2nd International Conference on "Innovative Trends in Science, Engineering and Management"
YMCA, Connaught Place, New Delhi ICITSEM-16
05 November 2016, www.conferenceworld.in ISBN : 978-93-86171-10-8

PROCESS CAPABILITY STUDY ON AXLE HOUSING LINE OF A COMMERCIAL VEHICLE

Sree Harsha Bharadwaj H

Department of Mechanical Engineering, The National Institute of Engineering, Mysuru, India

ABSTRACT

Process capability analysis ensures that processes are fit for industry company specification while reducing the process variation and important in achieving product quality characteristic. Its indices are to measure the inherent variability of a process and thus to reflect its performance. The main objective of this paper is to predict current and future capability of the process to produce product within specification in the company and to investigate the product produced by the company meet the customer's specification. This project focuses on process capability analysis that had been applied to different processes in housing line of Axle Manufacturing Company, which includes select critical parameters, data collection, study on process capability and data evaluation. A particular case study on centre less grinding process has been focused where improvement measures are suggested and implemented.

Keywords: *Centreless grinding, Capability, process capability index Machine Process, thermal expansion*

I. INTRODUCTION

Gopala Raju, V. D. (Oct 2005) [1], The process capability study is a powerful tool, which can significantly improve the quality and productivity of manufacturing processes. Through the SPC theory of lessening variation in the manufacturing process, the greatest rate of profitability can be realized. Lesser raw material utilization and enhanced profitability are the two major advantages in addition to decrease in process variation.

II. MAJOR OBJECTIVES

The major objectives for carrying out this study are listed below

1. To foresee present and future capability of the process to deliver product inside specification in the organization.

2. To investigate the product and improve the process capability if required, created by the organization in meeting the customer's specification.

3. To re check the final Cpk by re studying the process.

III. METHODOLOGY

Cheryl Hild, D. S. (2000-01) [2], The most effective method to perform a Process Capability Study is as follows,

The steps for coordinating a process capability study are:

1) Planning for the Study.
2) Deciding the Process Output.
3) Contrasting the Output with the Specification.
4) Making a Move to Enhance the Process.

IV. STUDY OF PROCESS CAPABILITY ON AXLE HOUSING LINE

This section involves all the relevant work carried out at the axle housing line starting with a brief introduction of various processes involved in manufacturing a housing from scratch. The case study carried out was centreless grinding of the spindles for the inner and outer bearing seating. This process was considered for the study as it was a safety related characteristics (SRC).

Considering the centreless grinding process for its lower Cpk value, improvement measures is put up, so as to rectify the process to the normal condition and is the major focus of this study. Analysis of the data obtained is performed by the software called as MINITAB®.

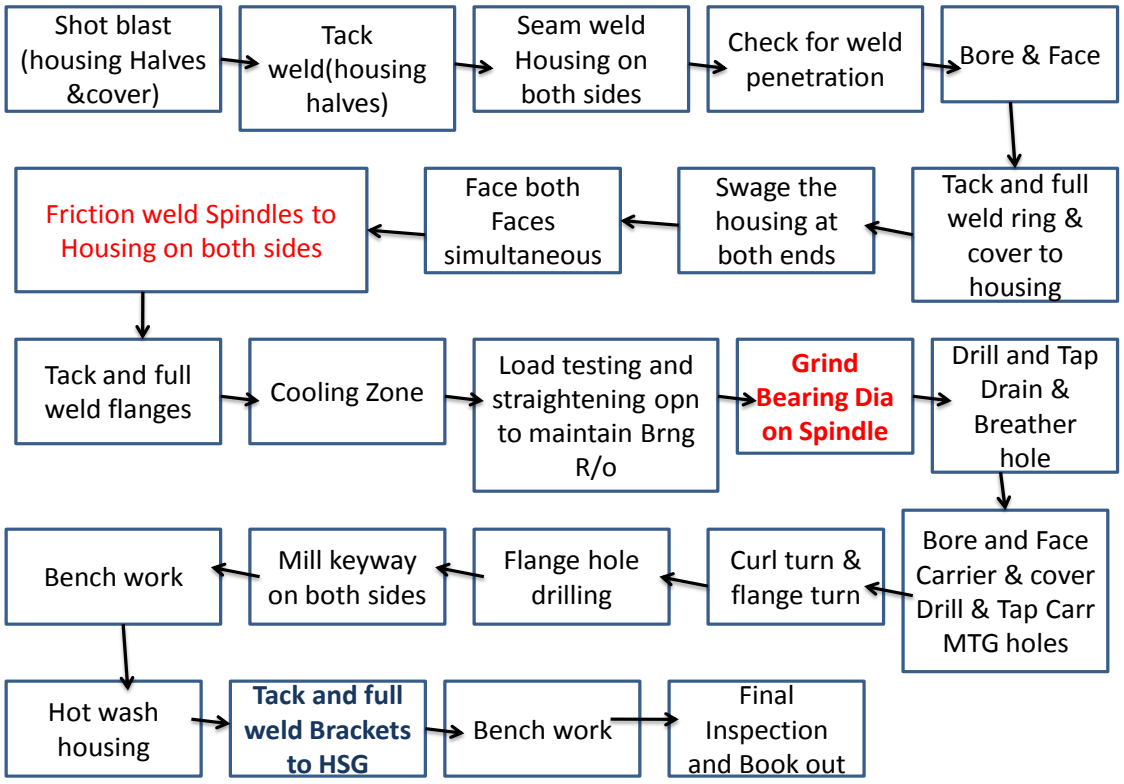

Figure 4.1: Flow Chart of Housing Line Manufacturing

Housing line of Axle Manufacturing company has 20 different processes to manufacture a single housing of a complete axle. The flow of process is clearly evident from the above figure. Firstly, two halves of the housing are short blasted for good surface finish and is then tack welded, followed by seam welding process and inspection for weld penetration for the same. Boring and facing is carried out to the housing faces. It is then processed to tack and completely weld the ring and cover. The ends of housing are processed in cold swage to obtain a required diameter followed by facing on the either ends simultaneously. Followed by facing, spindles are friction welded with the curl formation. Followed by tack and full weld of the flanges is carried out with cooling. Load testing is then carried out onto the axle to know if the axle can withstand the load in the field test. Grinding process is then carried on both the spindles, drill and tapping is performed for the breather hole. Followed with curl turn and flange turn, flange hole drilling and keyway milling on either side of the spindle. In the final stage of housing manufacturing, tack and full weld of brackets is performed, which connects to the chassis of the vehicle.

4.1 Case Study 1(A) –Centreless Grinding Process-Before Improvement

Table 4.1: Data Collection of Inner Bearing Diameter

Part Name	Housing
Process	IB Grinding
Specification	95.212-95.245 mm
Measurement Method	Dial gauge
Machine Name	Grinding Bay-1

Sl. No	***Readings (mm)***	***Sl. No***	***Readings (mm)***	***Sl. No***	***Readings (mm)***	***Sl. No***	***Readings (mm)***
1	95.222	33	95.235	65	95.231	97	95.233
2	95.222	34	95.229	66	95.230	98	95.238
3	95.217	35	95.231	67	95.234	99	95.224
4	95.232	36	95.225	68	95.232	100	95.220
5	95.222	37	95.227	69	95.234	101	95.223
6	95.222	38	95.239	70	95.232	102	95.222
7	95.227	39	95.232	71	95.218	103	95.224
8	95.227	40	95.226	72	95.214	104	95.224
9	95.227	41	95.231	73	95.217	105	95.225
10	95.222	42	95.226	74	95.217	106	95.222
11	95.224	43	95.225	75	95.219	107	95.224
12	95.222	44	95.227	76	95.227	108	95.225
13	95.232	45	95.224	77	95.236	109	95.228
14	95.232	46	95.226	78	95.220	110	95.223
15	95.224	47	95.232	79	95.220	111	95.230
16	95.227	48	95.227	80	95.228	112	95.234
17	95.228	49	95.227	81	95.221	113	95.237

18	95.228	50	95.214	82	95.226	114	95.224
19	95.225	51	95.223	83	95.227	115	95.228
20	95.230	52	95.229	84	95.217	116	95.227
21	95.224	53	95.225	85	95.215	117	95.238
22	95.227	54	95.222	86	95.221	118	95.230
23	95.225	55	95.222	87	95.220	119	95.228
24	95.226	56	95.218	88	95.233	120	95.230
25	95.227	57	95.222	89	95.234	121	95.229
26	95.227	58	95.221	90	95.227	122	95.227
27	95.226	59	95.231	91	95.232	123	95.230
28	95.227	60	95.226	92	95.226	124	95.231
29	95.223	61	95.227	93	95.224	125	95.233
30	95.221	62	95.222	94	95.234		
31	95.227	63	95.225	95	95.235		
32	95.227	64	95.230	96	95.225		

Minitab Analysis Results: The graphs below explain the results of the analysis performed in Minitab software with the help of the data as shown table 4.5

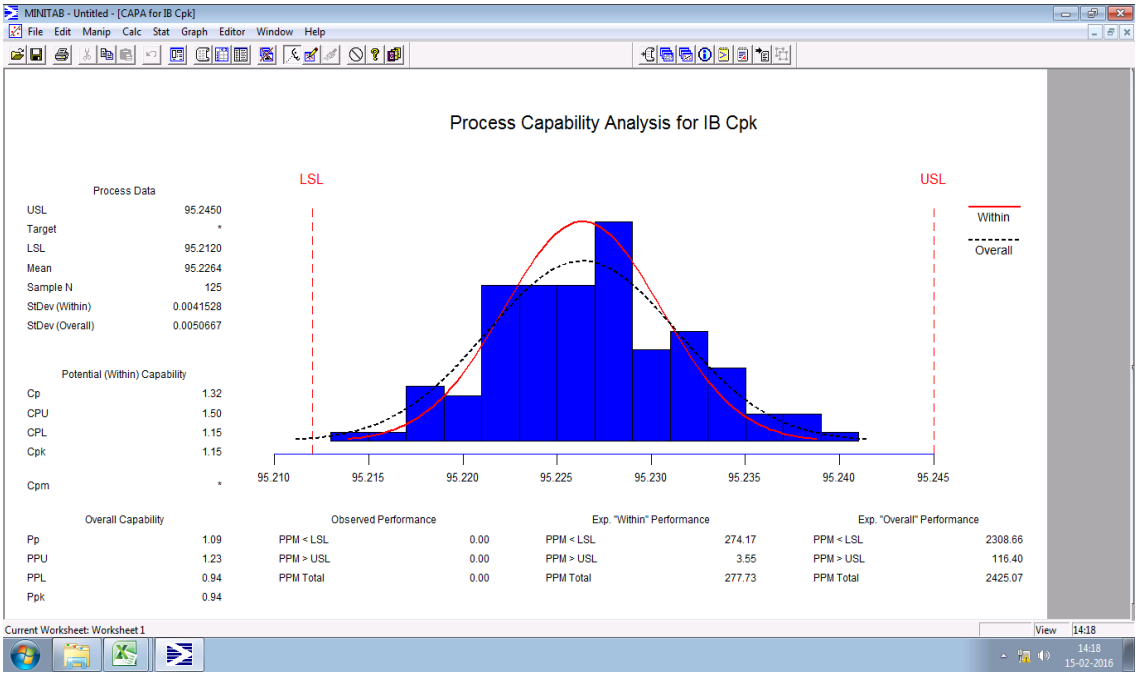

Fig 4.2: process capability index of IB Diameter

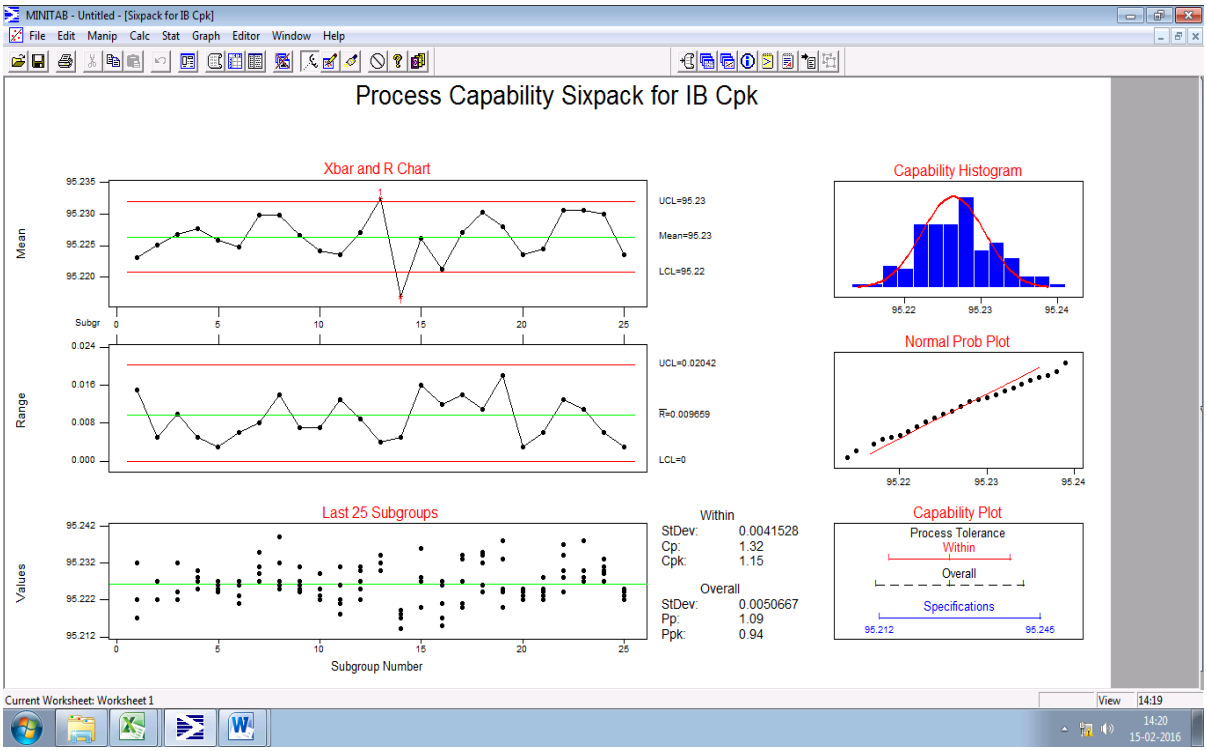

Fig 4.3: six pack normal of IB Diameter

Interpretation-From the above figure, it is clearly evident that the Cpk obtained is 1.15 which is lesser than 1.33 and ppm is 2425.07 which is really not an appreciable process. Also from the probability plot, it can be noticed that the process overall is lying outside the specifications and hence this process is not capable. From the X bar chart, it can be seen that a subgroup is falling out of the USL. In those situations, a new set of subgroups has to be recorded with a gap of certain interval of time. Each Dot in a X bar and R chart represents the average and range of subgroup. Also, Cp is 1.32 which is greater than Cpk.

4.2 CASE STUDY 1(B) - BEFORE IMPROVEMENT

Table 4.2: Data Collection of Outer Bearing Diameter

Part Name	Housing
Process	OB Grinding
Specification	82.520-85.540 mm
Measurement Method	Dial Gauge
Machine Name	Grinding Bay-1

Sl. No	*Readings (mm)*	*Sl. No*	*Readings (mm)*	*Sl. No*	*Readings (mm)*	*Sl. No*	*Readings (mm)*
1	82.527	33	82.527	65	82.528	97	82.520
2	82.522	34	82.527	66	82.523	98	82.524
3	82.520	35	82.524	67	82.517	99	82.527
4	82.522	36	82.517	68	82.521	100	82.527
5	82.522	37	82.517	69	82.524	101	82.527
6	82.527	38	82.520	70	82.522	102	82.528
7	82.522	39	82.514	71	82.520	103	82.530
8	82.522	40	82.523	72	82.524	104	82.527

9	82.524	41	82.517	73	82.527	105	82.529
10	82.524	42	82.520	74	82.527	106	82.520
11	82.527	43	82.529	75	82.527	107	82.518
12	82.522	44	82.523	76	82.528	108	82.520
13	82.524	45	82.529	77	82.530	109	82.519
14	82.527	46	82.530	78	82.527	110	82.512
15	82.527	47	82.524	79	82.529	111	82.530
16	82.522	48	82.525	80	82.520	112	82.525
17	82.522	49	82.523	81	82.518	113	82.531
18	82.532	50	82.521	82	82.520	114	82.532
19	82.522	51	82.526	83	82.519	115	82.529
20	82.527	52	82.523	84	82.512	116	82.512
21	82.523	53	82.524	85	82.530	117	82.507
22	82.528	54	82.527	86	82.525	118	82.514
23	82.530	55	82.521	87	82.531	119	82.516
24	82.529	56	82.518	88	82.532	120	82.514
25	82.523	57	82.522	89	82.529	121	82.510
26	82.520	58	82.522	90	82.512	122	82.522
27	82.529	59	82.527	91	82.507	123	82.518
28	82.529	60	82.524	92	82.514	124	82.513
29	82.527	61	82.524	93	82.516	125	82.514
30	82.530	62	82.530	94	82.514		
31	82.525	63	82.522	95	82.510		
32	82.522	64	82.524	96	82.520		

Minitab Analysis Results: The graphs below explain the results of the analysis performed in Minitab software with the help of the data as shown table 4.6

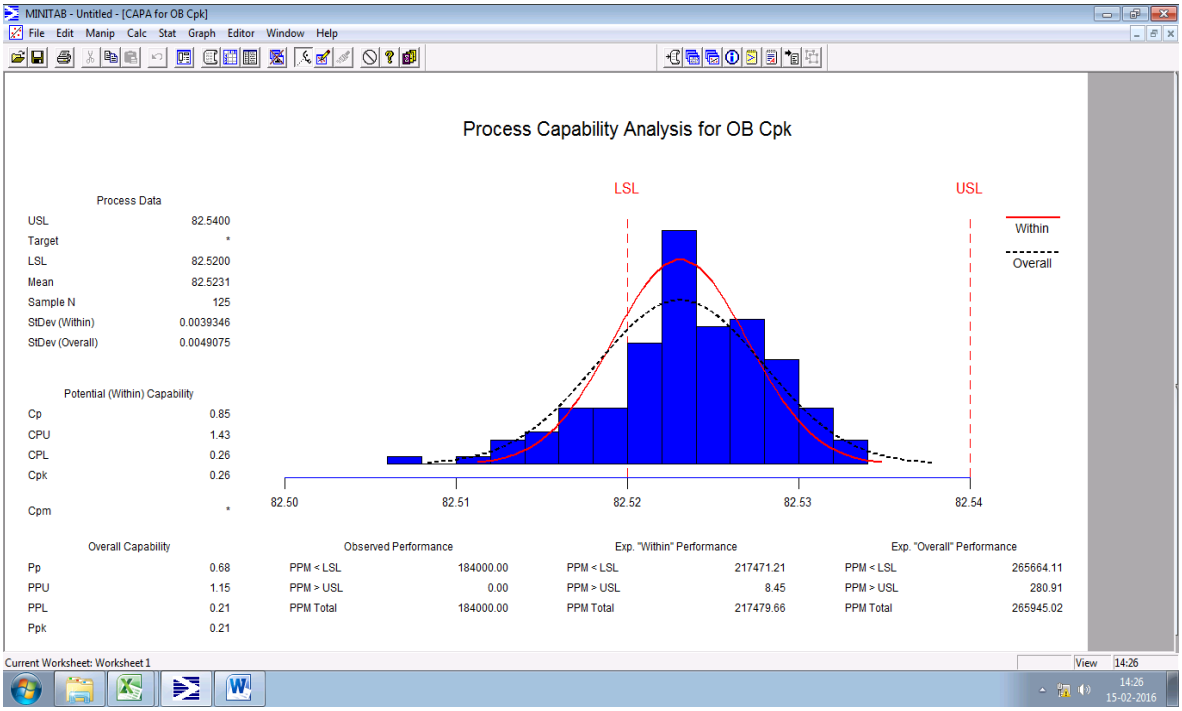

Figure 4.4: process capability index of OB

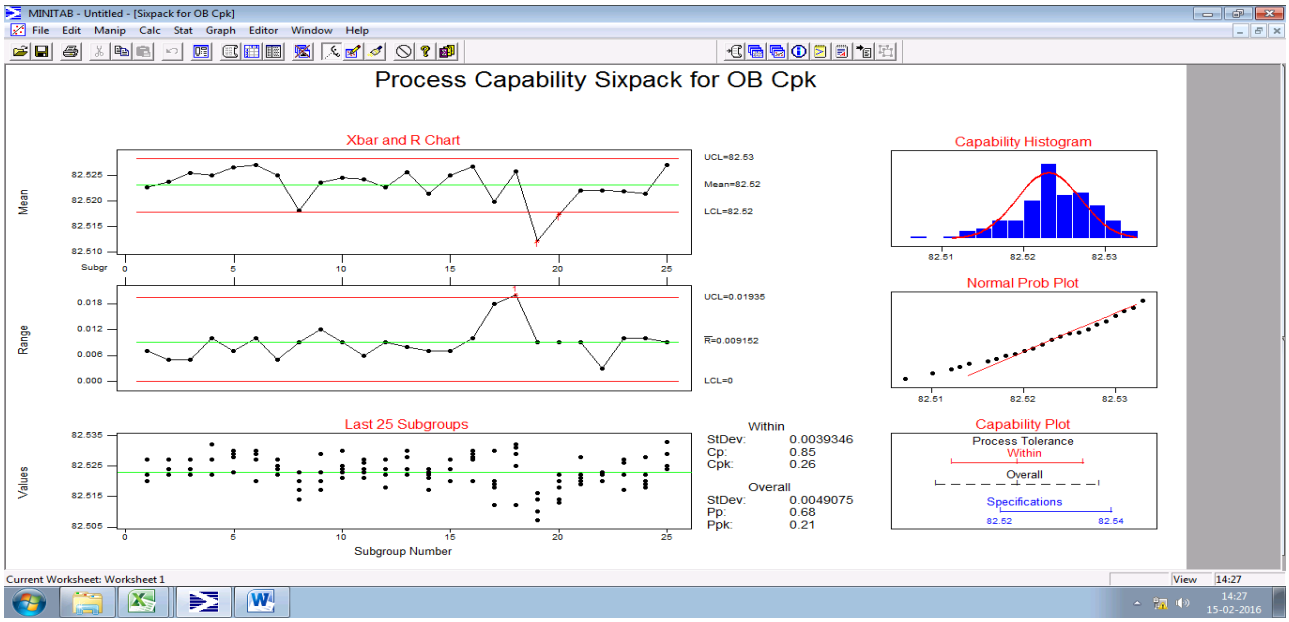

Figure 4.5: six pack normal of OB

Interpretation-From the above figure, it is clearly evident that the Cpk obtained is 0.26 which is lesser than 1.33 and ppm is 265945.02 which is really not an appreciable process. Also from the probability plot, it can be noticed that the process tolerance "within "and "overall" is lying outside the specifications and hence this process is not capable. From the R chart, it can be seen that a subgroup is falling out of the USL. In those situations, a new set of subgroups has to be recorded with a gap of certain interval of time. Also, Cp is 0.85 which is greater than Cpk.

4.3 Method of Investigation - Centre Less Grinding Process

There are four noteworthy causes out of 6M's for deviation and most likely are man, machine,method and material.

1) Machine Investigation report
2) Material investiagtion
3) Method and
4) Man/operator

4.3.1 MACHINE INVESTIGATION REPORT

There are totally six different parameters on which the centerless grinding machine was relying on and are; rough grinding, semi finish grinding, finish grinding, speed of the grinding wheel, regulating wheel speed, dressing frequency

The standard of the process was referred from the machine catalogue and the observed was noted down to compare with the standard.

Table 4.3: Process parameters and finding in the machine

Process Parameters and Findings					
Process Parameter	**standard**	**observed**	**Conclusion**	**correction**	**permanent action**
Rough Grinding	1.1 to 1.5 mm/min	1.5mm/min	Ok	Nil	Nil
Semi finish grinding	0.75 to 1.2 mm/min	1.0mm/min	Ok	Nil	Nil
finish grinding	0.4 to 0.6 mm/min	0.45mm/min	Ok	Nil	Nil
Grinding wheel speed	1050 to 1150 RPM	1070rpm	Ok	Nil	Nil
regulating wheel speed	16 to 18 RPM	16rpm	Ok	Nil	Nil
dressing frequency	1in 10no's	ok	Ok	Nil	Nil

From the above table, it is very evident that there is No fault in the machine since the observed characteristics of the machine lies within the standard.

Material Investigation: Inward inspection department is the one which receives the casted parts from its external suppliers. After receiving the casted parts, the material inspection was carried out. Its respective hardness number and the material composition was found OK with the assistance of the inward inspection officer.

Method of Measurement: Before the measurement of the product was carried out, the gauges were calibrated and was set to the mean of the USL and LSL so that the deflection could be measured in the dial if the pointer was running out of zero in the dial.

Man: Operators were qualified and trained, but had few flaws in them. Operators were just trained to handle the products and operate the machine, rather had no knowledge of the tolerance zone in which they were working.

4.4 CAUSE IDENTIFIED AFTER INVESTIGATING THE PROCESS FOR ITS LOWER CPKVALUE

Model 10 TG is a kind of variety in the axle housing and the study with respect to the same model is declared below. Before optimization or improvement measures was implemented, the diameter of the Inner Bearing was noted to be 95.245mm and 95.212mm as USL and LSL. Likewise, the diameter of the outer bearing was noted to be 82.540mm for USL and 82.520 as LSL. The major causes which was identified is shown below.

A) Operator had the Liberty of working at the tolerance zone at a Maximum of 33 microns, when the machine itself can perform at a tolerance zone of 10micron, as per the machine specification catalogue. Below table shows the tolerance zone of inner bearing and Outer bearing before optimisation.

B)

Table 4.4: Bearing Diameter Specification and Tolerance before Optimization

BEARING DIA SPECIFICATIONS - BEFORE OPTIMISATION						
MODEL	**IB DIA**			**OB DIA**		
	USL	**LSL**	**TOL**	**USL**	**LSL**	**TOL**
10TG	95.245	95.212	0.033	82.540	82.520	0.020

C) Unequal Thermal Expansion and Contraction of the Spindle -The subsequent process after the Centre less Grinding process, the heat generated lead to the thermal expansion at an unequal rate of contraction after cooling. The major process which affected the thermal expansion was Bracket Welding which is the final process of the housing line Manufacturing.

A Study of few samples at Bracket Welding Process which was the last process in the Housing line manufacturing revealed that there was an increase in diameter by 10-15 microns due to unequal thermal expansion and contraction.

4.5 MEASURES TAKEN TO IMPROVE THE CPK VALUE

A) New Tolerance zone has been created after optimisation which is 12microns. By this, the operator had to maintain the tolerance within 12microns.

Table 4.5: Bearing Diameter Specification and Tolerance after Optimization

BEARING DIA SPECIFICATIONS- After Optimization						
MODEL	**IB DIA**			**OB DIA**		
	USL(mm)	**LSL(mm)**	**TOL(mm)**	**USL(mm)**	**LSL(mm)**	**TOL(mm)**
10G	95.230	95.215	**0.015**	82.536	82.524	**0.012**

B) As per the study Conducted W.R.T to the second identified cause i.e. Unequal thermal expansion and contraction, it is evident that there is a deviation of 10-15 microns. With respect to the same deviation, new control limits have been defined to keep the process in control. The control limits refined to 95.230 for the USL and 95.215 for the LSL for the Inner Bearing seating diameter. Similarly, new control limit 85.236 and 82.524 was applied for the Outer Bearing seating diameter on the spindle. The new control limits which has been prepared and is being used by the operators after Optimization is as shown figure below.

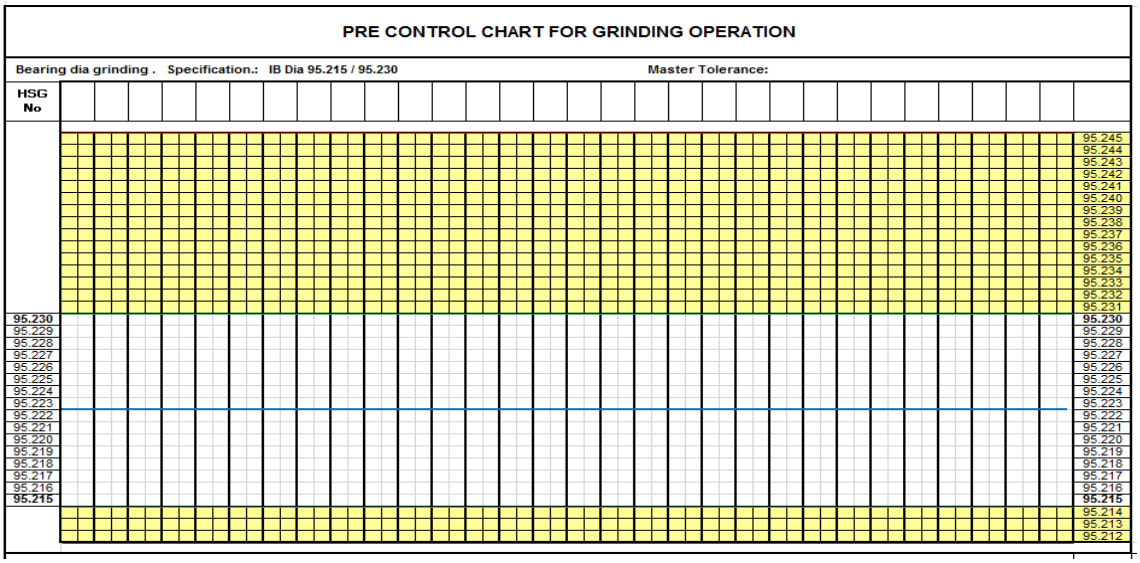

Figure 4.6: Pre-control chart for inner bearing after improvement

It is evident from the above figure that the operators had the liberty to work in a specification range of 95.212-95.245 mm for inner bearing which has a tolerance zone of 33 microns (both yellow/shaded and white/unshaded zone).

After the study conducted at the bracket welding process and applying the optimized control limits, the operators were supposed to work in the white zone/unshaded region. The operators were insisted to work in LSL zone (95.215-95.222 mm) so that, at the worst case of expansion and contraction due to thermal effect, the diameter could not exceed the USL i.e. 95.230mm. The same follows for the inner bearing control chart with respect to its specifications as shown below.

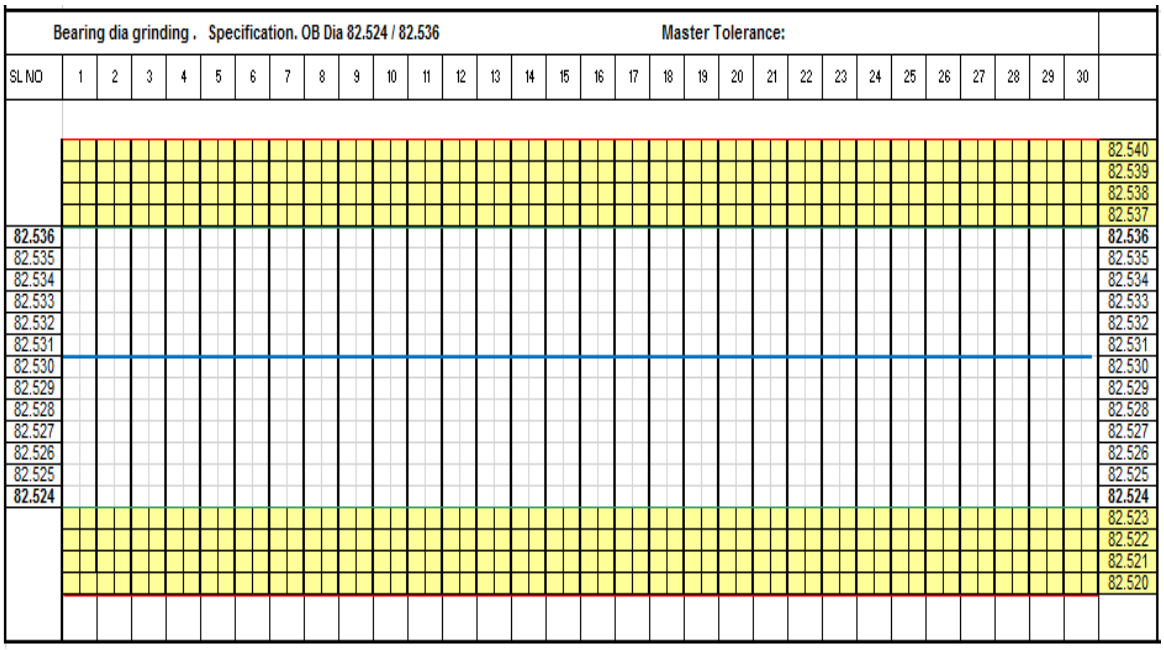

Figure 4.7: Pre-control chart for inner bearing after improvement

Further after the implementation of the new control charts and optimization, a re-study has been conducted at the center less grinding process in order to verify the improvements efforts made and to check the Improved Cpk value.

The same methodology of the process capability study has been re carried out and is analyzed using Minitab software as shown below to check the capability of the machine after improvement.

4.6 RESTUDY OF CENTERLESS GRINDING PROCESS

The process has been restudied so as to ensure that improvement efforts are made worthy and the capability of the process is improved.

4.6.1 CASE STUDY 2 (A) - AFTER IMPROVEMENT MEASURES IMPLEMENTED

The data collected is as shown below

Table 4.6: Data Collection of Inner Bearing Diameter

Part name	Housing
Process	IB Grinding
Specification	95.215-95.230 mm
Measurement method	Dial Gauge
Machine name	Grinding Bay-1

Sl. No	*Readings (mm)*	*Sl. No*	*Readings (mm)*	*Sl. No*	*Readings (mm)*	*Sl. No*	*Readings (mm)*
1	95.222	**33**	95.227	**65**	95.224	**97**	95.220
2	95.221	**34**	95.224	**66**	95.224	**98**	95.220
3	95.221	**35**	95.226	**67**	95.227	**99**	95.220
4	95.222	**36**	95.224	**68**	95.224	**100**	95.220
5	95.220	**37**	95.223	**69**	95.227	**101**	95.219
6	95.219	**38**	95.227	**70**	95.221	**102**	95.220
7	95.219	**39**	95.224	**71**	95.222	**103**	95.219
8	95.223	**40**	95.223	**72**	95.220	**104**	95.222
9	95.224	**41**	95.226	**73**	95.221	**105**	95.224
10	95.224	**42**	95.224	**74**	95.221	**106**	95.224
11	95.225	**43**	95.223	**75**	95.219	**107**	95.224
12	95.222	**44**	95.225	**76**	95.221	**108**	95.219
13	95.221	**45**	95.222	**77**	95.221	**109**	95.220
14	95.223	**46**	95.222	**78**	95.220	**110**	95.224
15	95.219	**47**	95.223	**79**	95.220	**111**	95.226
16	95.221	**48**	95.221	**80**	95.221	**112**	95.225
17	95.224	**49**	95.226	**81**	95.221	**113**	95.224
18	95.224	**50**	95.222	**82**	95.220	**114**	95.223
19	95.220	**51**	95.226	**83**	95.220	**115**	95.224
20	95.221	**52**	95.223	**84**	95.221	**116**	95.224
21	95.224	**53**	95.223	**85**	95.221	**117**	95.221
22	95.226	**54**	95.222	**86**	95.220	**118**	95.221
23	95.224	**55**	95.223	**87**	95.220	**119**	95.219
24	95.226	**56**	95.224	**88**	95.221	**120**	95.221
25	95.224	**57**	95.227	**89**	95.224	**121**	95.222
26	95.224	**58**	95.225	**90**	95.221	**122**	95.220

27	95.224	**59**	95.227	**91**	95.222	**123**	95.221
28	95.224	**60**	95.224	**92**	95.220	**124**	95.220
29	95.227	**61**	95.227	**93**	95.221	**125**	95.223
30	95.223	**62**	95.223	**94**	95.220		
31	95.226	**63**	95.227	**95**	95.220		
32	95.224	**64**	95.223	**96**	95.219		

Minitab Analysis Results: The graphs below explain the results of the analysis performed in Minitab software with the help of the data as shown table 4.6

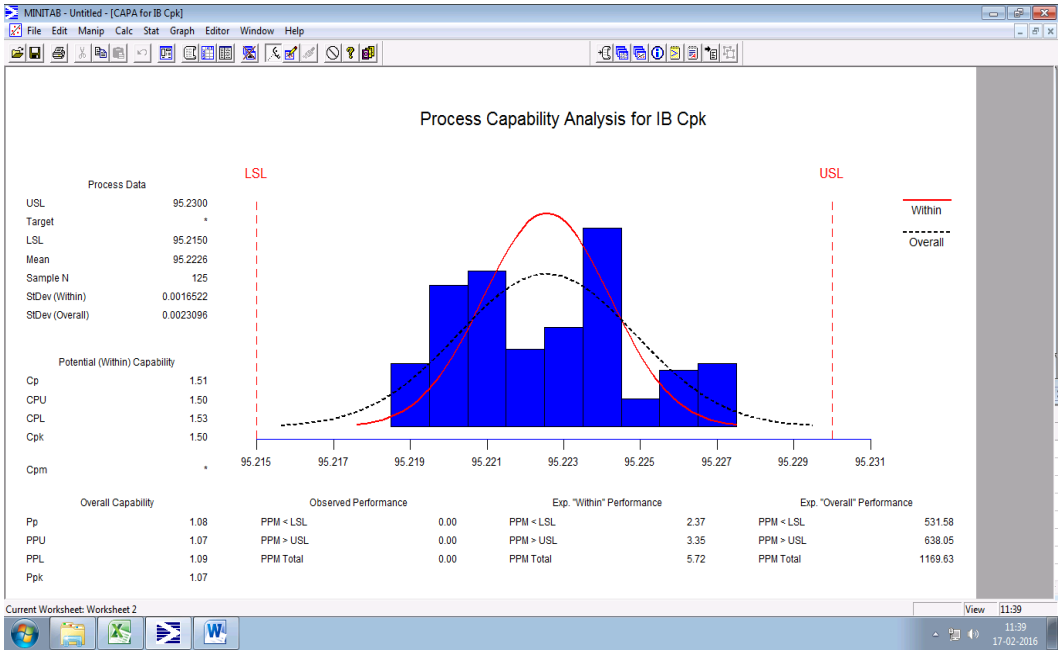

Figure4.8: process capability index of Inner bearing diameter

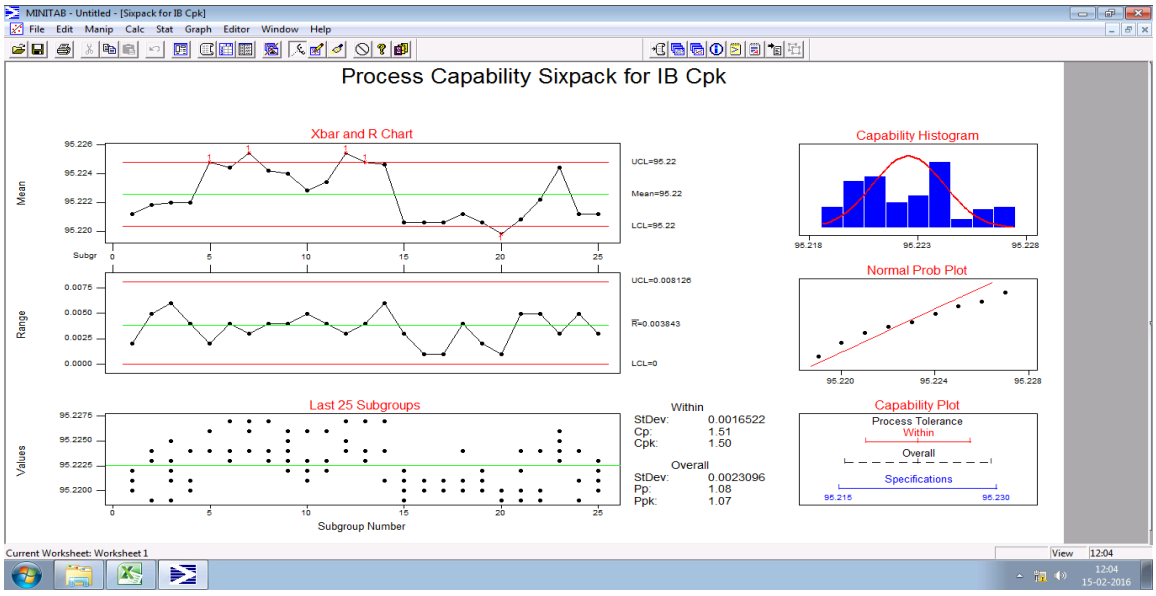

Figure 4.9: six pack normal of inner bearing diameter

Interpretation-From the above figure, it is clearly evident that the Cpk obtained is 1.50 which is greater than 1.33 and ppm is 1169.63 which is really an appreciable process. Also from the probability plot, it can be noticed that the process tolerance "within "and "overall" is lying within the specifications and hence this process is capable. From the X bar chart, it can be seen that a subgroup is falling out of the USL. In those situations, a new set of subgroups has to be recorded with a gap of certain interval of time. Also, Cp is 1.51 which is greater than Cpk. The ppm obtained is 1169.63 is acceptable as compared with the study performed before improvement with respect to the process.

4.6.2 CASE STUDIES 2 (B) AFTER IMPROVEMENT MEASURES IMPLEMENTED

Table 4.7: Data Collection of Outer Bearing Diameter

Part name	Housing
Process	OB Grinding
Specification	82.524-85.536 mm
Measurement method	Dial gauge
Machine name	Grinding Bay-1

Sl. No	*Readings (mm)*	*Sl. No*	*Readings (mm)*	*Sl. No*	*Readings (mm)*	*Sl. No*	*Readings (mm)*
1	82.528	**33**	82.528	**65**	82.528	**97**	82.529
2	82.529	**34**	82.529	**66**	82.529	**98**	82.528
3	82.528	**35**	82.529	**67**	82.527	**99**	82.529
4	82.527	**36**	82.526	**68**	82.529	**100**	82.528
5	82.528	**37**	82.530	**69**	82.527	**101**	82.529
6	82.529	**38**	82.527	**70**	82.528	**102**	82.528
7	82.528	**39**	82.528	**71**	82.529	**103**	82.529
8	82.529	**40**	82.527	**72**	82.529	**104**	82.530
9	82.528	**41**	82.528	**73**	82.529	**105**	82.529
10	82.530	**42**	82.530	**74**	82.528	**106**	82.527
11	82.528	**43**	82.528	**75**	82.529	**107**	82.528
12	82.529	**44**	82.530	**76**	82.526	**108**	82.527
13	82.529	**45**	82.530	**77**	82.527	**109**	82.529
14	82.530	**46**	82.529	**78**	82.526	**110**	82.529
15	82.527	**47**	82.528	**79**	82.528	**111**	82.526
16	82.527	**48**	82.528	**80**	82.529	**112**	82.527
17	82.530	**49**	82.527	**81**	82.526	**113**	82.528
18	82.528	**50**	82.529	**82**	82.530	**114**	82.527
19	82.530	**51**	82.526	**83**	82.527	**115**	82.528
20	82.527	**52**	82.529	**84**	82.529	**116**	82.528
21	82.529	**53**	82.527	**85**	82.527	**117**	82.530
22	82.527	**54**	82.530	**86**	82.527	**118**	82.529
23	82.528	**55**	82.529	**87**	82.527	**119**	82.528
24	82.529	**56**	82.528	**88**	82.528	**120**	82.529
25	82.527	**57**	82.528	**89**	82.529	**121**	82.528
26	82.528	**58**	82.529	**90**	82.526	**122**	82.528
27	82.529	**59**	82.527	**91**	82.529	**123**	82.528
28	82.527	**60**	82.529	**92**	82.528	**124**	82.530
29	82.529	**61**	82.529	**93**	82.529	**125**	82.528

30	82.528	**62**	82.530	**94**	82.528
31	82.530	**63**	82.528	**95**	82.528
32	82.529	**64**	82.529	**96**	82.529

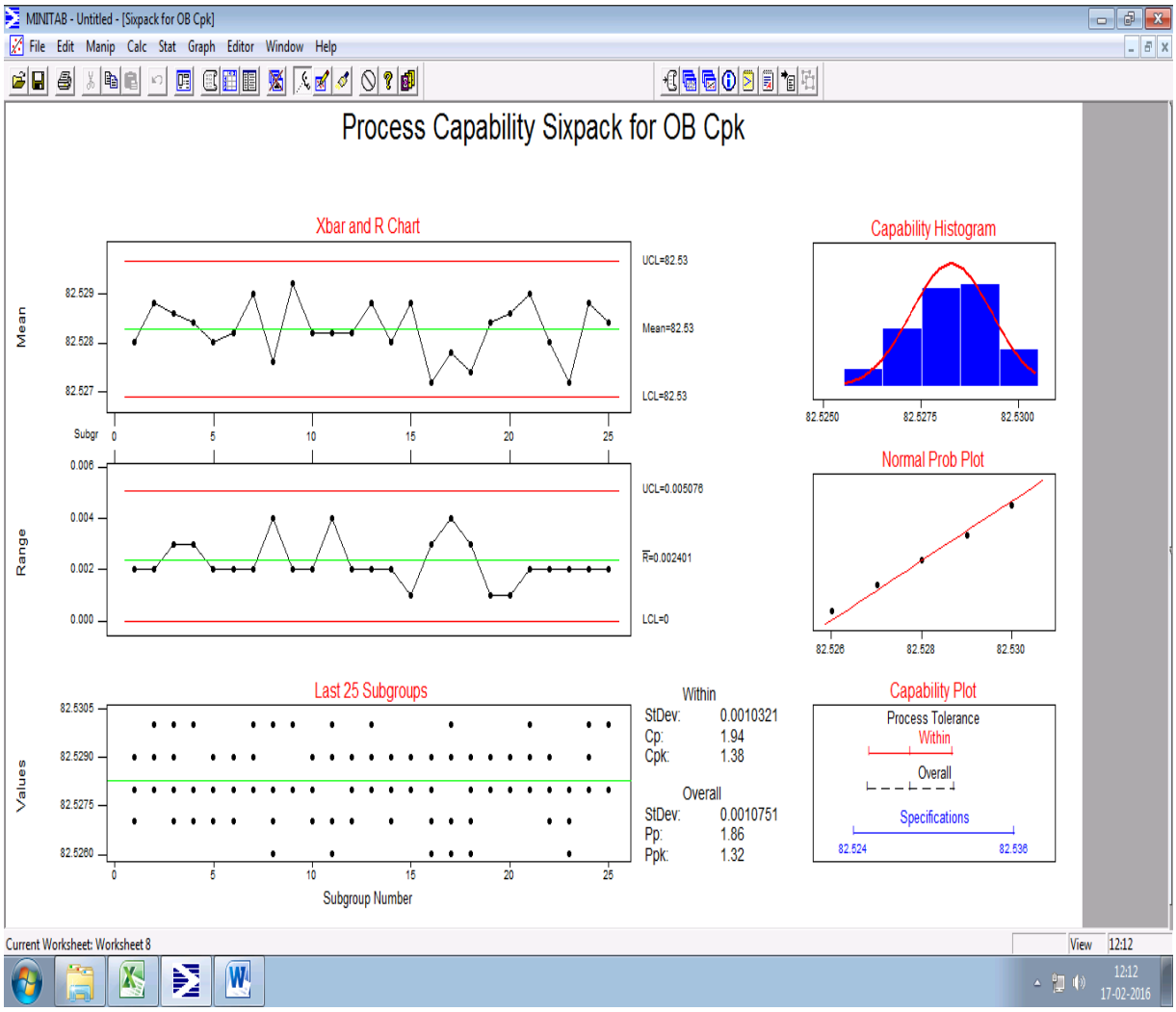

Fig 4.10: six pack normal for outer bearing diameter

Interpretation-From the above figure, it is clearly evident that the Cpk obtained is 1.538 which is greater than 1.33 and ppm is 749.86 which is really an appreciable process. Also from the probability plot, it can be noticed that the process tolerance "within "and "overall" is lying within the specifications and hence this process is capable. From the X bar chart and R chart it can be seen that a NO subgroup is falling out of the USL/LSL.

V. RESULTS AND CONCLUSION

This section concludes briefly the work carried out at Axle Manufacturing Company. The list of the work carried out is shown in the tabular format and its respective results after the study is put up for better and easy understanding.

Table 5.1: Operations and Its Respective Cpk Before and After Improvement

Sl. No	Operation	Characteristics	Before Cpk	Cpk Ok/Not OK	Cpk after Improvement
1	*Grinding*	*Spindle Inner Bearing Diameter*	*1.15*	*Not ok*	*1.50*
		spindle outer bearing diameter	*0.26*	*Not ok*	*1.38*

The targets which have been accomplished to improve the fundamental goal of the task are

1. A study has been conducted with proper measures and standards for the present and future capability of the process to deliver product inside specification in the organization.
2. Centre less grinding process has been investigated so that the product created by the organization meet the customer's specification. The problem identified was unequal thermal expansion and contraction of the spindle due to the heat produced in subsequent process.
3. The same centre less grinding machine has been re studied to cross check the process capability index and to predict the performance of the process for a period of time.

As per the study conducted during the period of project, it is evident from the above table that the Cpk values are appreciable and is above 1.33 as per standard.

REFERENCES

[1] Gopala Raju, V. D. (Oct 2005). "Cause and Affect Analysis as a means of Improving Quality and Productivity in a paper mill- A Case Study". *IIIE Journal, Vol 34, No. 10, pp 29-33.*

[2] Cheryl Hild, D. S. (2000-01). "Six Sigma on continuous processes: How &why it differs?". *Quality Engineering, Vol 13, No1, pp 1-9.*