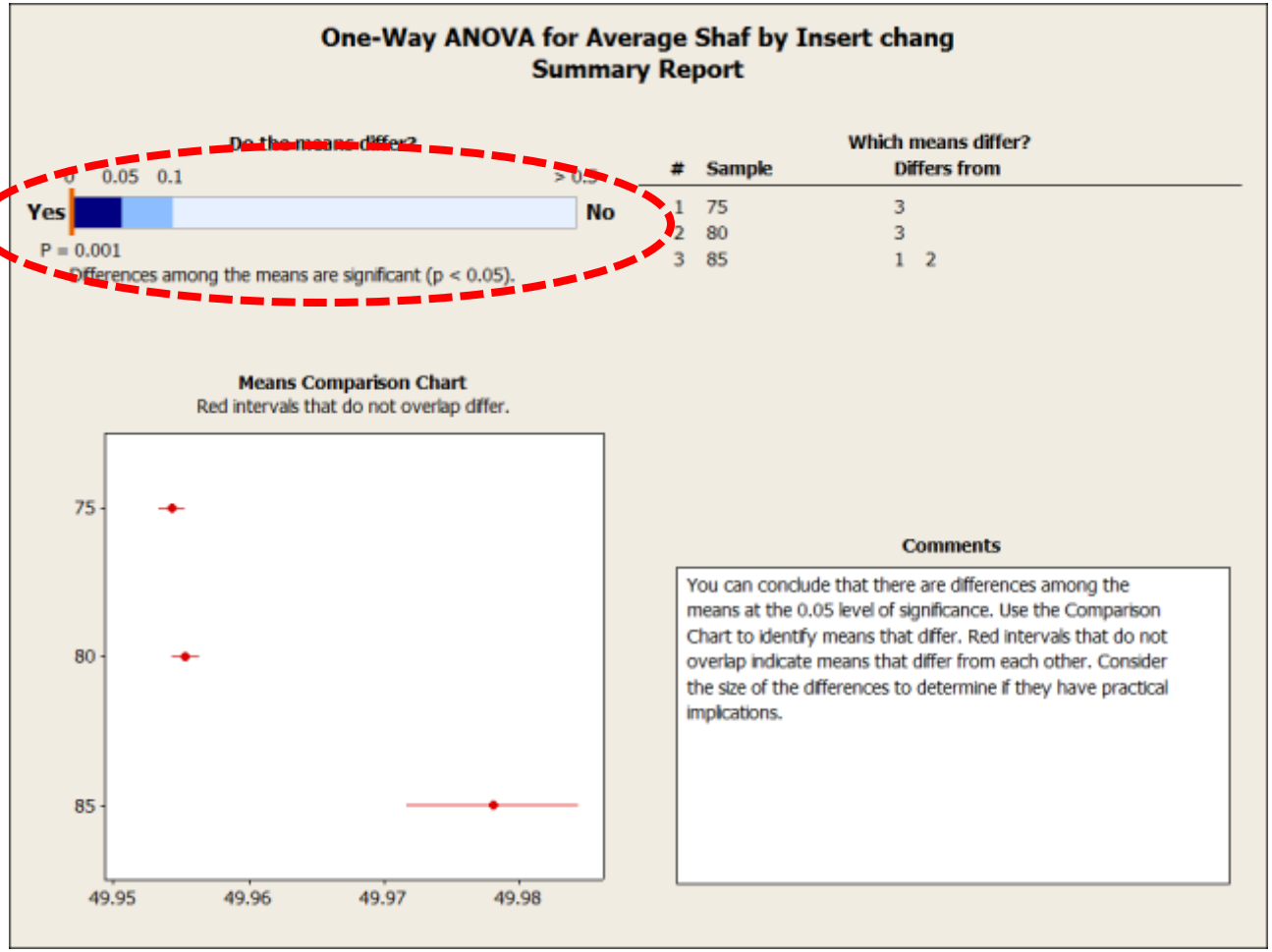
Box Plot



Inference / Conclusion from the Data

There is significant change in the average value between 80-85 component readings.

Hypothesis Test - One way Anova



Inference / Conclusion from the Data

Since P-Value < 0.05, Accept Ha, Atleast one of the sample is different

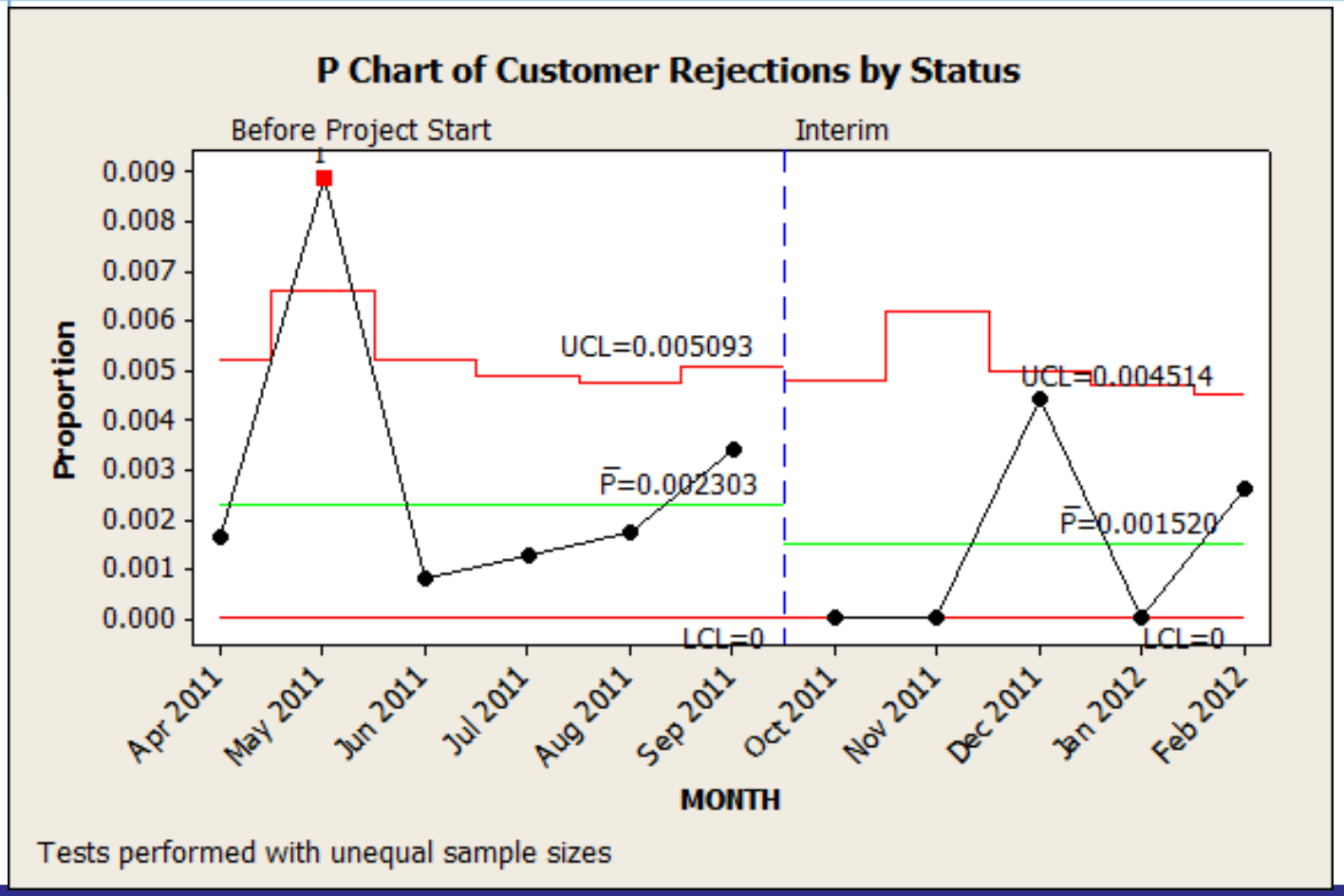
Brainstorming - Outcome

✓ Inability to identify **Insert worn out**, leads to oversized components;
✓ Inability to set the **right offset** after tool change, leads to undersized components;
✓ Currently **no mechanism** to keep track of the number of components that are processed for that operation;
✓ Currently **no instruction** to the operator, as to when to change the insert for 1st operation. Onus is on the operator to keep track and also monitor the dimension of the components and then change the insert accordingly.

Inference / Conclusion from the Data

Output of Brain storming with team members in CFL, Ambattur Plant, Chennai

Attribute P-Chart – Interim Monitoring



Inference / Conclusion from the Data

During the interim period, awareness on LSS project was created to all operators, executives & management staff was created, hence a decreasing trend was visible


Improve

Improvements DONE

✓Modified the **CNC program** to automatically **STOP** the machine after processing **80 numbers** in the 1st operation.

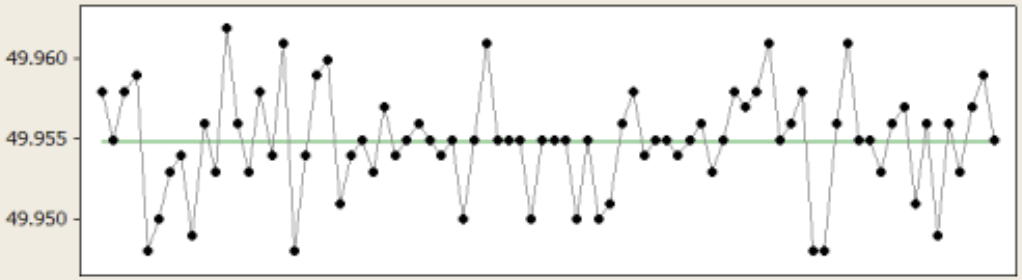
Inference / Conclusion from the Data

Modify the CNC program and then repeat the tests to confirm process capability and study in process rejections

Hypothesis Tests - One-Sample T Test

1-Sample t Test for the Mean of SHAFT OD
Diagnostic Report

Data in Worksheet Order
Investigate outliers (marked in red).



Power
What is the chance of detecting a difference?

For alpha = 0.05 and sample size = 80:
If the true mean differed from the target by 0.00081207 in either direction, you would have a 60% chance of detecting the difference. If it differed by 0.0011894, you would have a 90% chance.

What difference can you detect with a sample size of 80?

Difference	Power
0.00081207	60.0
0.00091154	70.0
0.0010280	80.0
0.0011894	90.0

Power is a function of the sample size and the standard deviation. To detect a difference smaller than 0.0010280, consider increasing the sample size.

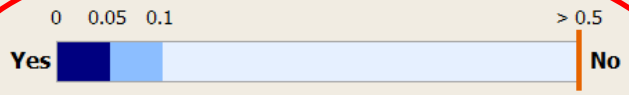
Inference / Conclusion from the Data

The mean of the sample data (after improvement) remains close to the expected mean 49.955

Hypothesis Tests - One-Sample T Test

1-Sample t Test for the Mean of SHAFT OD
Summary Report

Does the mean differ from 49.955?



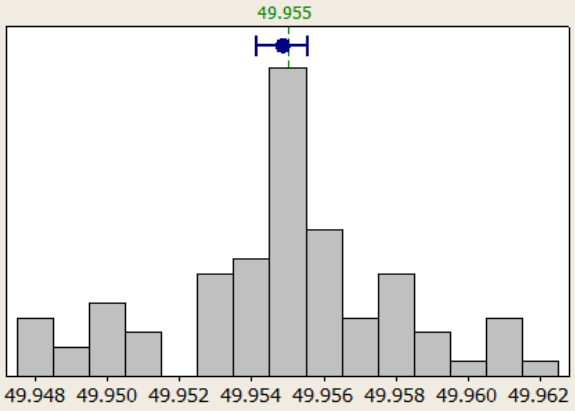
P = 0.680

The mean of SHAFT OD is not significantly different from the target (p > 0.05).

Statistics

Sample size	80
Mean	49.955
95% CI	(49.954, 49.956)
Standard deviation	0.0032417
Target	49.955

Distribution of Data
Where are the data relative to the target?



Comments

-- Test: There is not enough evidence to conclude that the mean differs from 49.955 at the 0.05 level of significance.
-- CI: Quantifies the uncertainty associated with estimating the mean from sample data. You can be 95% confident that the true mean is between 49.954 and 49.956.
-- Distribution of Data: Compare the location of the data to the target. Look for unusual data before interpreting the test results.

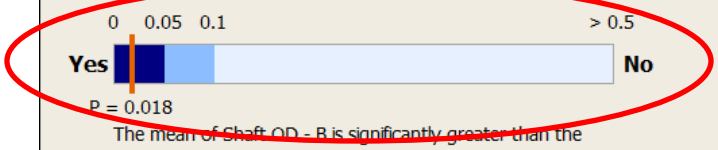
Inference / Conclusion from the Data

Since P-Value > 0.05, there is no significant difference between the Shaft OD actuals and Target

Hypothesis Tests - Two-Sample T Test for Data before and after improvement

2-Sample t Test for the Mean of Shaft OD - B and Shaft OD - A
Summary Report

Mean Test
Is Shaft OD - B greater than Shaft OD - A?



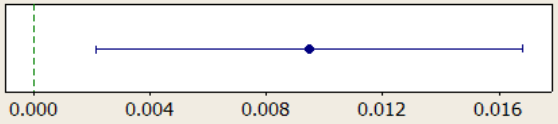
P = 0.018

The mean of Shaft OD - B is significantly greater than the mean of Shaft OD - A ($p < 0.05$).

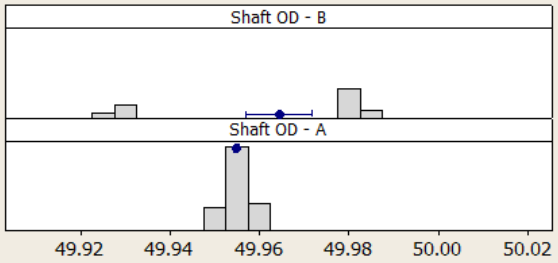
Statistics	Shaft OD - B	Shaft OD - A
Sample size	34	80
Mean	49.964	49.955
90% CI	(49.96, 49.97)	(49.954, 49.955)
Standard deviation	0.025293	0.0032417

Difference between means* 0.0094735
90% CI (0.0021069, 0.016840)
* The difference is defined as Shaft OD - B - Shaft OD - A.

90% CI for the Difference
Does the interval include zero?



Distribution of Data
Compare the data and means of the samples.



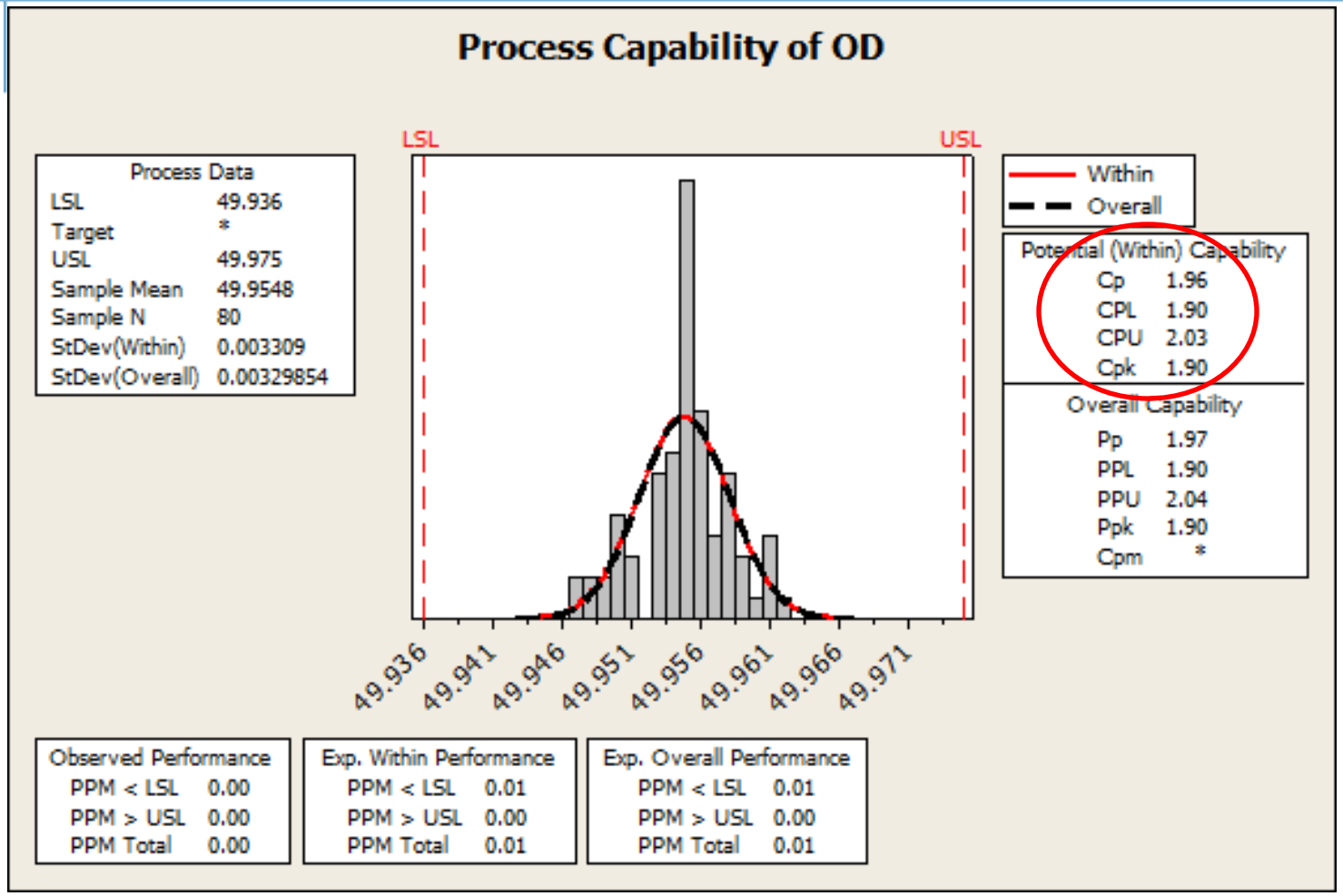
Comments

-- Test: You can conclude that the mean of Shaft OD - B is greater than Shaft OD - A at the 0.05 level of significance.
-- CI: Quantifies the uncertainty associated with estimating the difference from sample data. You can be 90% confident that the true difference is between 0.0021069 and 0.016840.
-- Distribution of Data: Compare the location and means of samples. Look for unusual data before interpreting the results of the test.

Inference / Conclusion from the Data

Since P-Value < 0.05, Accept Ha, there is significant difference between Before Vs After

Process Capability – OD Variations - After Improvement



Inference / Conclusion from the Data

Cpk > 1.67, finishing 1st operation process is capable

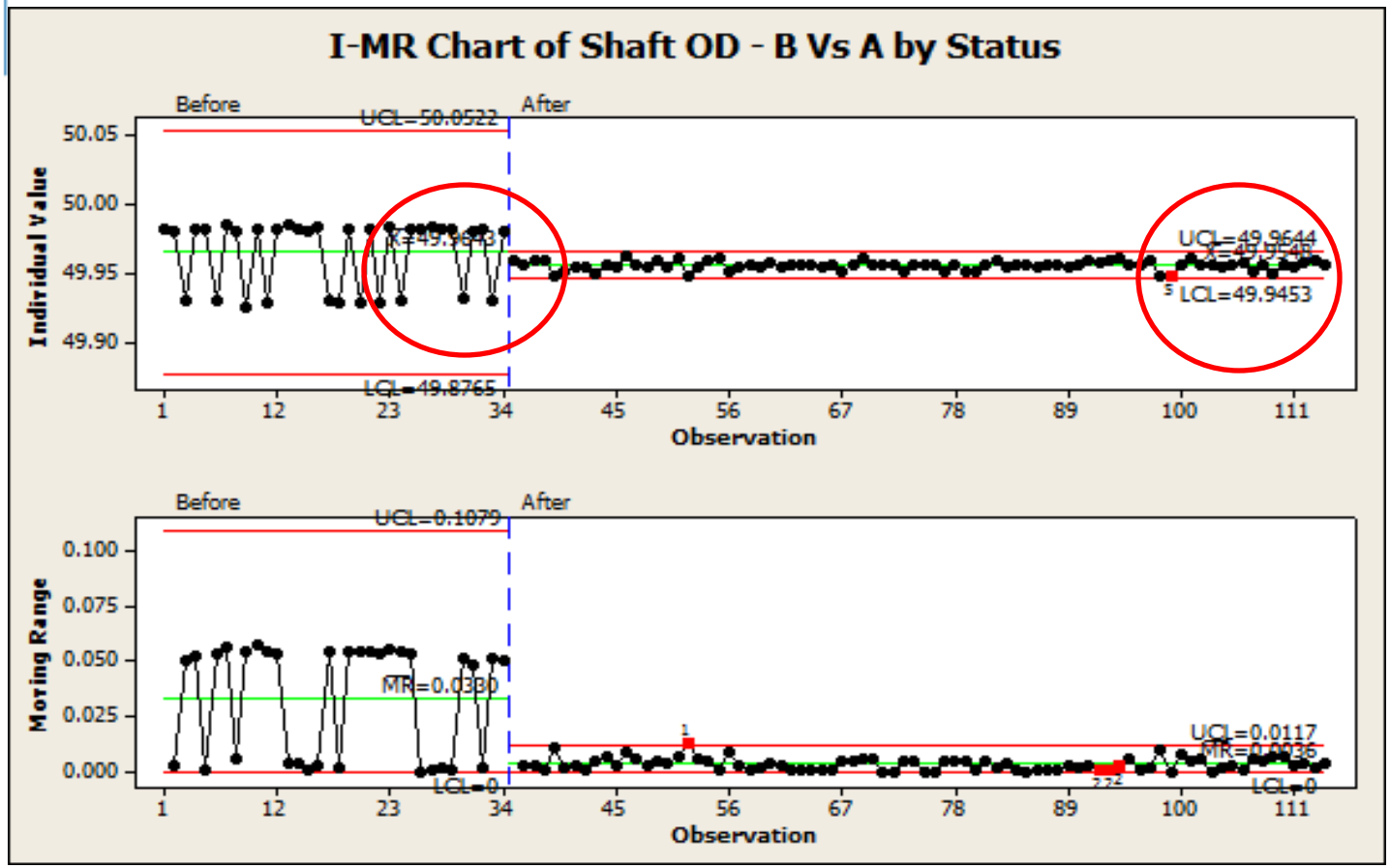
FMEA - After Improvement

Process Function / Requirements	Potential Failure Mode	Potential Effect(s) of Failure	SEV	CLA	Potential Cause(s) / Mechanism(s) of Failure	OCC	Current Process Controls Prevention	Current Process Controls Detection	DET	R.P.N.	Recommended Action(s)	Responsibility & Target Completion Date	Action Results: Actions Taken	Sev	Occ	Det	R.P.N.
30.CNC FINISHING 2nd OPERATION	Run out 0.1 variation	Assembly Fitment Problem at customer end	6		Improper loading	4	Trained operator	Line Inspection Report	3	72	Taper Mandrel used to check down the Run Out Variation using Dial Gauge	P.Rakku muthu	12/15/2012	6	3	2	36

Inference / Conclusion from the Data

RPN number reduced after intervention

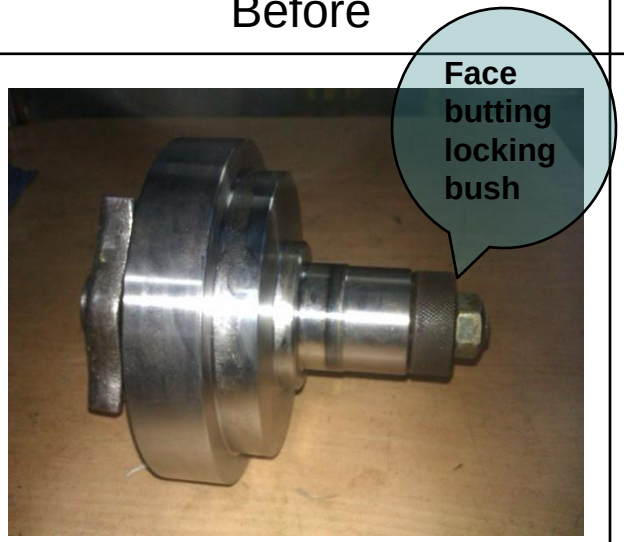
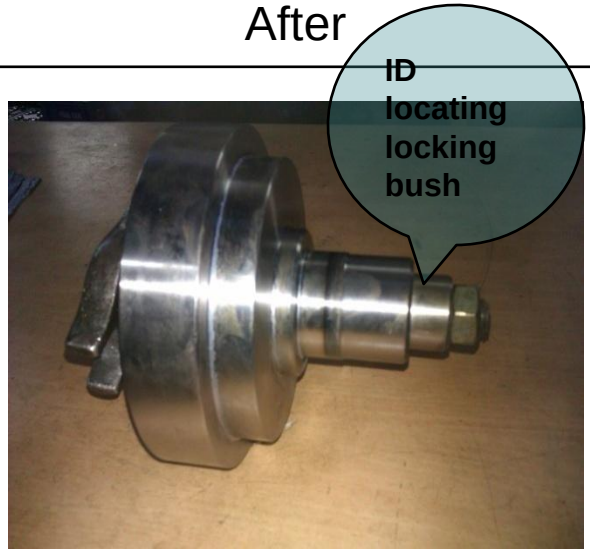
Control Charts – Before Vs After



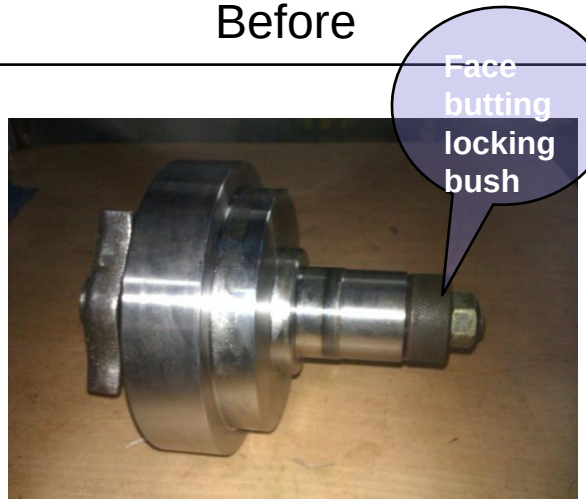
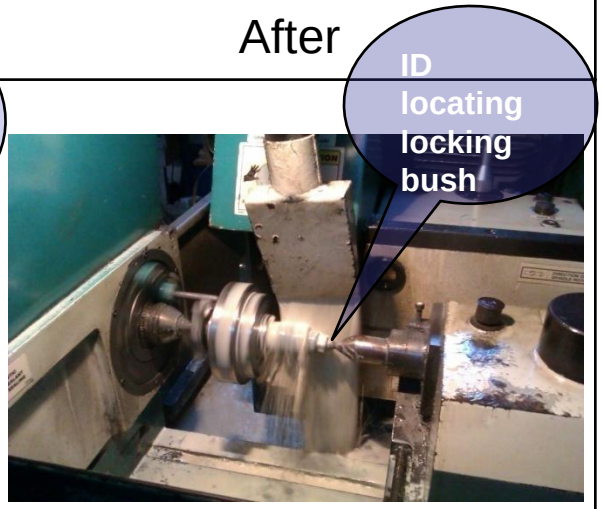
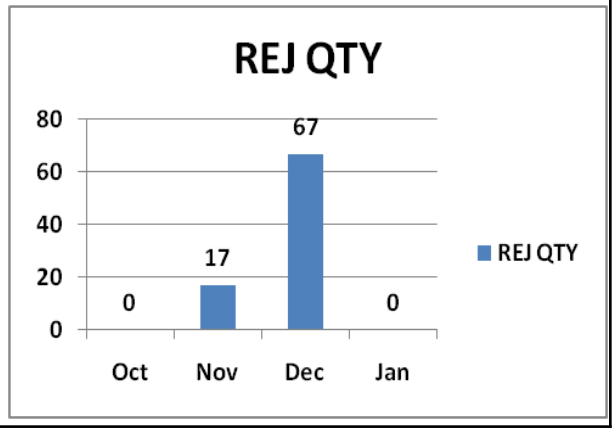
Inference / Conclusion from the Data

Shaft OD size variation reduced drastically

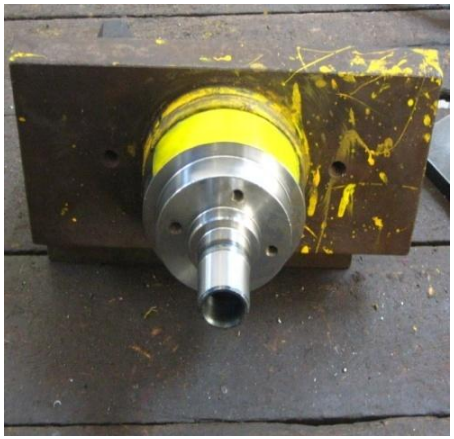
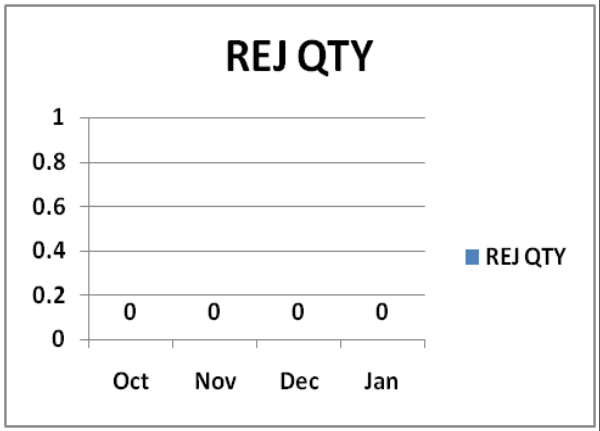
Improvements

Problem Description	Before	After
Flange Coupling excess concentricity		
Root Cause	**Implementation Details**	**Trend**
1. Face butting locking bush used in grinding operation, caused variations in the run out. 2. Measuring the run out with the current locking bush didn't give repeatability.	1. Replaced the existing locking bush with ID locating locking bush with taper. 2. We were able to achieve the required repeatability with this change.	

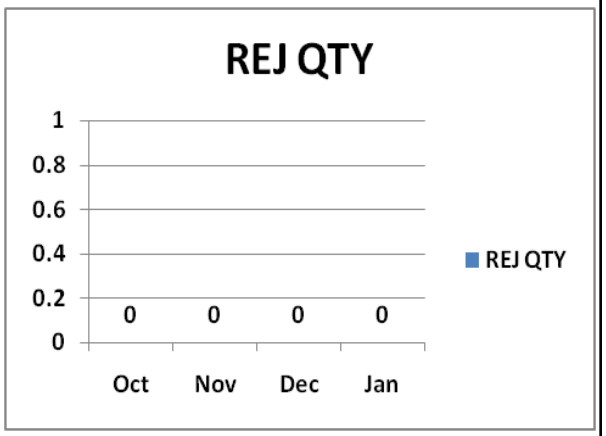
Improvements

Problem Description	Before	After
Flange Coupling excess concentricity		
Root Cause	**Implementation Details**	**Trend**
	3. During final inspection after key way operation, run out is 100% checked and readings noted and sent to AL. 4. Implementation date: **17/12/2011**	

Improvements

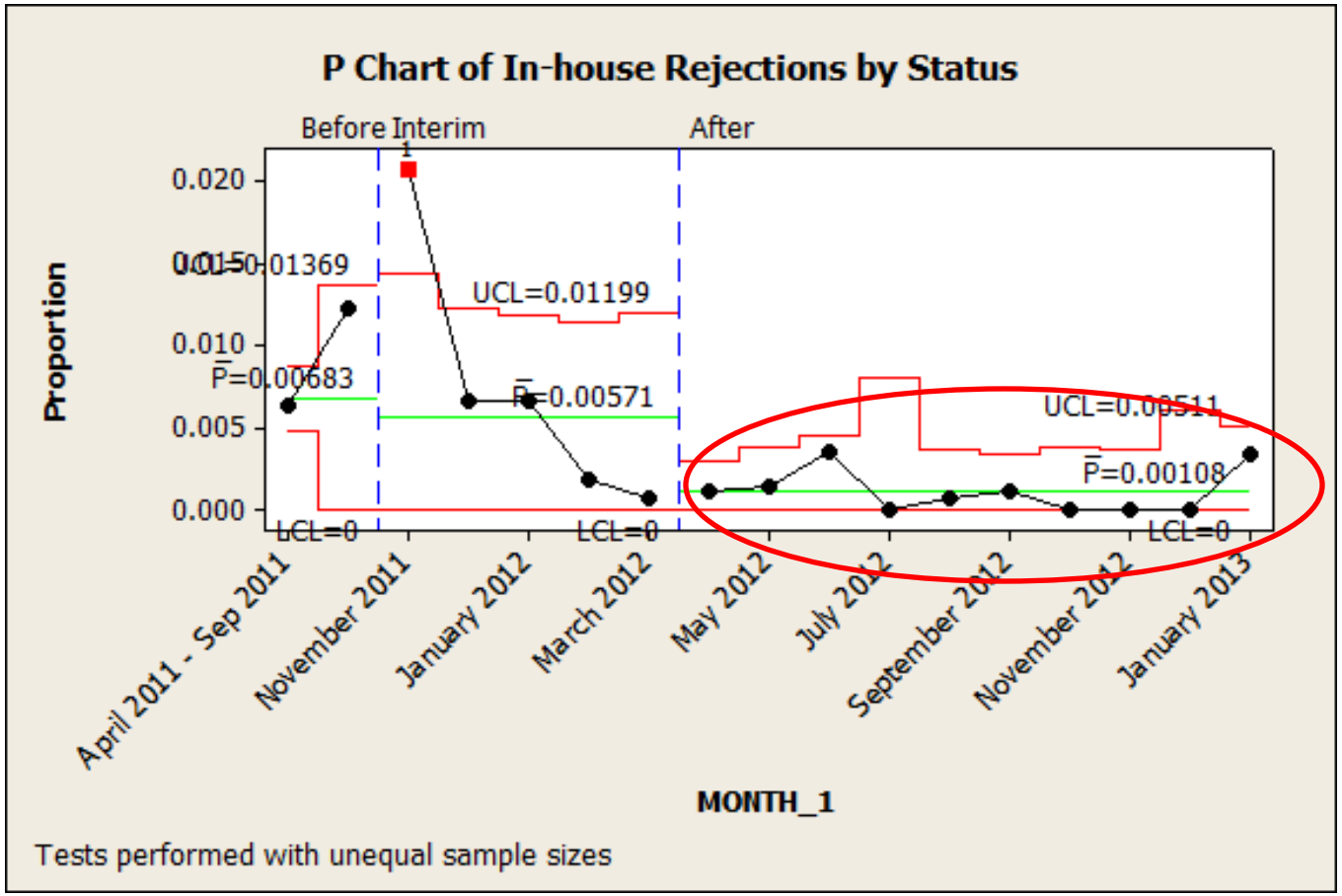
Problem Description	Before	After
Flange Coupling Painting Issue		
Root Cause	**Implementation Details**	**Rejections Trend**
MANUAL PAINTING DONE WITHOUT FIXTURE	PAINTING DONE WITH THE HELP OF FIXTURE (KEY WAY LOCATION) Implementation Date: 10/08/2011	

Improvements

Problem Description	Before	After
Flange Coupling Damage Issue	Components handled in open bins	
Root Cause	Implementation Details	Rejections Trend
Internal movement of components in open bins	Introduced plastic bins with partition exclusively for Flange Coupling. Also introduced wooden boxes for dispatch to AL Implementation Date: 15/09/2011	


Control

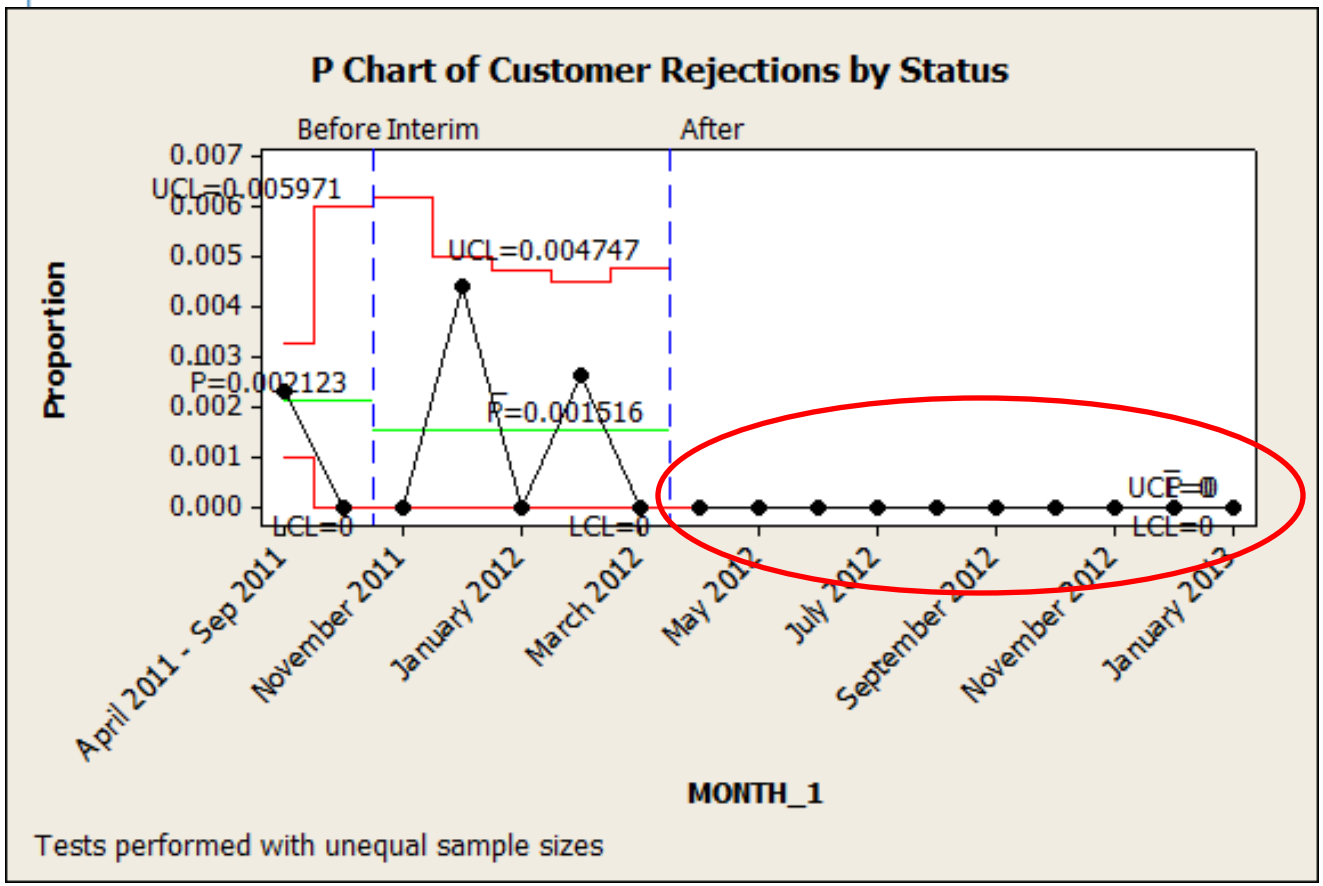
Control Chart – Before Vs After – In-House



Inference / Conclusion from the Data

Before the project, PPM was 6830, In the interim period PPM reduced to 5,710, while after project completion in March 2012 PPM reduced to 1080

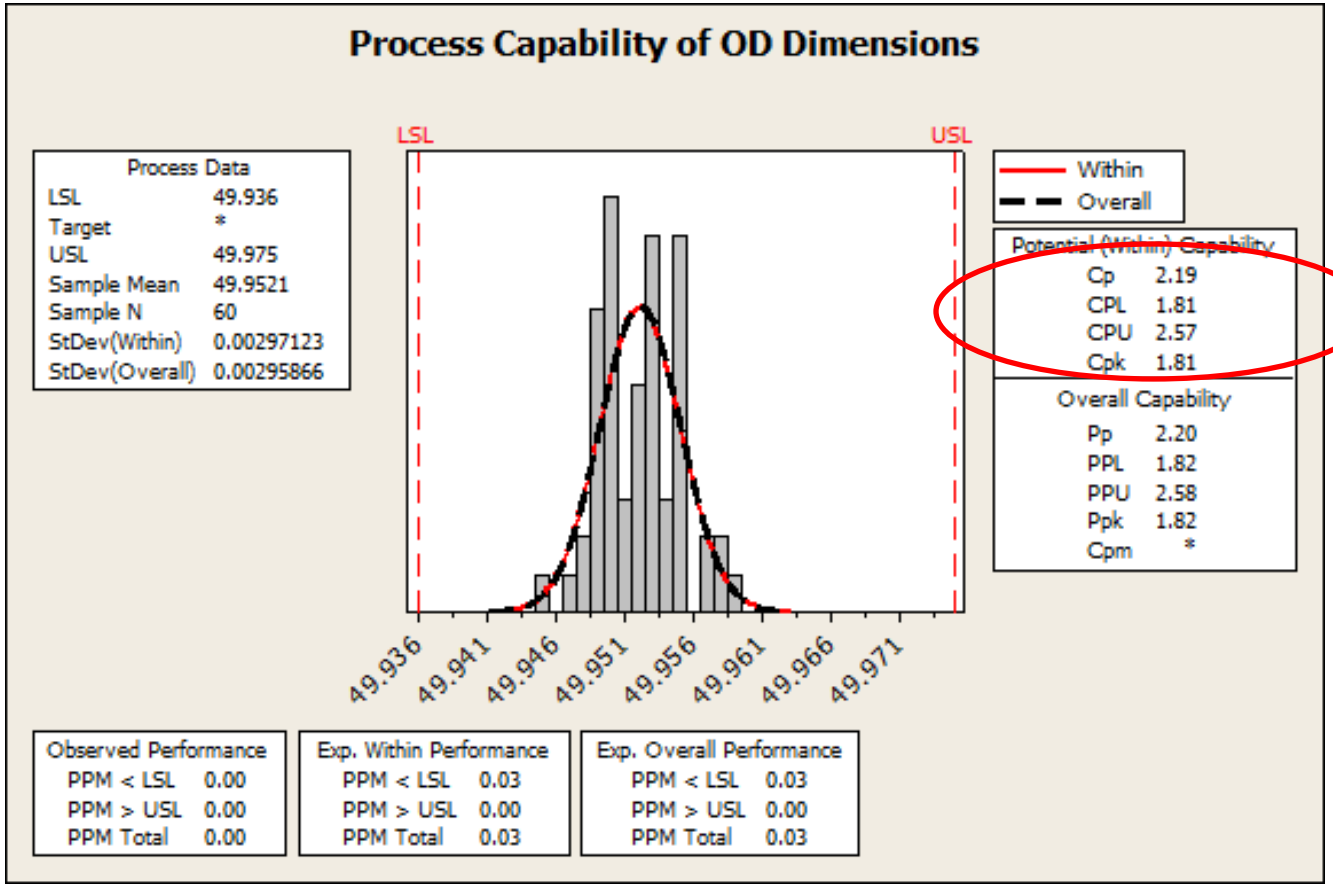
Control Chart – Before Vs After – Customer End



Inference / Conclusion from the Data

Before Project, Customer PPM was 2120 and In the interim period PPM decreased to 1516, while after project completion in March 2012, PPM reduced to Zero.

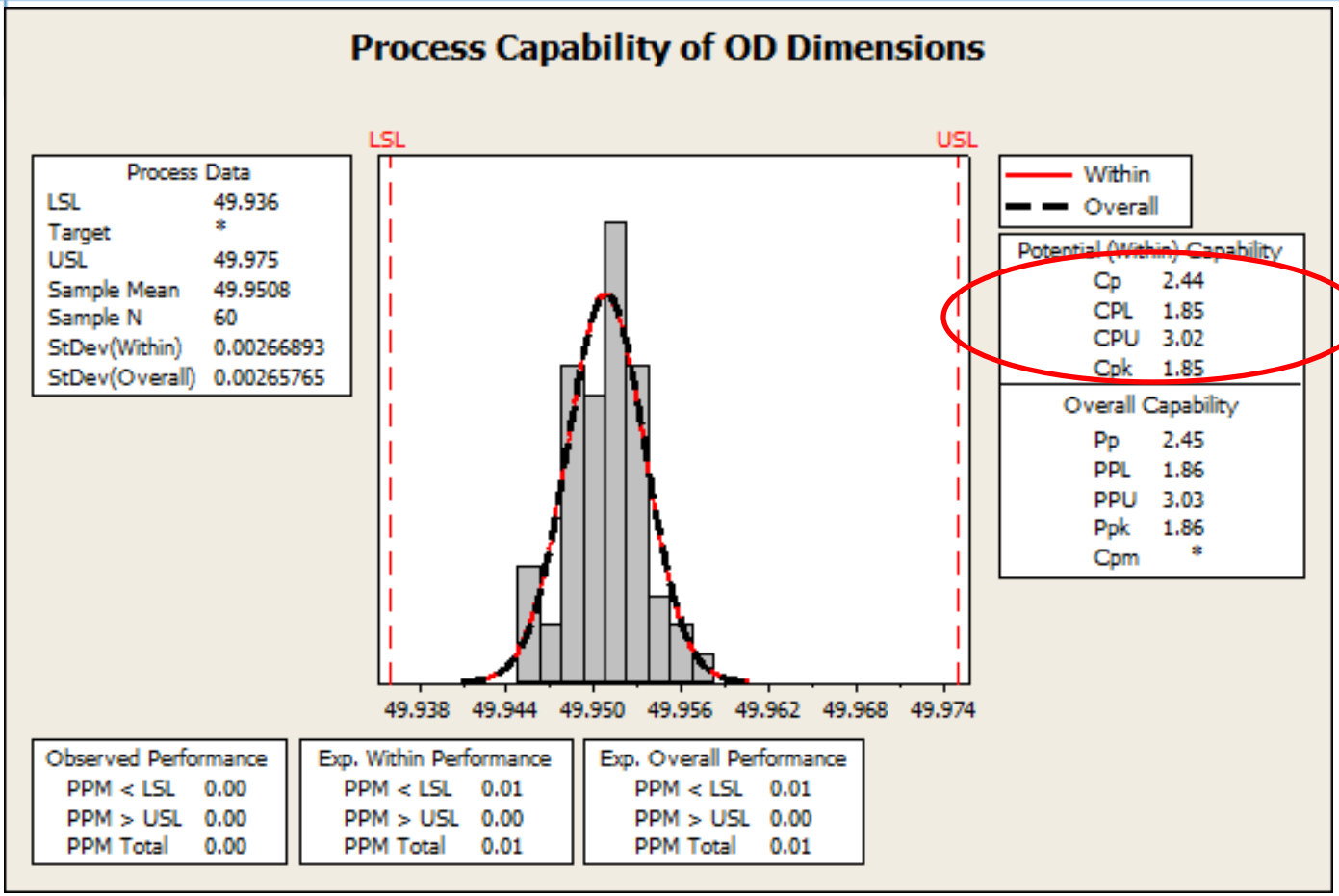
Sustenance of Cp, Cp_k April 2012



Inference / Conclusion from the Data

Process is controlled well within the limits.

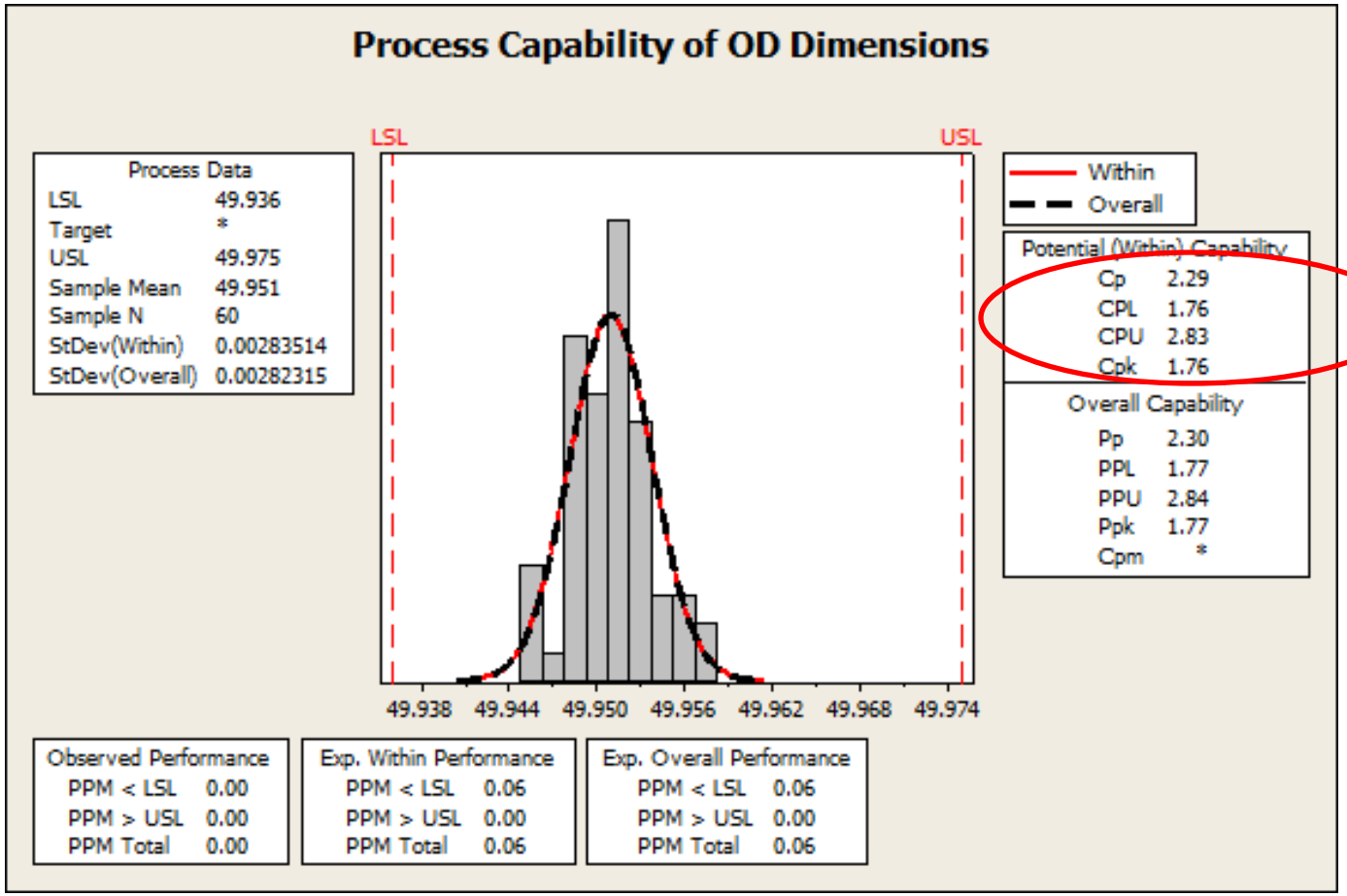
Sustenance of Cp, Cp_k
June 2012



Inference / Conclusion from the Data

Process is controlled well within the limits.

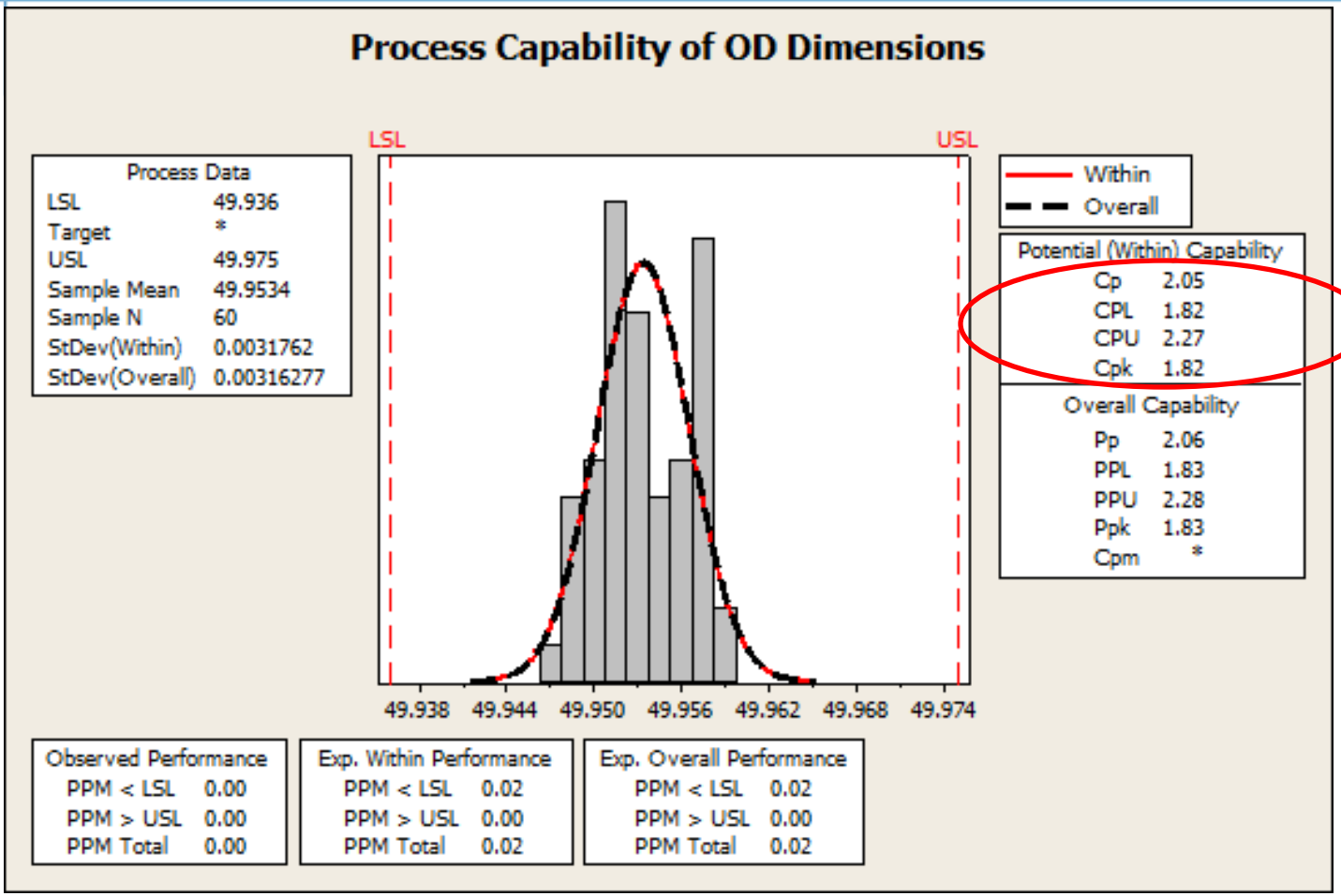
Sustenance of Cp, Cp_k Aug 2012



Inference / Conclusion from the Data

Process is controlled well within the limits.

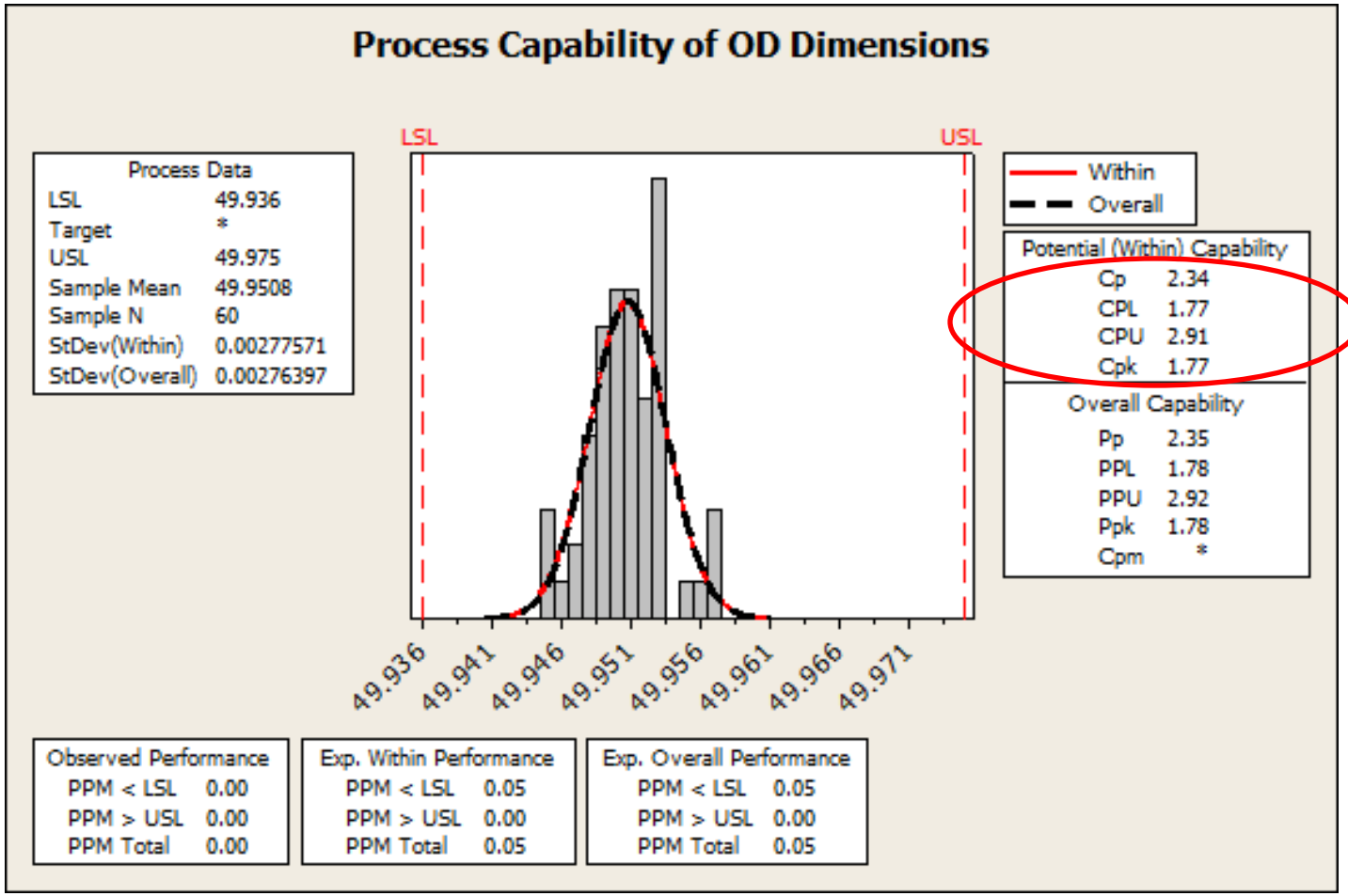
Sustenance of Cp, Cp_k Sep 2012



Inference / Conclusion from the Data

Process is controlled well within the limits.

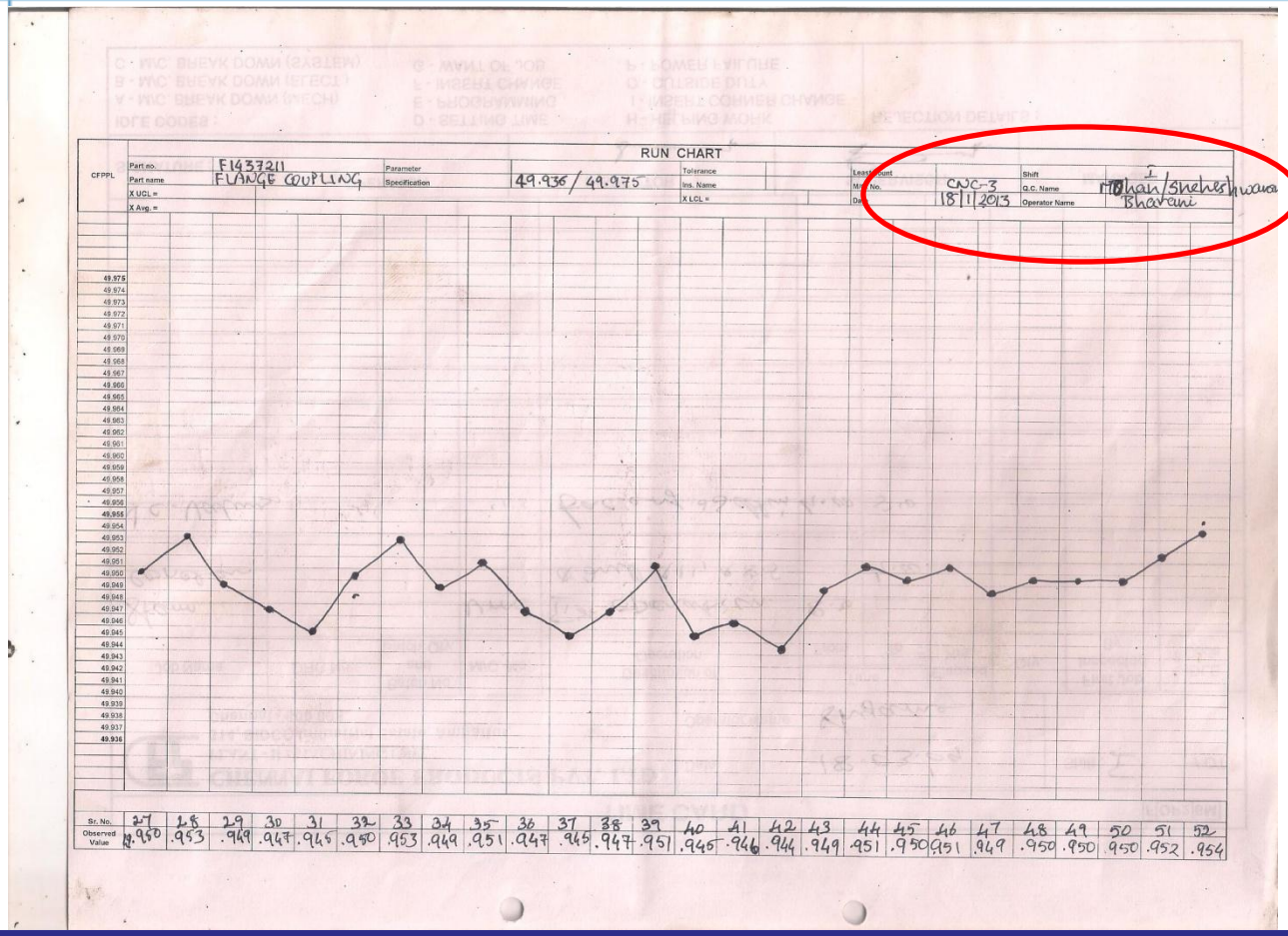
Sustenance of Cp, Cp_k Nov 2012



Inference / Conclusion from the Data

Process is controlled well within the limits.

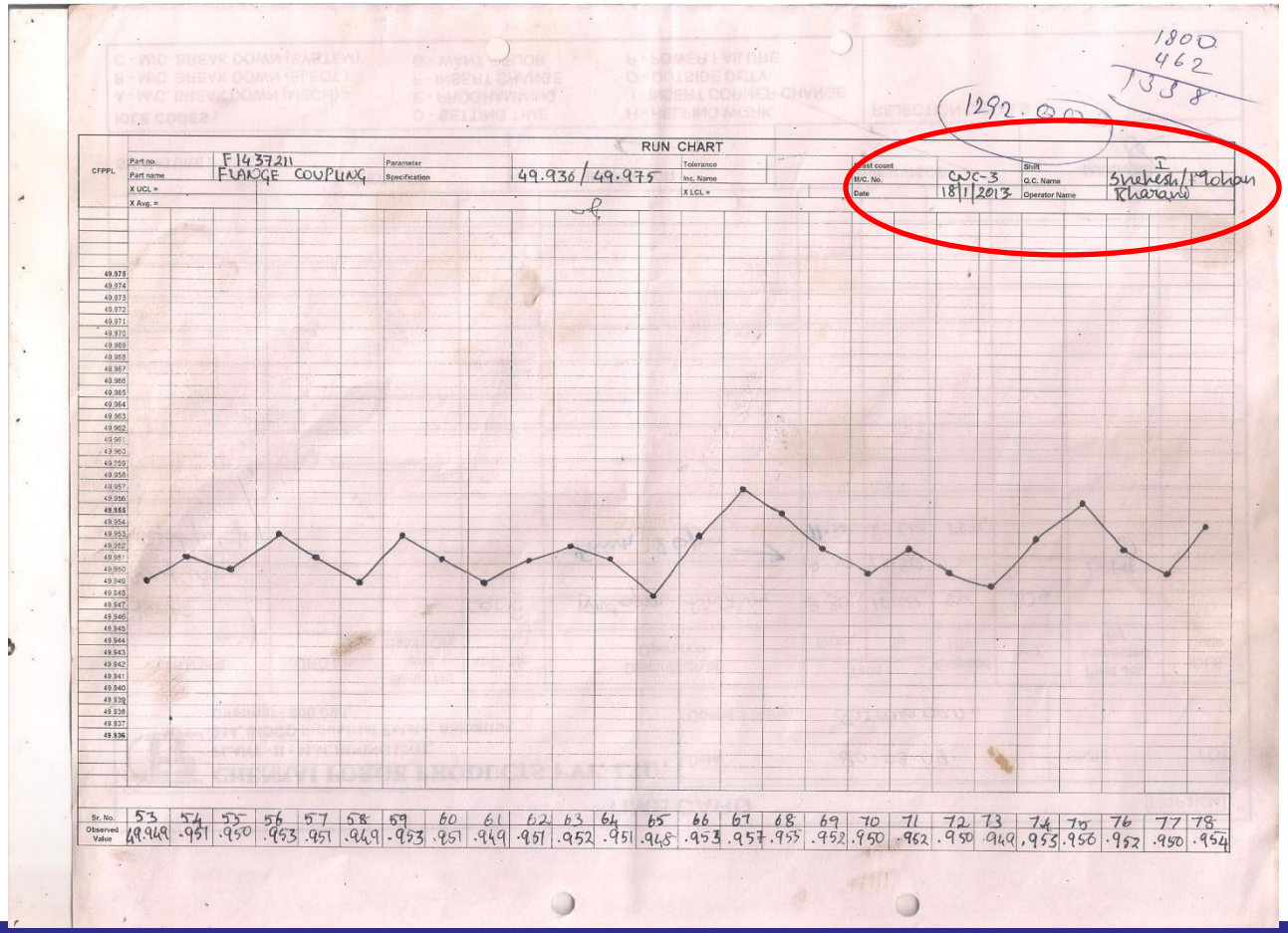
Monitoring of Critical Characteristic



Inference / Conclusion from the Data

Process is controlled well within the limits.

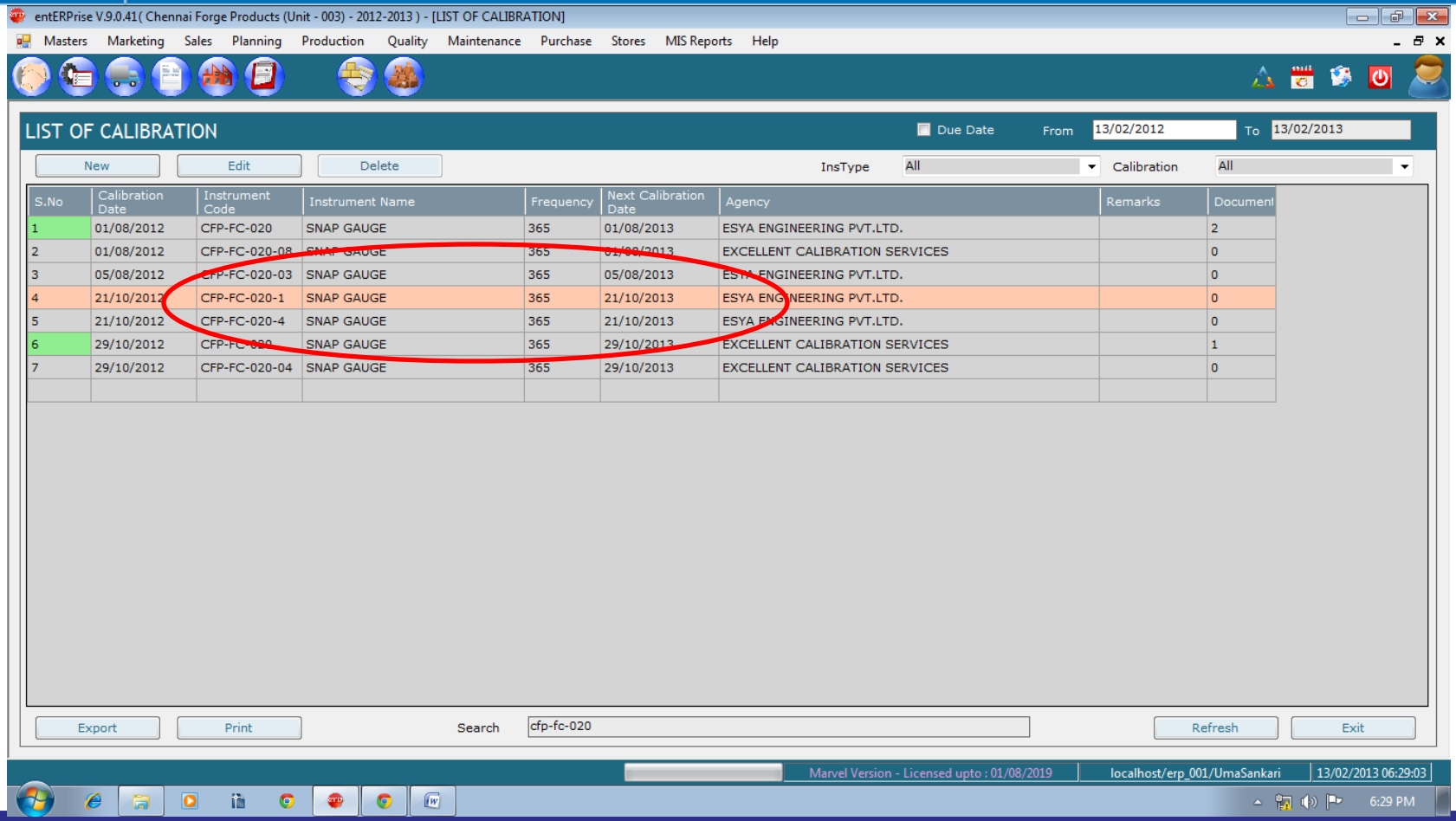
Monitoring of Critical Characteristic



Inference / Conclusion from the Data

Process is controlled well within the limits.

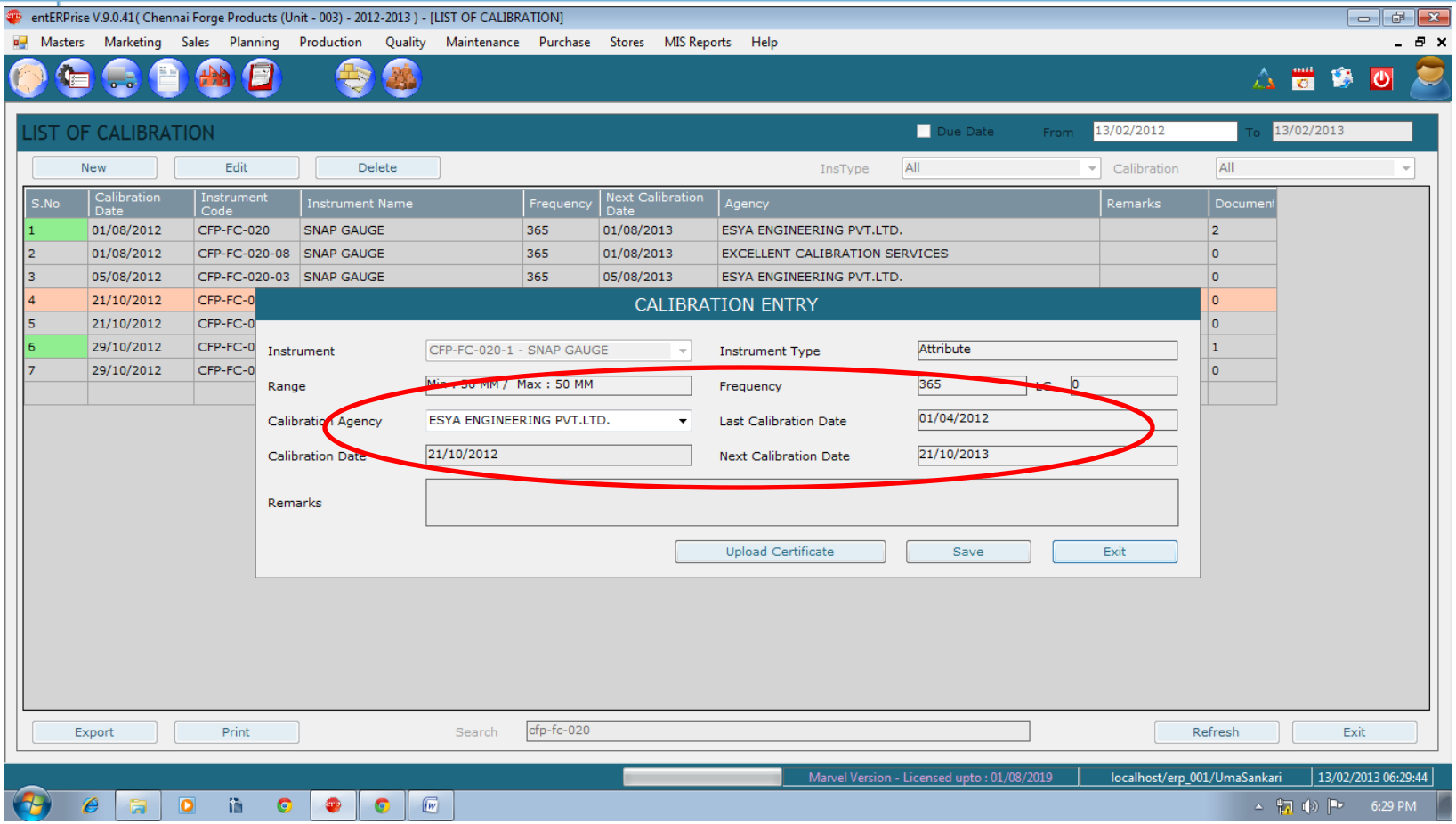
System (ERP) to maintain Gauge/Instrument Calibration data



Inference / Conclusion from the Data

Automated System to indicate gauge calibration alerts and maintain data

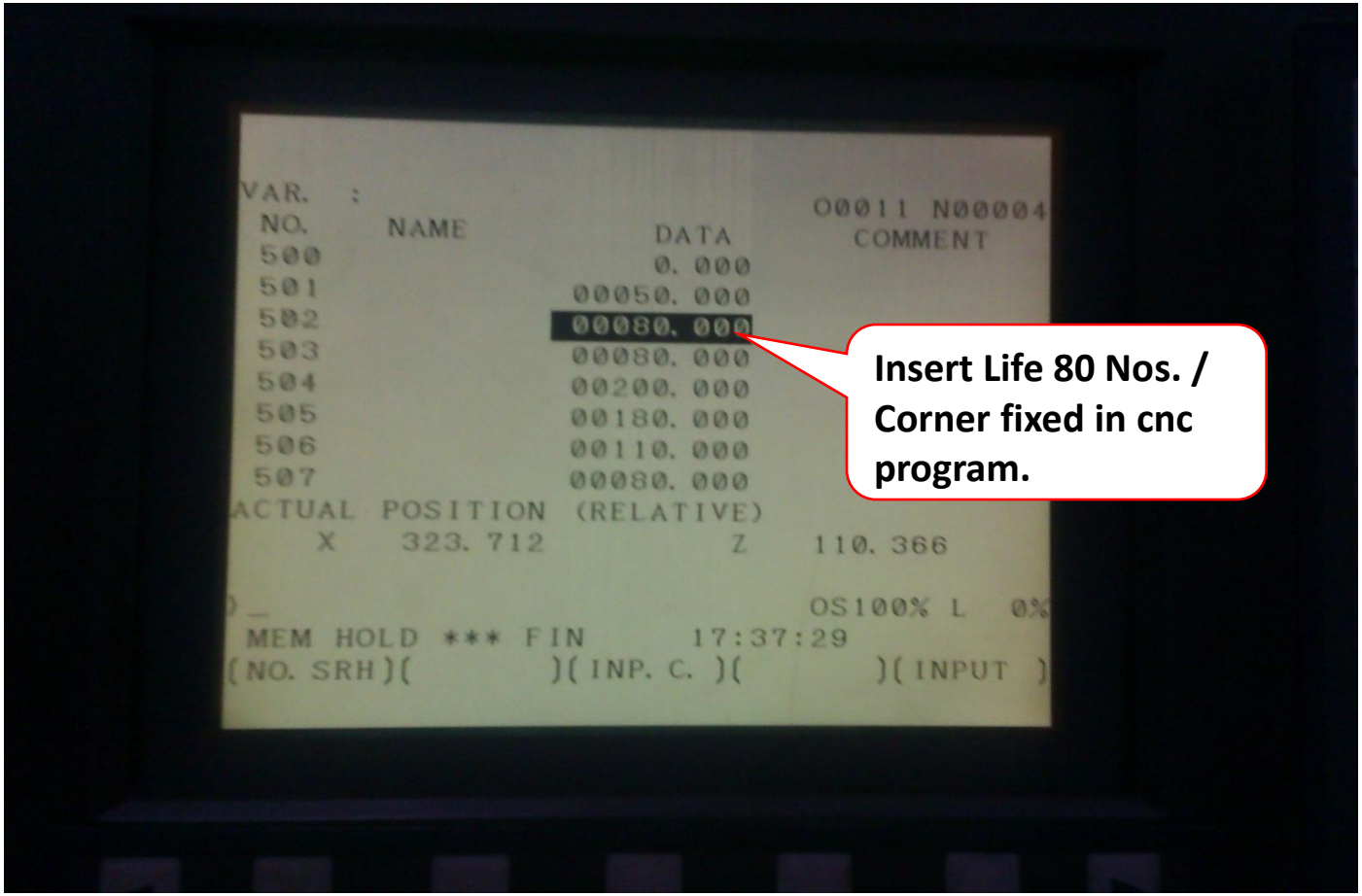
System (ERP) to maintain Gauge/Instrument Calibration data



Inference / Conclusion from the Data

Automated System to indicate gauge calibration alerts and maintain calibration data

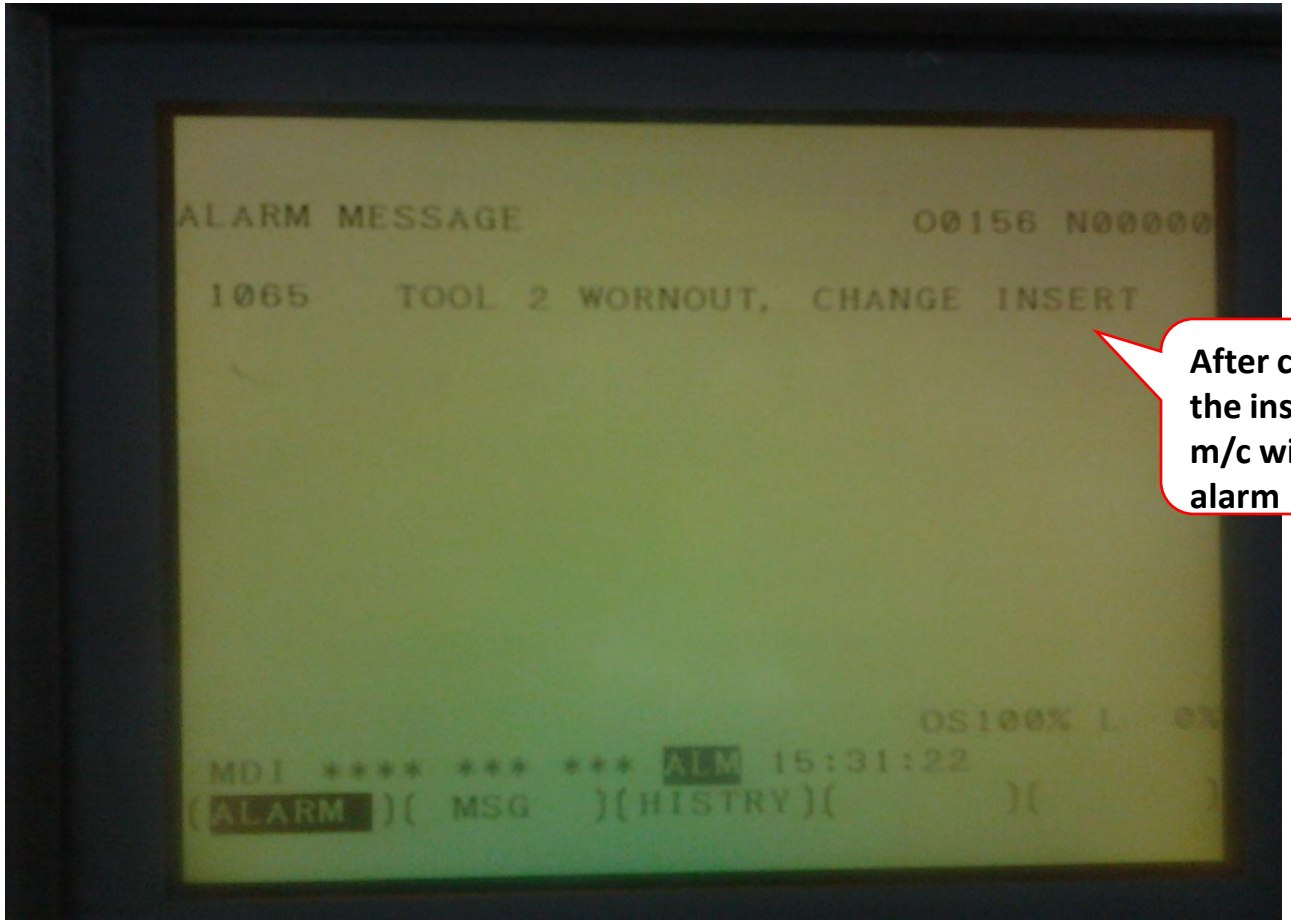
Mistake Proofing at CNC Machine Level



Inference / Conclusion from the Data

The count of 80 nos mentioned in the CNC Program for Full Finishing First Operation

Mistake Proofing at CNC Machine Level – ALARM MESSAGE

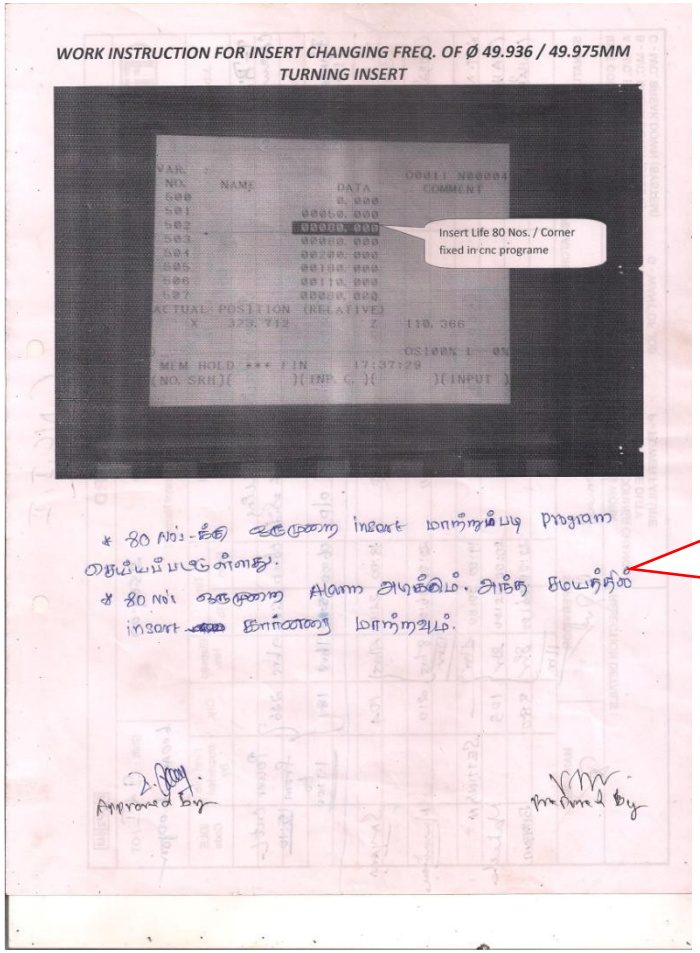


After completion of the insert life, CNC m/c will raise an alarm

Inference / Conclusion from the Data

ALARM MESSAGE instructing the operator to change the Insert Corner

Mistake Proofing at CNC Machine Level – ALARM MESSAGE

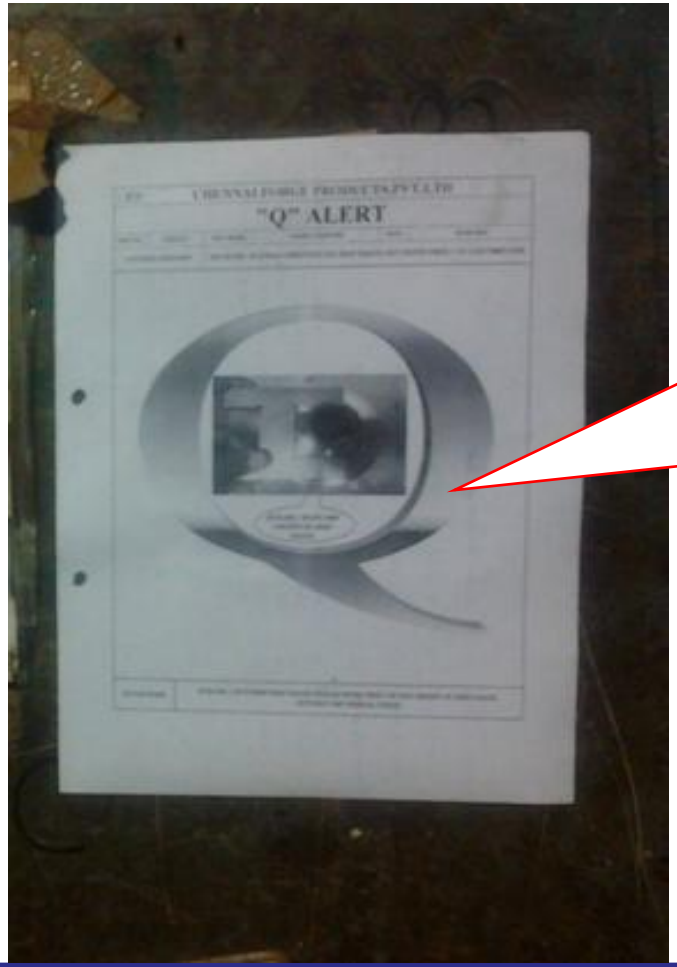


Work Instructions in local language for the operator

Inference / Conclusion from the Data

Work Instruction in local language for the operator

Work Instructions at CNC Machine Level – Full Finishing First Operation



'Q' ALERT DISPLAYED ON CNC M/C FOR CHECKING THE DIA 49.936 / 49.975MM BY SNAP GAUGE

Inference / Conclusion from the Data

Visual Control – Quality Alert displayed to check the diameter with Snap Gauge

Control Plan

PROTO TYPE ☐ PRE-LAUNCH ☐ PRODUCTION ■			**CONTROL PLAN**	
CONTROL PLAN NUMBER : 002	Key Contact/Phone : M.Sukumar 9444904212 / A. Senthil kumar - 9444757321		DATE (ORIG) : 22.09.2007	DATE (REV) : 24/11/2011
PART NUMBER / LATEST CHANGE LEVEL : **F 1437211 / HC**	Core Team : M.SUKUMAR / P.RAKKUMUTHU / P.PERUMAL / S.RAJIV GANDHI / S.PREM KARTHICK/B.PREMKUMAR		CUSTOMER ENGINEERING APPROVAL / DATE (IF REQ'D)	
PART NAME : **FLANGE COUPLING**	SUPPLIER / PLANT APPROVAL DATE		CUSTOMER QUALITY APPROVAL / DATE (IF REQ'D)	
SUPPLIER NAME : **CHENNAI FORGE PRODUCTS (P) LTD.,**	OTHER APPROVAL / DATE (IF REQ'D)		OTHER APPROVAL / DATE (IF REQ'D)	

PART / PROCESS NO.	OPERATION NAME & DESCRIPTION OF OPEARATION	MACHINE, DEVICE, JIG, FIXTURE, TOOLS FOR MANAUFACTURE	CHARACTERISTICS	METHODS					REACTION PLAN
			PRODUCT	PRODUCT / PROCESS SPECIFICATION AND TOLERANCE	SPL CHAR	EVALUATION MEASUREMENT TECHNIQUE	SAMPLE SIZE	SAMPLE FREQ	CONTROL METHOD	
10	FORGING DONE AT INHOUSE WITH 70 mm ROD /MATERIAL CK-45	DIE & TOOL USED	AS PER INCOMING INSPECTION PLAN	OUTER DIA 70		VERNIER	5%	EVERY LOT	IIR	INFORM TO SUPPLIER & TAKE IMMEDIATE ACTION FOR REPLACEMENT
				MATERIAL CK-45		VERIFYING MILL TC	5%	EVERY LOT	IR	INFORM TO SUPPLIER & TAKE IMMEDIATE ACTION FOR REPLACEMENT

Control Plan

PART / PROCESS NO.	OPERATION NAME & DESCRIPTION OF OPEARATION	MACHINE, DEVICE, JIG, FIXTURE, TOOLS FOR MANAUFACTURE	CHARACTERISTICS	METHODS						REACTION PLAN
			PRODUCT	PRODUCT / PROCESS SPECIFICATION AND TOLERANCE	SPL CHAR	EVALUATION MEASUREMENT TECHNIQUE	SAMPLE SIZE	SAMPLE FREQ	CONTROL METHOD	
20	FORGING INSPECTION		OUTER DIAMETER	43		VERNIER	5%	EVERY LOT	FIR	QUARANTINE ADJUST & RECHECK
			LENGTH	118						
			OUTER DIAMETER	120						
			OUTER DIAMETER	37						
			OUTER DIAMETER	98						
			OUTER DIAMETER	53						
30	RECEIVING INSPECTION		OUTER DIAMETER	43		VERNIER	5%	EVERY LOT	RIR	QUARANTINE ADJUST & RECHECK
			LENGTH	118						
			OUTER DIAMETER	120						
			OUTER DIAMETER	37						
			OUTER DIAMETER	98						
			OUTER DIAMETER	53						
40	CNC 1ST OPERATION (ROUGH MACHINING - I)	WNMG 080412 FACING & TURNING TOOL	OUTER DIAMETER	39.80 / 40.20		VERNIER	5 NOS	PER HOUR	LIR	QUARANTINE ADJUST & RECHECK
			CHAMFER	2 × 45°		BEVEL PROTRACTOR & VERNIER				
			LENGTH	40.50 / 41.00		VERNIER				
			TOTAL LENGTH	110.20 / 110.80		VERNIER				
50	CNC 2 ND OPERATION (ROUGH MACHINING - II)	WNMG 080412 FACING & TURNING TOOL	OUTER DIAMETER	117.30 / 117.70		VERNIER	5 NOS	PER HOUR	LIR	QUARANTINE ADJUST & RECHECK
			OUTER DIAMETER	52.30 / 52.70		VERNIER				
			LENGTH	14.80 / 15.20		VERNIER				
			TOTAL LENGTH	108.10 / 108.80		VERNIER				
			LENGTH	25.80 / 26.20		VERNIER				
			DRILL DIAMETER	Ø13.30/13.70		VERNIER				
			LENGTH	52.30/53.00		VERNIER				
			CHAMFER	1.5 × 45°		BEVEL PROTRACTOR & VERNIER				
			RUN OUT	0.50 WRT A		HEIGHT VERNIER				
			CHAMFER	1.5 × 45°		BEVEL PROTRACTOR & VERNIER				
60	CASE HARDENING	PIT TYPE FURNANCE	HARDNESS	227/277 BHN		BRENELL HARDNESS TESTER	5 Nos Per LoT		RIR & SIR	QUARANTINE ADJUST & RECHECK

Voice of Customer – AL Ennore

From: Senthil S (Quality "H" & "N" Engines)
Sent: Tuesday, June 26, 2012 9:40 AM
To: Muthuraman R (CQ – Supplier Quality)
Cc: Sethuraman R (CQ – Supplier Quality)
Subject: RE: Flange Coupling LSS Project Presentation

Dear Muthuraman,

Supply of flange couplings from M/s Chennai forge supplies have improved now and the rejections for the period from March '2012 to May'2012 is nil. Keep monitoring the supplier closely on the improvements / changes made at their end to maintain the same.

Regards,
S.Senthil

From: Muthuraman R (CQ – Supplier Quality)
Sent: Sunday, June 24, 2012 9:07 AM
To: Senthil S (Quality "H" & "N" Engines)
Cc: Sethuraman R (CQ – Supplier Quality)
Subject: FW: Flange Coupling LSS Project Presentation

Dear sir,

As discussed Please find the attached LSS project of Chennai forge for the flange coupling OD undersize/oversize (49.936/49.975) . Kindly check at your end and request to send your feedback for the completion of projects.

Quality Audit Plan by Customer (AL)

Chennai forge Private ltd		Supplier Quality audit plan - Process Audit 2012										Date : 02.01.2012				
DOC/QAD/001 A	As per Control plan															
Slno	Machining oiperation	Jan-12	Jan-12	Feb-12	Mar-12	Apr-12	May-12	May-12	Jun-12	Jul-12	Aug-12	Sep-12	Sep-12	Oct-12	Nov-12	Dec-12	Jan-13
1	Roughing- CNC 2nd operation	MRM 01(Sep 2011 - Dec 2011	3 shift ★				MRM 02 (Jan 2012 - Apr 2012)	3 shift ★				MRM 03 (May 2012 -Aug 2012)	3 shift ★				MRM 04 (Sep 2012 - Dec 2012)
2	CNC finishing 1st operation			3 shift ★					3 shift ★					3 shift ★			
3	CNC finishing 2nd operation/MSA				3 shift ★					3 shift ★					3 shift ★		
4	Induction hardening /					3 shift ★					3 shift ★					3 shift ★	
			1st cycle					2nd cycle					3rd cycle				

Cost Benefit – CFPPL

Cost Savings (In house + Customer) Rejections per month - INR 18,458 /-

Annual Projected Savings – INR 221,496 /-

Inference / Conclusion from the Data

Annual Savings of INR 2.2 Lakhs for the Supplier as Vetted by the Supplier, due to LSS project undertaken by Supplier to reduce OD variations

Cost Benefit – CFPPL

Chennai Forge Products Pvt. Ltd.

Manufacturers of Quality Steel Forgings

REGD. OFFICE & FACTORY :
PLOT No. OLD 67, NEW 57.
SIDCO INDUSTRIAL ESTATE,
AMBATTUR, CHENNAI - 600 098.
E-mail : info@chennaiforgeproducts.com
Website : www.chennaiforgeproducts.com

Phone : 26252859 / 26246752
Fax : 044-2635 7045
TIN No. : 33291441740 073
CST No. : 767343 / Dt. 27.03.2001
SME RATING : C5; D&B-D-U-N-S : 86-249-5541

Lean Six Sigma Project – Reduce Flange Coupling (F1437211)
Component Rejections

Financial Savings based on Rejections (In-house and Customer) data from **April – Sep 2011** for **Flange Coupling, Part No F1437211**:

Projected Cost Savings due to reduced In-house rejections and Customer Rejections following the implementation of various improvements: **Rs. 18458/month** or **Rs. 221,496/year**

For Chennai Forge Products Pvt. Ltd.

Authorized Signatory

Inference / Conclusion from the Data

Annual Savings of INR 2.2 Lakhs for the Supplier as Vetted by the Supplier, due to LSS project undertaken by Supplier to reduce OD variations

Tools Used

Tools	Define	Measure	Analyze	Improve	Control
Charter					
Gantt Chart					
Pareto Analysis					
Process Mapping					
Fish bone diagram					
Attribute P-Chart					
Process Capability					
Box Plot					
Individual Value plot					
Multi-Vari analysis					
Hypothesis Testing					
Analysis of Variance					
IMR Control charts					
Control Plan					
Horizontal Deployment					
Voice of Customer					

Lessons Learnt

- Critical analysis of difficult issues thru LSS approach gives more insights;
- Advantages of data collection and maintenance, and its positive impact on the process;
- Analysis of existing data, and its positive impact on the process;
- Use of current data to make future improvements and for sustenance;
- Horizontal deployment of control in CNC program for **Semi finished flange coupling** and other similar components **(Hub Fan to SFL)** at CFL Supplier end to meet customer requirements.

Acknowledgements

- Many thanks to the AL CQE Mr. R. Sethuraman & others and Mr. V. Rajagopal of LSS, AL Ennore for the project support & guidance of LSS approach and tools onsite;

- Thanks to CFPPL QA and Production team for the execution of project to meet organization deliverables;

- Many thanks to Mr. Hemant of Institute of Quality & Reliability for LSS training.

Thank You…