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Improving the Gear Box fork Quality by using Six Sigma Tools

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***Abstract*— The aim of this work is to Improve the Gear Box Fork Quality by using Six sigma tool. The fork component coupled in fork shifting rail and the fork pan located inside the gear by using the coupler. In Fork component the following problems as arrived while assembly & shifting the gear, Fork perpendicularity issue, Thickness taper issue, Positional dimensional deviation issue. Rectification of the problem to improve the fork quality using the mythology of six sigma and take ting the corrective action & preventive action.**

***Keywords* - UCL-upper critical limit, LCL-lower critical limit, QTY-Quantity, CP-Process capability, CP_k-Process capability index**

I. Introduction

A Vision and Philosophical commitment to our consumers to offer the highest quality, lowest cost products. A Metric that demonstrates quality levels at 99.9997% performance for products and process's. A Benchmark of our product and process capability for comparison to 'best in class'. A practical application of statistical Tools and Methods to help us measure, analyze, improve, and control our process

B. Comparison of 3 sigma & 6 sigma.

TABLE: 1.1: 3 Sigma Vs. 6 Sigma

The 3 sigma Company	The 6 sigma Company
Spends 15~25% of sales dollars on cost of failure	Spends 5% of sales dollars on cost of failure
Relies on inspection to find defects	Relies on capable process that don't produce defects
Does not have a disciplined approach to gather and analyze data	Use Measure, Analyze, Improve, Control and Measure, Analyze, Design
Benchmarks themselves against their competition	Benchmarks themselves against the best in the world
Believes 99% is good enough	Believes 99% is unacceptably
Define CTQs internally	Defines CTQs externally

II. Defence Phase

In Fork component the following problems as arrived while assembly & shifting the gear, Fork perpendicularity issue, Thickness taper issue, Positional dimensional deviation issue. Our aim is to improve the fork quality by finding the root cause by using the six sigma tool & take the corrective action tool.

TABLE: 1: Customer Complaint

Sl.No	Part No	Part Name	Supplier	MDU /DBR	REJ QTY	Problem details
1	0180443M01	Fork Planetary shifter	M/s. Accurate Steel Forging Limited	MDU	220nos	Dimensional Deviation (Bend, Pad twist and perpendicularity deviation)

III. Measure Phase

A. Prioritized Parts For Project Scoping

TABLE: 2 Prioritized parts for project scoping

Part No : 0180443M01 (TA01)	Part Name	Fork planetary Shifter
Parameters	Specification	Checking method
Thickness	7.00 +0.07/ - 0	Digital micrometer
Perpendicularity	0.3 maximum	DVhg with lever dial gauge
Thread position to pad position	18.59 ± 0.05	Position gauge

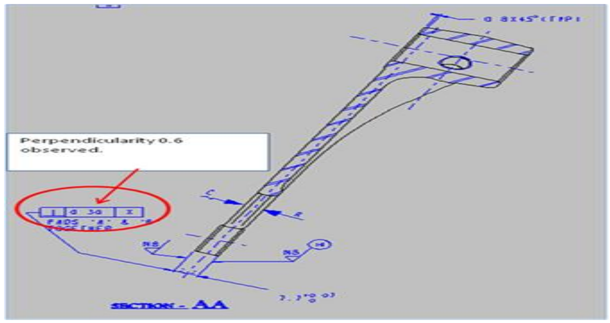


Fig: .1: Photo View of component 0180443M01

B. Cause & Effect Diagram

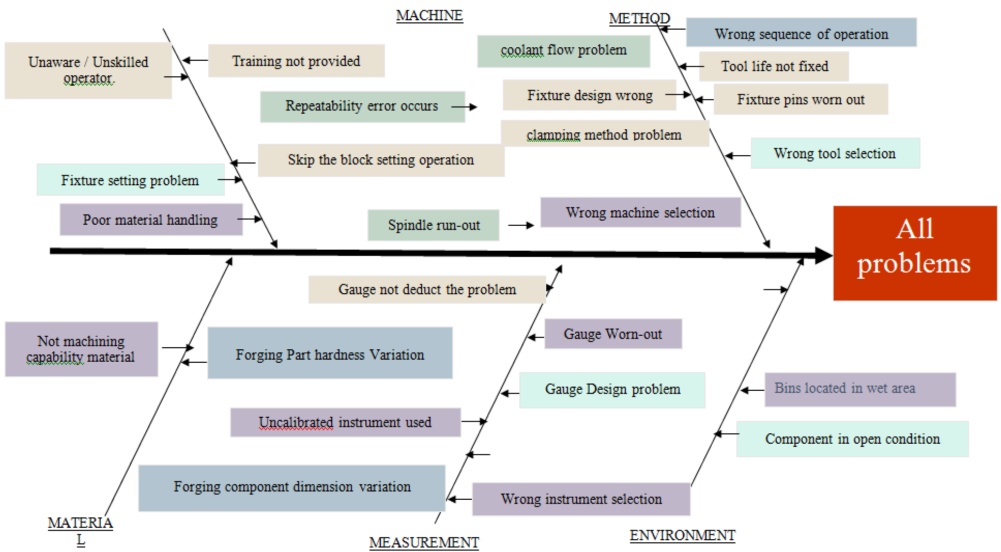


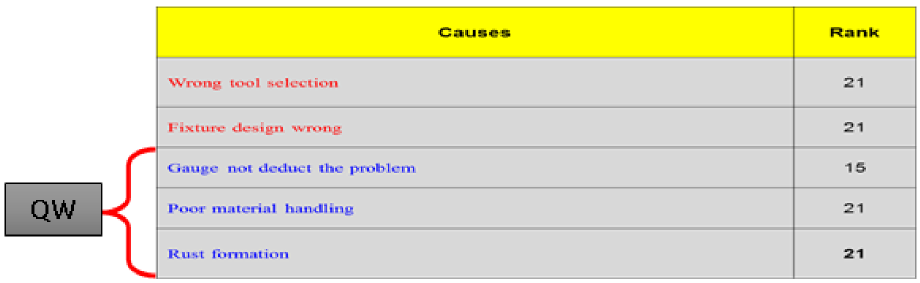
Fig. 2 Cause & Effect Diagram

C. Cause and Effect Matrix

TABLE: 3.2: Cause & Effect Matrix

	Selva Ganapathi	Thiyagarajan	srinivasan	Output Indicators
Input/ Process indicators	Correlation of input to output			Total
Unaware / Unskilled operator.	3	3	3	9
Training not provided	3	1	3	7
Fixture setting problem	3	1	1	5
Poor material handling	9	3	9	21
Skip the block setting operation	3	3	3	9
R.P. Oil not apply	1	1	1	3
Repeatability error occurs	1	1	1	3
Spindle run-out	0	0	3	3
coolant flow problem	0	0	3	3
Fixture design wrong	9	3	9	21
clamping method problem	3	3	1	7
Wrong machine selection	1	1	0	2
Wrong sequence of operation	0	0	0	0
Tool life not fixed	3	3	3	9
Fixture pins worn out	3	3	1	7
Wrong tool selection	9	9	3	21
	Selva Ganapathi	Thiyagarajan	srinivasan	Output Indicators
Not machining capability material	0	0	0	0
Forging Part hardness Variation	3	3	3	9
Forging component dimension variation	3	3	3	9

Gauge not deduct the problem	3	3	9	15
Uncelebrated instrument used	0	0	0	0
Gauge Worn-out	0	0	0	0
Gauge Design problem	3	3	3	9
method of inspection wrong	1	0	1	2
Wrong instrument selection	0	1	1	2
Rust formation	9	3	9	21
Bins located in wet area	3	3	3	9
Component in open condition	3	3	3	9



Causes	Rank
Wrong tool selection	21
Fixture design wrong	21
Gauge not deduct the problem	15
Poor material handling	21
Rust formation	21

Fig: 3: List of prioritized causes-top 5 causes

E. Operational Definitions

TABLE: 3: List of Operational definitions

Sl. No.	Y Measure	Operational definition
Y1	Fork bend problem	Both two Forks are perpendicular to the bore axis
Sl. No.	**X Measure**	**Operational definition**
X1	Wrong tool selection	Single disk milling cutter changed to double disk milling cutter
X2	Fixture design wrong	In vertical milling fixture design modified & introduces Horizontal pad milling fixture

F Data Measurement Plan

TABLE: 3.3: List of Operational definitions

Y Measure	Operational definition	Frequency of Data Collection	Sample Size	Method of Data collection	When will data be collected	Responsibility for data collection
Fork bend problem	Both two Forks are perpendicular to the bore axis	Hourly	50nos	Patrol report	Every shift	Selva Ganapathi

TABLE: 3.4: Data measurement plan

X Measure	Operational definition	Frequency of Data Collection	Sample Size	Method of Data collection	Responsibility for data collection
Wrong tool selection	Single disk milling cutter changed to double disk milling cutter	One time	50 nos	SPC & 100%	Selva ganapathi
Fixture design wrong	In vertical milling fixture design modified & introduces Horizontal pad milling fixture	One time	50 nos	SPC & 100%	Selva ganapathi
Gauge not deduct the problem	Gauge modified & slip will be provided for pad distance	One time	20 nos	Attribute type	Thiyagaragan

IV. Analysis Phase

Analyzing the problems by applying the statistical process control chart & verifying the outcome of the product result by dimensionally.

A. Process Capability Study

Specification: Thickness 7.70 + 0.07/ -0 UCL = 7.77mm LCL = 7.70mm Total tolerance = 0.07mm. Instrument used for measuring: Digital micro meter Least count: 0.001mm

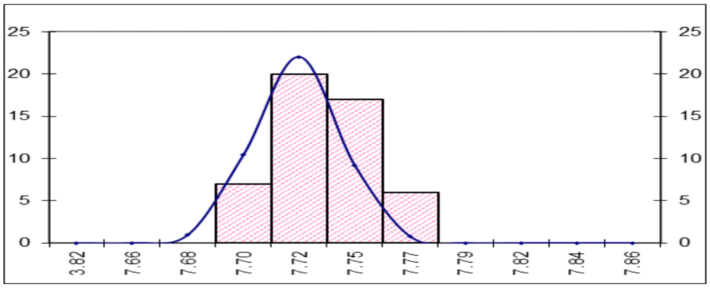


Fig 4.1 Histogram for Thickness

TABLE 4.1 thickness observations - *Thickness observations (X values)*

1 - 5	6 - 10	11 - 15	16 - 20	21 - 25	26 - 30	31 - 35	36 - 40	41 - 45	46 -50
7.720	7.754	7.765	7.770	7.703	7.714	7.720	7.754	7.765	7.770
7.726	7.729	7.745	7.715	7.748	7.701	7.726	7.729	7.745	7.715
7.734	7.724	7.746	7.760	7.741	7.738	7.734	7.724	7.746	7.760
7.725	7.733	7.736	7.710	7.705	7.746	7.724	7.733	7.736	7.712
7.741	7.754	7.732	7.710	7.749	7.724	7.741	7.754	7.732	7.710

Formula Used:

$\dot{X}$ = Avg. subgroup value of X and $\ddot{X}$ = Avg. value of the total $\dot{X}$

$\sigma = \bar{R}$ / D2 D2 is the standard subgroup value 2.33

Cp = Total tolerance / 6 σ and Cpk = Minimum of (CPU & CPL) and CPU= USL - $\ddot{X}$ / 3σ, CPL= $\ddot{X}$ - LSL / 3σ

Calculations:

$\dot{X}$ = 7.729 + 7.739 + 7.745 + 7.733 + 7.729 + 7.725 + 7.729 + 7.739 + 7.745+7.733 and $\ddot{X}$ = 7.735

σ = 0.069/ 2.33 = 0.0181 and D2 is the standard subgroup value 2.33

Cp = 0.07 / 6 x 0.0181 = 0.65 and Cpk = Minimum of (0.64 & 0.65) = 0.64

CPU= 7.77 – 7.735 / 3 x 0.0181 = 0.644 and CPL= 7.735 – 7.70 / 3 x 0.0181 = 0.650

Result : Standard Value : Cp = more than 1.67 Cpk = More than 1.33 Observations: Cp = 0.65

Cpk = 0.64

RESULT: Process not capable

B. Process Capability Study

Specification: Perpendicularity 0.3 max UCL = 0.3mm LCL = 0.001mm Total tolerance = 0.3mm, Instrument used for measuring : Digital height gauge with dial Least count : 0.001mm

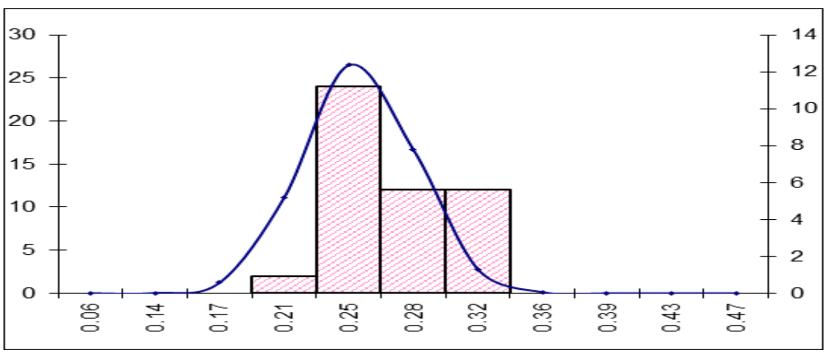


Fig 4.2 Histogram for perpendicularity

TABLE 4.2 Perpendicularity observations - Thickness observations (X values)

1 - 5	6 – 10	11 - 15	16 - 20	21 - 25	26 - 30	31 - 35	36 - 40	41 - 45	46 -50
0.310	0.210	0.210	0.280	0.250	0.230	0.320	0.250	0.310	0.240
0.250	0.320	0.240	0.290	0.290	0.260	0.310	0.230	0.320	0.250
0.290	0.250	0.250	0.310	0.240	0.280	0.250	0.260	0.310	0.230
0.310	0.290	0.230	0.320	0.240	0.290	0.290	0.280	0.250	0.260
0.240	0.260	0.260	0.310	0.250	0.310	0.240	0.290	0.290	0.280

Formula Used:

$\dot{X}$ = Avg. subgroup value of X, $\ddot{X}$ = Avg. value of the total $\dot{X}$

$\sigma = \bar{R} / D2$, D2 is the standard subgroup value 2.33 and Cp = Total tolerance / 6 σ
Cpk = Minimum of (CPU & CPL), and CPU= USL - $\ddot{X}$ / 3σ and CPL= $\ddot{X}$ - LSL / 3σ
Calculations:

$\dot{X}$ = 0.28 + 0.266 + 0.238 + 0.302 + 0.254 + 0.274 + 0.282 + 0.262 + 0.296 + 0.252
$\ddot{X}$ = 0.271 σ = 0.11/ 2.33 = 0.0318 D2 is the standard subgroup value 2.33
Cp = 0.3 / 6 x 0.0318 = 1.57 & Cpk = Minimum of (0.31 & 2.83) = 0.31
CPU= 0.3 – 0.271 / 3 x 0.0318 = 0.31 AND CPL=0.271-0.001 / 3 x 0.0318 = 2.83
Result:
Standard Value: Cp = more then 1.67 Cpk = More then 1.33 Observations: Cp = 1.57 Cpk = 0.31
RESULT: Process not capable

C. Process Capability Study

Specification: Thread position to pad position UCL = 18.54mm LCL = 18.64mm Total tolerance = 0.1mm. Instrument used for measuring: Digital height gauge with dial least count: 0.001mm

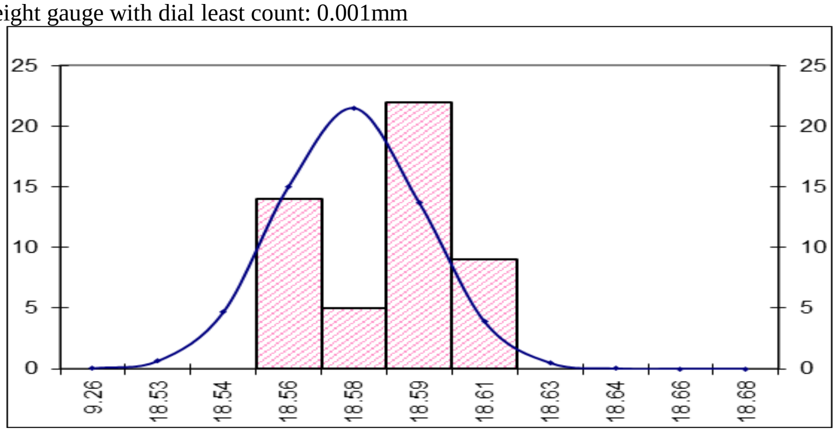


Fig 4.3 Histogram for perpendicularity

TABLE: Thickness observations (X values)

1 - 5	6 - 10	11 - 15	16 - 20	21 - 25	26 - 30	31 - 35	36 - 40	41 - 45	46 -50
18.560	18.610	18.590	18.590	18.560	18.560	18.590	18.570	18.610	18.590
18.590	18.600	18.560	18.610	18.590	18.590	18.560	18.560	18.590	18.570
18.570	18.610	18.590	18.600	18.560	18.610	18.590	18.590	18.560	18.560
18.560	18.590	18.570	18.610	18.590	18.600	18.560	18.610	18.590	18.590
18.590	18.560	18.560	18.590	18.570	18.610	18.590	18.600	18.560	18.610

Formula Used:
$\dot{X}$ = Avg. subgroup value of X , $\ddot{X}$ = Avg. value of the total $\dot{X}$ AND $\sigma = \bar{R} / D2$
D2 is the standard subgroup value 2.33, Cp = Total tolerance / 6 σ, Cpk = Minimum of (CPU & CPL)
CPU= USL - $\ddot{X}$ / 3σ AND CPL= $\ddot{X}$ - LSL / 3σ
Calculations:
$\dot{X}$ = 18.574 + 18.592 + 18.574 + 18.600 + 18.574 + 18.587 + 18.578 + 18.586 + 18.582 + 18.584
$\ddot{X}$ = 18.584 σ = 0.05/ 2.33 = 0.0185 D2 is the standard subgroup value 2.33
Cp = 0.31/ 6 x 0.0185 = 0.9 , Cpk = Minimum of (1.81 & 0.79) = 0.79
CPU= 18.64– 18.584 / 3 x 0.0185 = 1.81 AND CPL= 18.584 -18.54/ 3 x 0.0185 = 0.79
Result: Standard Value : Cp = more then 1.67 Cpk = More then 1.33
Observations: Cp = 0.90 Cpk = 0.79
RESULT: Process not capable:

Root cause result verified in the particular process in the machine:

- conformed & identified the failure area
- Root cause result proved by the analyzing result

Analyzing result : Implement improvement action against the root cause failures

V. IMPROVEMENT PHASE

Improvement action taken against the outcome of the root cause result by modifying the fixture design & tool design.

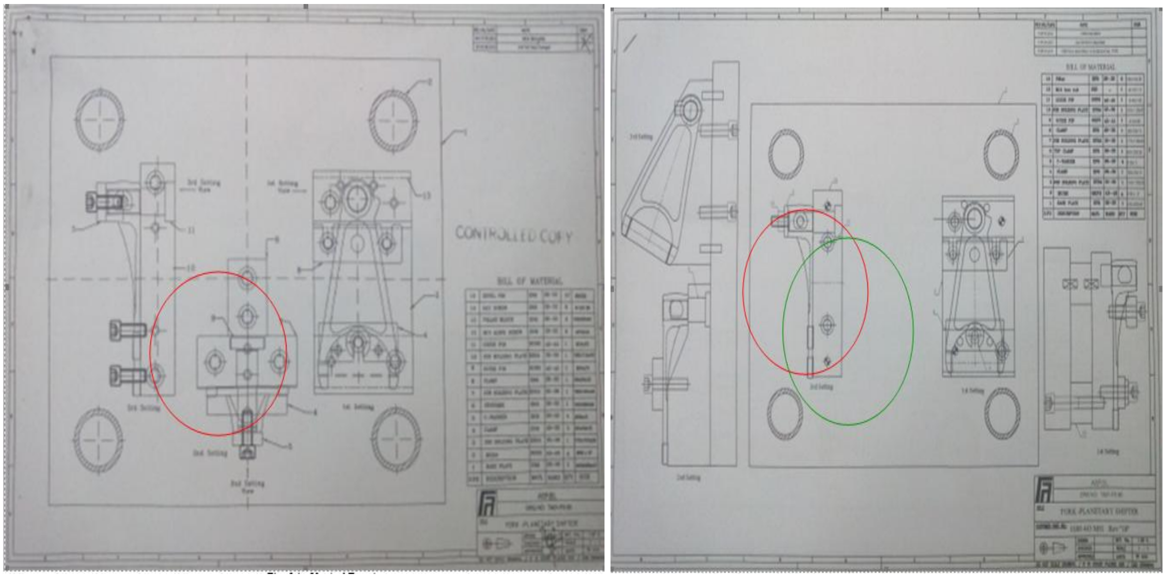


Fig: 5.1: Vertical Drawing and Horizontal Drawing

A. Before and After Improvement: vertricle mullimg

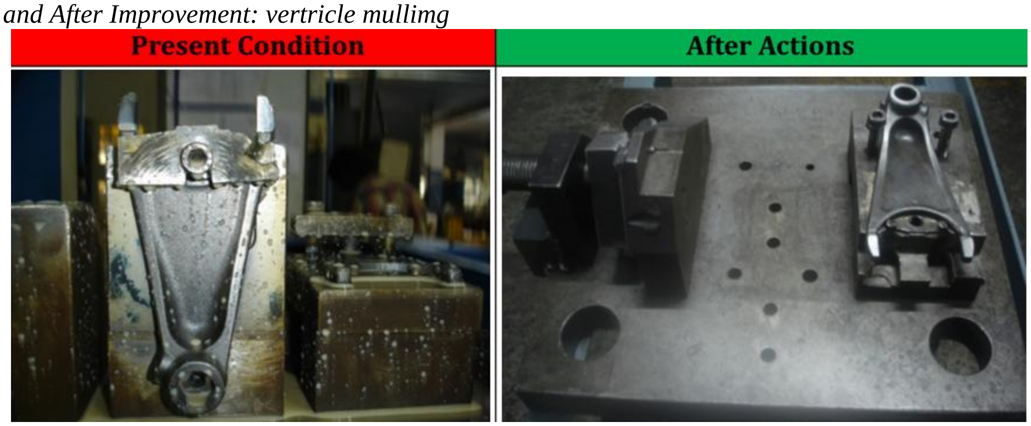


Fig: 5.3: VMC Fixture

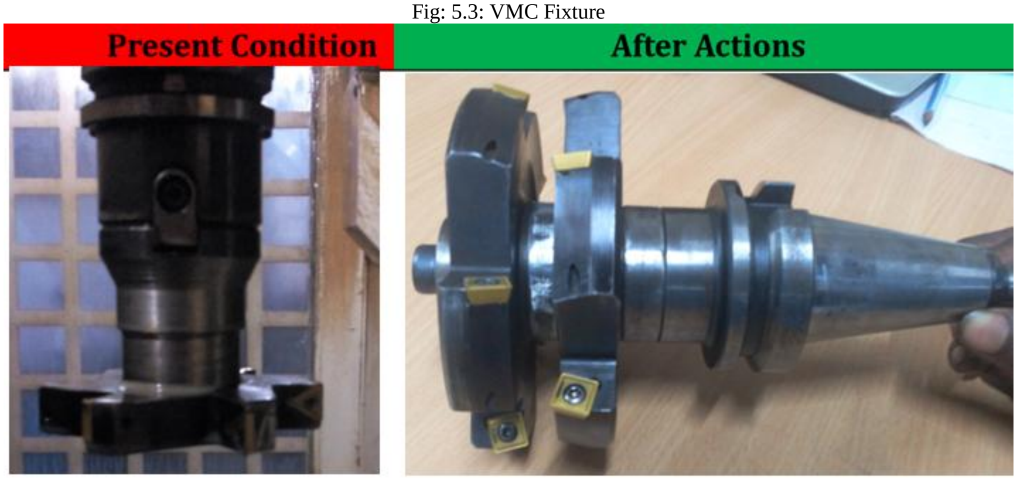


Fig 5.4: Disc Milling Tool

B. Improvement Verification

Improvement verified after improving the root cause result by applying the statistical process control chart & to check the CP & CPK value achieve more then CP value 1.67 &CPK value 1.33 7 to check the cycle time of the component to complete the process

Fig: 5.5: Milling cutter Vs component

Specification : Thickness 7.70 + 0.07/ -0 UCL = 7.77mm LCL = 7.70mm Total tolerance = 0.07mm Instrument used for measuring : Digital micrometer Least count : 0.001mm

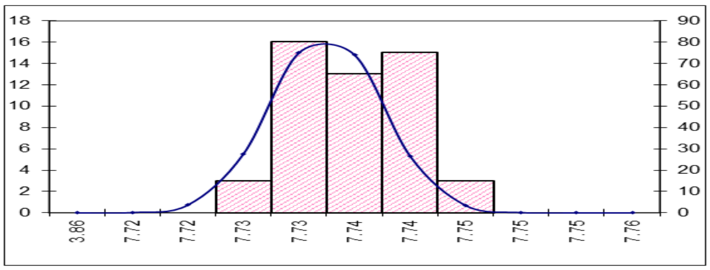


Fig 3. 5 Milling cutter Vs component

TABLE 1: Thickness observations (X values)

1 - 5	6 - 10	11 - 15	16 - 20	21 - 25	26 - 30	31 - 35	36 - 40	41 - 45	46 -50
7.730	7.740	7.740	7.732	7.739	7.744	7.740	7.732	7.745	7.744
7.735	7.731	7.730	7.738	7.741	7.733	7.741	7.735	7.733	7.728
7.734	7.736	7.732	7.733	7.729	7.738	7.742	7.734	7.736	7.730
7.736	7.741	7.736	7.732	7.726	7.732	7.736	7.736	7.736	7.726
7.738	7.742	7.731	7.736	7.738	7.730	7.738	7.741	7.731	7.735

Formula Used:

Ẋ = Avg. subgroup value of X, Ẍ = Avg. value of the total Ẋ

Ϭ = R̄ / D2 and D2 is the standard subgroup value 2.33, Cp = Total tolerance / 6 Ϭ, Cpk = Minimum of (CPU & CPL) and CPU= USL - Ẍ / 3Ϭ and CPL= Ẍ - LSL / 3Ϭ

Calculations:

Ẋ = 7.735 + 7.738 + 7.734 + 7.734 + 7.735 + 7.735 + 7.739 + 7.736 + 7.736 + 7.733 and Ẍ = 7.735

Ϭ = 0.011/ 2.33 = 0.0047 and D2 is the standard subgroup value 2.33

Cp = 0.07 / 6 x 0.0047 = 2.47, Cpk = Minimum of (2.48 & 2.44) = 2.44

CPU= 7.77 – 7.7345 / 3 x 0.0047 = 2.482, CPL= 7.7345 – 7.7 / 3 x 0.0047 = 2.446

Result :

Standard Value: Cp = more then 1.67 Cpk = More then 1.33

Observations: Cp = 2.47 Cpk = 2.44

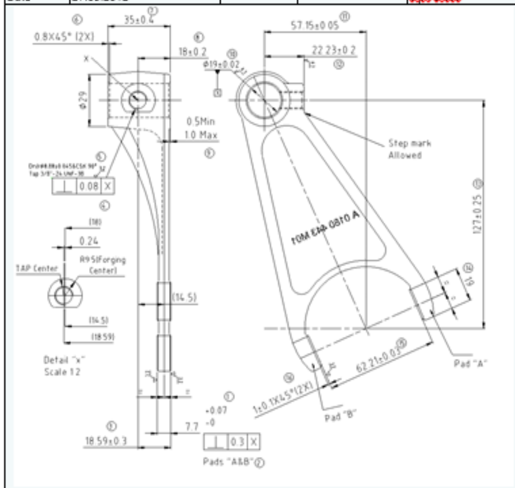
RESULT: Process capable

VI. Improvement Results

The statistical process control applied after introducing the double disk tool

- Cpk achieved more then 1.33 observed 2.44
- Process cycle time reduced from 92sec to 40sec
- Cost saving by implementing the double disk milling cutter
  - 92-40= 52sec (1sec = Rs.0.133) , Rs.7.049saved per component
  - total 8000Nos for monthly schedule, 8000 X 7.049 = Rs.56,392 saved per month
- Pad Thickness consistency achieved
- Thickness taper problem reduced
- Pad distraction problem reduced

ASFIL					OPERATION STANDARD			F/CFT/7.1/07
Part No	TA01	Opn STD No:	ASF-OSF-TA01-90	M/c No	05,13,27	Prepared	E. Jaya kumar	
Desc	Fork- Planetary Shifter	Rev No	02	M/c Desc	All VMC M/Cs	Checked	P.C. Selvaganapathi	
Rev No	00	Date	15.10.2014	Opn No	90	Checked	S. Srinivasan	
Date	27.09.2012			Opn Desc	VMC Operation	Approved	K.Vinoth kumar	



CONTROL PLAN

Sl No	Control Item	Spec	Set no	Method of Check	Freq of Check	Tool of Control	Spl Char	Reaction plan
PROCESS CHARACTERISTICS								
1	speed & Feed	Refer program No :6003		Monitor	Every setting	Oper. std	-	C2
TOOL CHARACTERISTICS								
1	Face Mill	Ø40 (50Bull Insert) or 32 (SPMT 11) & Ø90			First off	Oper. std	-	C2
2	Drill	Ø17 HHS & Ø8.5 Drll HSS Ø18.7 Twinb Boring bar (SPMT07)			First off	Oper. std	-	C2
3	Chamfer mill & Center drill	25x45° Top & Bottom (SPMT07) & BS5 Center			First off	Oper. std	-	C2
4	End mill	Ø16 mm			First off	Oper. std	-	C2
5	Tap	Tap3/8"-24UNF-3B			First off	Oper. std	-	C2
6	Counter sink	Ø16x45°			First off	Oper. std	-	C2
7	Double Disk Milling cutter	Ø110 (10 Inserts SPMT 11)			First off	Oper. std	-	C2
PRODUCT CHARACTERISTICS								
1	Thickness	7.7 +0.07/-0	1	Snap Gauge	100%	☐	©	C2
2	Perpendicular	0.3 Wrt "X"	1	Digital Height Gauge	1No/Hour	☐	-	C2
3	Position	18.59 ± 0.3	3	Thread plug gauge with ht gauge	1No/Hour	☐	-	C2
4	Perpendicular	0.08 Wrt "X"	3	Digital Height Gauge	1No/Hour	☐	-	C2
5	Drill & Tap	Tap3/8"-24UNF - 3B	3	Thread plug gauge	1 No/hour	☐	-	C2
6	Chamfer (2X)	0.8X45°	1	Bevel protector	1st & L off	☐	-	C2
7	Thickness	35 ± 0.4	2	Digital Vernier	1No/Hour	☐	-	C2
8	Distance	18 ± 0.2	2	Digital Height Gauge	1No/Hour	☐	-	C2
9	Distance	0.5/1.0	2	Digital Height Gauge	1No/Hour	☐	-	C2
10	Diameter	Ø 19 ± 0.02	1	Air Plug Gauge	100%	☐	-	C2
11	Position	57.15 ± 0.05	1	Position Gauge	1 No/hour	☐	-	C2
12	Distance	22.23 ± 0.2	3	Digital Height Gauge	1No/Hour	☐	-	C2
13	Position	127±0.25	1	Position Gauge	1 No/hour	☐	-	C2
14	Distance	19 +0.8/-0.4	1	Digital Vernier	1 No/hour	☐	-	C2
15	Width	62.21 ± 0.03	1	Inner width gauge	1 No/hour	☐	-	C2
16	Chamfer	1 X 45°	1	Bevel protector	1st & Lasoff	☐	-	C2
17	Burr	remove all sharp corner & burr		Visual	100%	☐	-	C2

Follow the work instruction:		
Previous operation:Coining(op.no:80) Next operation: Burnishing (op.no:100)		
Note : Layout inspection once in a Year		
Special Charate	Control method	Reaction plan
©- Critical	☐ - Check sheet	C1 - Stop, qua,100% inspection and adjust
		C2 - Stop,quarantine,100 % inspection & inform supervisor

Fig 5.3: Operation Charted

VII. CONCLUSIONS

The component Quality issues was analyzed by using the six sigma methodology Improved the quality of the gear shifting FORK by introducing the Double disk cutter Reduced the manufacturing the cost by reducing the machining cycle time from 92sec to 40sec Yearly cost saving Rs.56,392 by cycle time reduction Customer end PPM reduced from 1600PPM to 20PPM for this component

REFERENCES

[1] Pardeep Rattan, Dr. Pyare Lal.,"Pros and Cons of Six Sigma:A Library Perspective", International Journal of Digital Library Services, Vol 2, Issue 4, Oct – Dec 2012.

[2] Ahmad Ali Al-Zubi, Imtiaz Basha,"Six Sigma In Libraries: A Management Perspective, Canadian Journal on Computing in Mathematics Natural Sciences, Engineering & Medicine Vol. 1, No. 3, April 2010.

[3] Chitra Koushik, Et al.,"Six sigma application for library services, DESIDOC Bulletin of information technology, Vol. 27, No. 5 September 2007.

[4] Coronado, R.B., Antony, J.,"Critical success factors for the successful implementation of six sigma projects in organizations", The TQM Magazine, Vol. 14, No. 2, pp. 92 – 99, 2002.

[5] Dong-Suk Kim,"Eliciting success factors of applying Six Sigma in an academic library: A case study", Performance Management and Metrics, Vol. 11, No. 1, pp. 25-38, 2010.

[6] El-Haik, B., Roy, D.M.,"Service design for six sigma: a roadmap for excellence, John Wiley and Sons, Inc., Hoboken: New Jersey, 2005.

[7] Harry M., Schroeder, R.,"Six sigma: The breakthrough management strategy revolutionizing the world's top corporations, 1st ed., Random House Inc., New York, 2000.

[8] Sarah Anne Murphy,"Leveraging Lean Six Sigma to Culture, Nurture, and Sustain Assessment and Change in the Academic Library Environment", College and research Libraries, May 2009.

[9] Suresh N.,"Application of Six sigma concept to effective academic library management and users satisfaction", National conference on future academic libraries challenges and opportunities 2011, Madurai Kamaraj university.

[10] Susan Kumi, John Morrow,"Improving self service the six sigma way at Newcastle University Library", Program: Electronic library and Information systems, Vol. 40, No. 2, pp. 123-136, 2006.

[11] Yong Kim et al.,"A Six Sigma-based method to renovate information services Focusing on information acquisition process. Library Hi Tech, Vol. 28, No. 4, pp. 632-647,2010.

[12] Snee, R. D. "Focus on Improvement, Not Training", (2001) Quality Management Forum, Spring 2001, 7,8,16.

[13] Snee, R. D. and R. W. Hoerl "Integrating Lean and Six Sigma – A Holistic Approach", (2007) Six Sigma Forum Magazine, May 2007, 15-21.

[14] Snee, R. D. and R. W. Hoerl Leading Six Sigma – A Step-by-Step Guide Based on Experience with GE and Other Six Sigma Companies, (2003) Chapters 3-4.