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Implementation of Statistical Process Control Tools in Small Scale Industry for Productivity Improvement- A Case Study

Vishwajit V. Patil
Ashokrao Mane Polytechnic, Vathar
Corresponding Author:Mr. Vishwajit V. Patil,
Lecturer,
Ashokrao Mane Polytechnic, Vathar, India 416112

Abstract: *In current industrial era, smooth operation support is the necessity to survive in global competitive organizations. Statistical Process Control (SPC) is the key factor in strong operation support. It includes the implementation of statistical tools for observing and control of industrial processes. Some factual information and knowledge of the process is the base for smooth SPC execution. It is not a big issue for large scale industries. It is difficult to observe and control the process using SPC tools in small scale industries. This paper reflects the case study in which SPC tools are implemented in pump machining industry in order to reduce process variability and improve productivity.*

Keywords: *Improve Productivity; Operation Support; Reduce Process Variability; Statistical Process Control SPC; SPC Tools*

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I. Introduction

Statistical methods are analytical tools that can be used to evaluate machines, processes, materials and measurement methods for their capabilities. Evaluation obtained by these methods assist in maintaining desired results by using past history to predict capabilities and trends. [1] Statistical methods can be used as management tools which provide feedback for all levels in manufacturing operations for appropriate action. Statistical control methods help to inform us weather the process is operating at satisfactory level or not. If the process level not satisfactory, type of corrective actions is necessary to correct problems in our product or service. [2]

Every part having some critical characteristics which having precisely maintains; these critical characteristics are suggested from the customer. If critical characteristics are not maintained that affect component specifications which further leads to rejection. This product conformity to specific standards can be controlled through SPC tools. Thus, SPC Analysis is the need of every manufacturing process having critical characteristics in order to reduce process variation and improve product quality. Pump machining industry is developing new component that is Impeller Casing. In this paper SPC Analysis and implementation is done in house in which surface finishing process of Impeller Casing of pump is analyzed by SPC Tools and corrective actions are suggested for process improvement.[3]

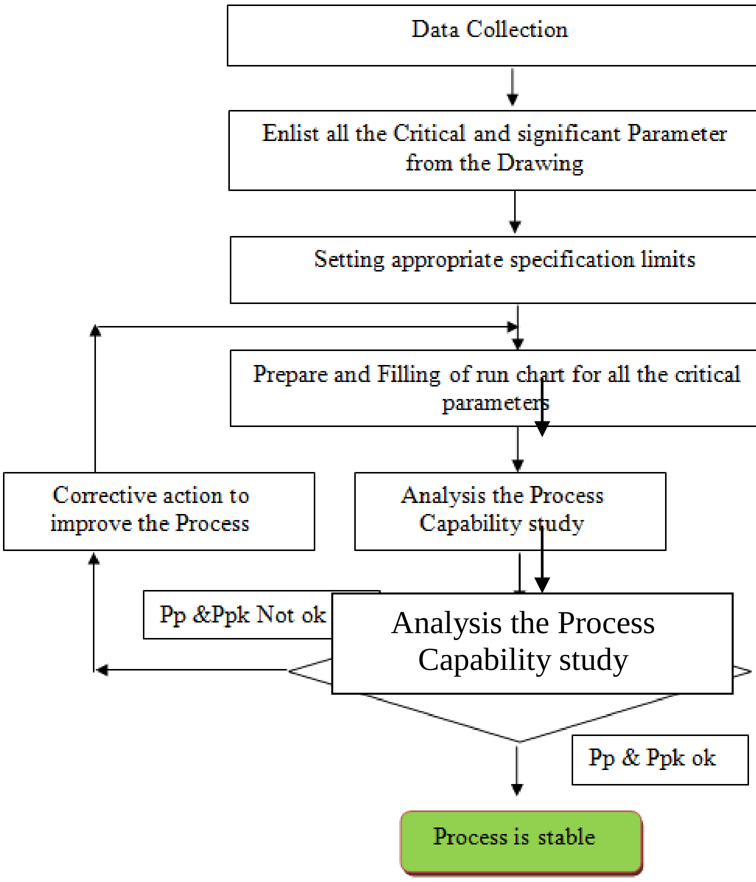


Figure 1: Flow Chart of Statistical Process Control Tools Implementation in Industry

II. CASE STUDY

2.1 Company Profile: -

The project has been done in small scale pump machining industry. The company has ISO9001:2015 quality management system. Company is main supplier of pump machining components and developing new pump component first time inhouse. The objective of the project is to analyse the process which is operating in limit or not using SPC Tools and suggest the corrective action if the process is not stable.[4]

Table 1 Part Information

SR. NO.	PART NAME	CRITICAL PARAMETER	OPRATION NUMBER	CHARACTER	SPECIFICATION	REQUIRED VALUE
1	MOTOR ADAPTOR IMPILLER CASING LX 30B	A	300	<SC>	SURFACE FINISH	Ra0.8

2.2 Activities performed by the Team: -

During the case study, Surface Finish of Impeller Casing LX30B is considered as critical parameter and process was analysed using SPC Tools by the team. Following activities were performed during the case study: -

- Prepared Part wise Inspection Plan for Machining parameter.
- Prepared Run chart for machining parameter.
- Prepared SPC format and analysed the result.
- Understood Calculation for Process Capability (Pp) & Process Capability Index (Ppk).
- Implemented SPC Tools as process was operating out of Limit and analysed the result.

2.3 Elements of Statistical Process Control in Industry:

A) Significant or Critical Values:

Critical dimension is subjective, based upon the function of the particular component being inspected. Function and fit requirement for the part critical print dimension. Non critical dimension are normally areas of the part that do not come into close proximately to marring assembly component, and that do not impact the design intent or the overall performance of the part. This Critical dimension are indicating with the various method like

<SC> =Significant Characteristics ▼ = Critical Characteristics

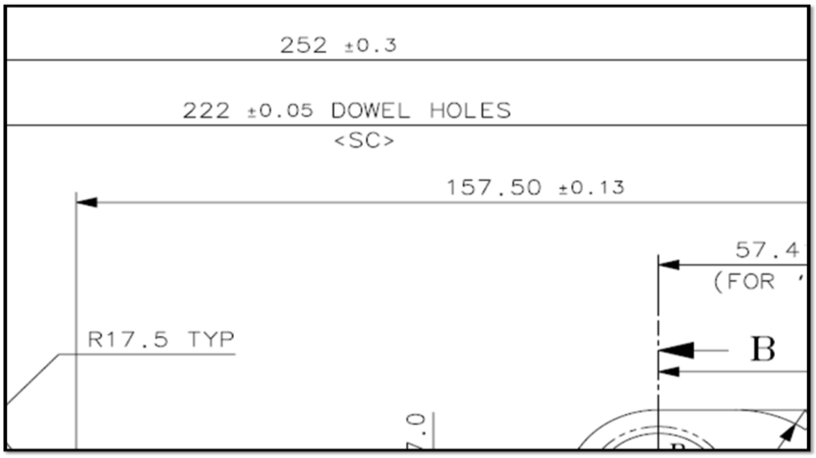


Figure 2 Representation of significant characteristic on drawing

In pump machining industry Surface finish of Impeller casing is considered as significant characteristic and the process is monitored using SPC Tools.

B) Run Chart

A run chart represents observations of measurable performance parameters in a proper sequential order. Run chart is divided into two main types including:

- Variable Control Charts
- Attribute Control Charts

Variable Control Chart: In this type of chart the Amount which can be measured is considered and information is collected. Examples: - Weight, Height, Speed, Volume. In the Variable control chart following types are available

- X-Bar chart
- R chart
- MA chart

Attribute Control Chart: These charts represent the quality parameters of a process which indicates process is operating at satisfactory level or not. In the Attribute control chart following types are available

- P chart
- C Chart
- U Chart

In pump machining industry, X bar and R chart was used to observe and control the process parameters. The applicability of X bar and R chart is valid only under normally distributed variables. During SPC Implementation in industry, surface finishing operations of Impeller Casing was observed. The recorded values were used to find out the range and mean of the process using X bar and R chart. [5]

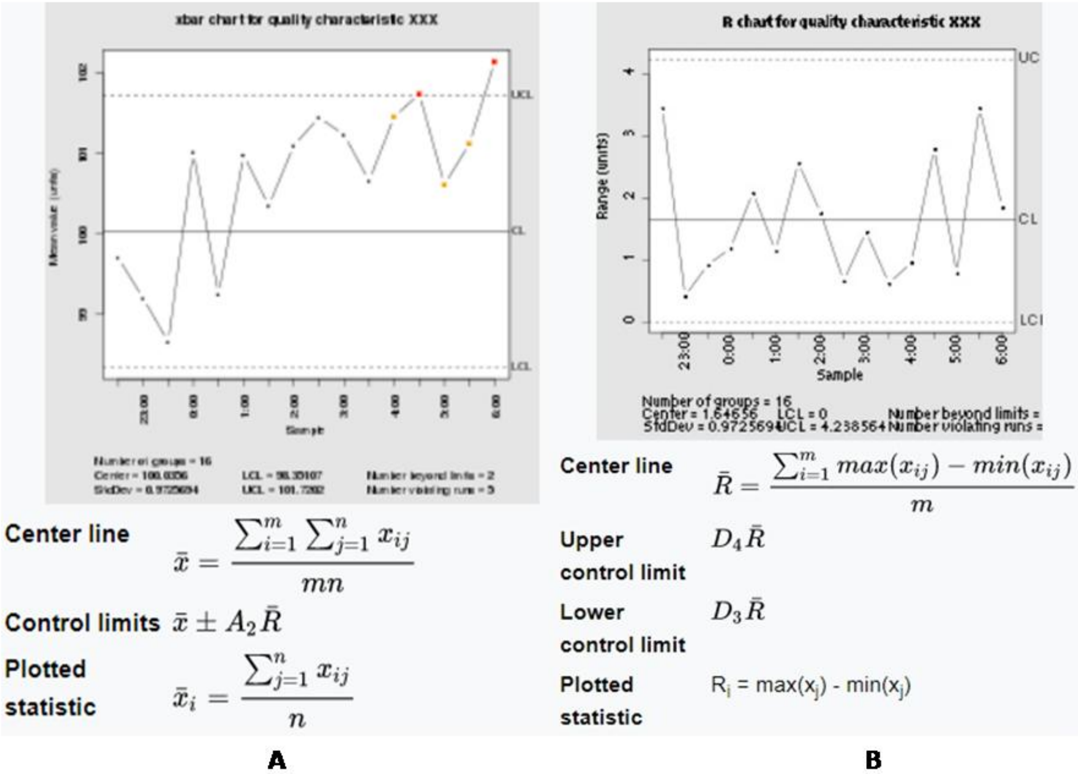


Figure 3: Method of Preparation of X-Bar and R chart

C) Process Capability (Pp) & Process Capability Index (Ppk):

The Process capability (Pp) and Process capability index (Ppk) is used to monitor the process which indicates product conformity with required standards. It is mandatory for products having critical characteristics in order to control the process variation. The observed readings are put into the subgroups for calculating Ppk. For a process to operate in satisfactory level process capability index should be in between 1.33 and 1.67. If Ppk goes beyond these limits then the process is supposed to be improved and needs corrective action. [6] In pump machining industry surface finish readings were taken and put into 5 subgroups. Each subgroup contains 10 readings. SPC analysis of the machining process is done using input data. Process capability (Pp) and Process capability index (Ppk) of the process is calculated and the process is monitored. [7]

Table 2 Readings of Impeller Casing Surface Finish before SPC Implementation

PART NAME: - IMP CASING LX 30B CRITICAL PARAMETER: -SURFACE FINISH Ra 0.8					
SR.NO.	SUBGROUP 1	SUBGROUP 2	SUBGROUP 3	SUBGROUP 4	SUBGROUP 5
1	0.100	1.460	2.100	0.1	0.14
2	0.160	1.520	2.100	0.12	0.018
3	0.240	1.480	2.000	0.12	0.015
4	0.300	1.420	2.100	0.13	0.018
5	1.200	1.480	2.100	0.12	0.015
6	1.400	1.520	2.200	0.1	0.014
7	1.420	1.600	2.100	0.13	0.015
8	1.420	1.600	2.000	0.12	0.02
9	1.440	1.500	2.200	0.12	0.012
10	1.400	2.100	2.100	0.12	0.018

STATISTICAL PROCESS CONTROL STUDY

PART NAME :	IMP.CASING LX30	INSTRUMENT :	SURFACE FINISH TESTER	L.COUNT :	0.0001		
PART NO. :	C 15769	SPECIFICATIONS	Ra 0.8	MACHINE :	VMC		DATE:
SAMPLE SIZE :	50 nos	OPERATION :	VMC MILLING	NO.OF DECIMALS:	4		

DATA COLLECTION: -

SNO.	1	2	3	4	5	6	7	8	9	10	U.T.L.	0.8000
1	0.100	0.160	0.240	0.300	1.200	1.400	1.420	1.420	1.440	1.400		
2	1.460	1.520	1.480	1.420	1.480	1.520	1.600	1.600	1.500	2.100		
3	2.100	2.100	2.000	2.100	2.100	2.200	2.100	2.000	2.200	2.100	L.T.L.	0.0000
4	0.100	0.120	0.120	0.130	0.120	0.100	0.130	0.120	0.120	0.120		
5	0.140	0.018	0.015	0.018	0.015	0.014	0.015	0.020	0.012	0.018		

SAMPLE	D2	A2	D4
1	1.123	2.560	3.270
2	1.128	1.880	3.270
3	1.693	1.020	2.570
4	2.059	0.730	2.230
5	2.326	0.590	2.110

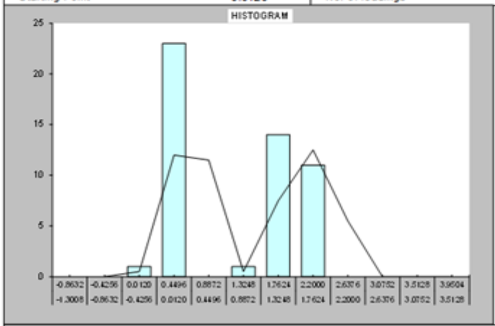
CALCULATIONS FOR HISTOGRAM : -

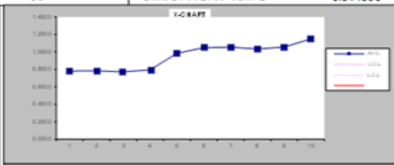
X_{LARGE}	2.1000	2.1000	2.0000	2.1000	2.1000	2.2000	2.1000	2.0000	2.2000	2.1000	Xmax. =	2.2000
X_{SMALL}	0.1000	0.0180	0.0150	0.0180	0.0150	0.0140	0.0150	0.0200	0.0120	0.0180	Xmin. =	0.0120
RANGE	2.0000	2.0820	1.9850	2.0820	2.0850	2.1860	2.0850	1.9800	2.1880	2.0820	R - BAR =	2.07550
AVG.	0.7800	0.7836	0.7710	0.7936	0.9830	1.0468	1.0530	1.0320	1.0544	1.1476	X - BAR =	0.9445

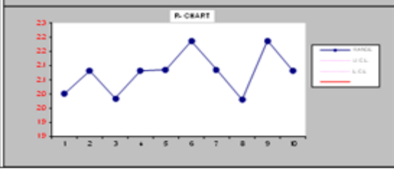
NO.OF NON CONFORMING PART =	26	NOS.
NO. OF PARTS ABOVE U.T.L. =	26	NOS.
NO. OF PARTS BELOW L.T.L. =	0	NOS.

Process Width (P) =	2.1880	Specification Width(S) =	0.800000	Index (K)={2 x (D-XBAR)/S} =	1.3613
Design Centre (D) =	0.4000	Interval =	0.437600	Selecting no. of classes =	5
Starting Point =	0.0120	No. of readings =	50	Shift Of 'X-BAR' from 'D' =	0.544500

INTERVAL		FREQ.	CU. FREQ.
-1.3008	-0.8632	0	0
-0.8632	-0.4256	0	0
-0.4256	0.0120	1	1
0.0120	0.4496	23	24
0.4496	0.8872	0	24
0.8872	1.3248	1	25
1.3248	1.7624	14	39
1.7624	2.2000	11	50
2.2000	2.6376	0	50
2.6376	3.0752	0	50
3.0752	3.5128	0	50
3.5128	3.9504	0	50







U.C.L_{XBAR}	=	2.169045
L.C.L_{XBAR}	=	-0.280045
U.C.L_{RBAR}	=	4.379305
L.C.L_{RBAR}	=	0
Std.Dev."s"	=	0.86044
Pp=(S/6s)	=	0.15500
Ppk=(1-K)xPp)	=	-0.05610

CONCLUSION :- PROCESS IS VERY POOR TAKE IMMEDIATE ACTION

Figure 4: SPC Analysis of Impeller Casing Surface Finish Before SPC Tool Implementation The SPC Analysis Result of surface Finish Process Capability is 0.1550 which is less than 1.33 thus the process needs to improved and requires corrective action.

III. Implementation of SPC Tools:

Root Cause Analysis for the process variation is done using SPC Tools and the process is monitored. Following tools are suggested to the company top management for root cause analysis which includes:

- Pareto Chart
- 5 Whys
- Fishbone Diagram
- Scatter Diagram
- Failure Mode and Effects Analysis (FMEA)

We are taking participation in company top management and employee to solve this Problem. Company refers the fishbone diagram to find out cause of the problem.

Fishbone Diagram: Fishbone diagram also known as Cause-and-Effect diagrams represents causes for the specific problem with total effect. The problem is based on 4M point known as Man, Machine, Material, and Method as shown in diagram. Common causes for the poor surface finish are detected and corrective actions are suggested to company for process improvement.

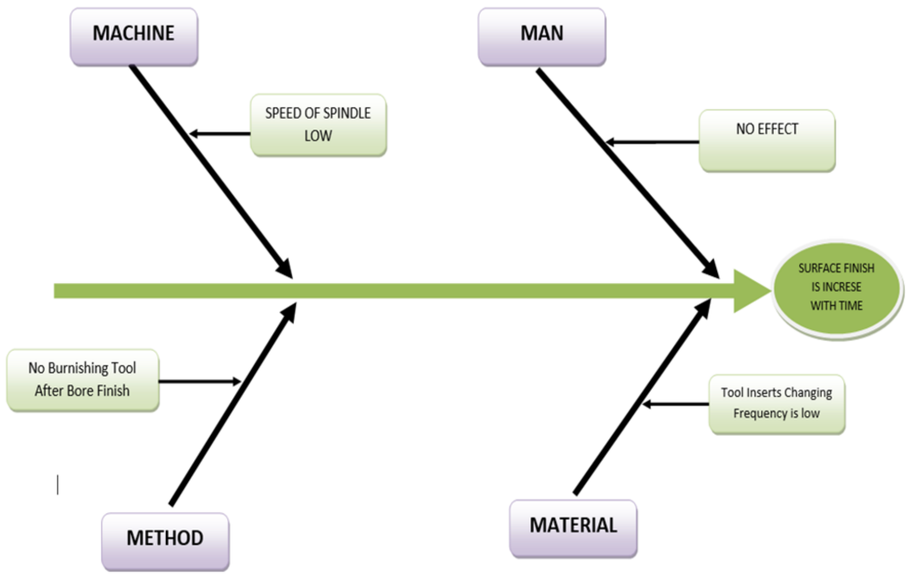


Figure 5: Root Cause Analysis-Fishbone Diagram

IV. Results and Discussion:

After doing root cause analysis following observations were recorded.

1. In case of machine effect, spindle speed was observed and it was 1200 rpm. Company team suggested increasing the spindle speed but as the part is eccentric after increasing the spindle speed up to 1800 rpm centrifugal force is generated which leads to vibration. Thus, the surface finish of the bore is affected. So, this process is not applicable to solve the problem.

2. In case of material effect, it was observed that tool changing frequency is low. After 30 no. part finish tool inserts were changed. We suggested changing the tool inserts after 15 no. part finish and it was observed that during changing of the inserts lots of time has been waste so loss of cycle time and production target not achieved.

3. Finally, in this method no any special surface finish process was added. But, after bore finishing burnishing tool was added which results in very good surface finish after analyzing.[8]

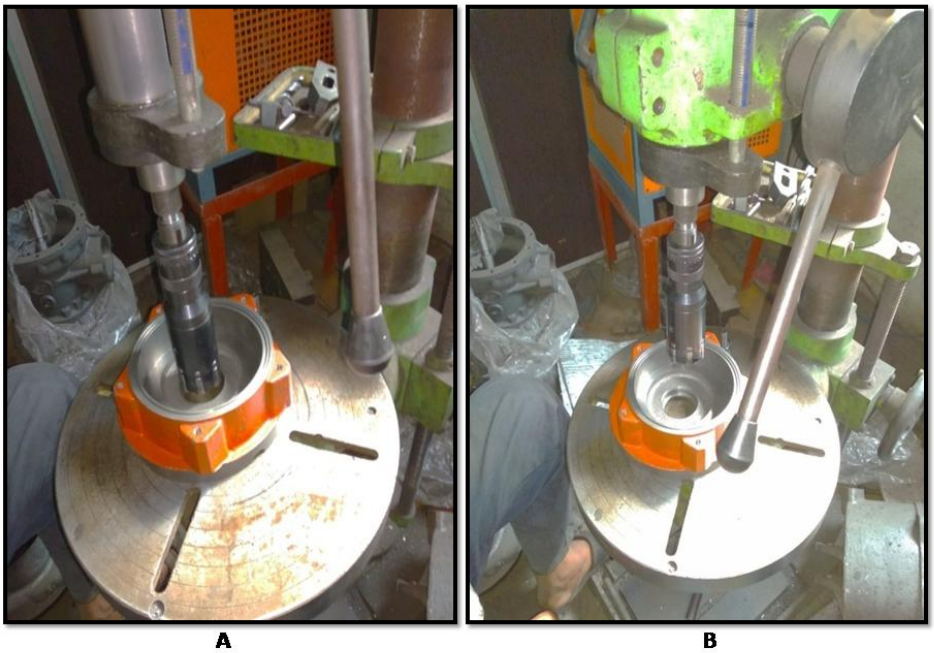
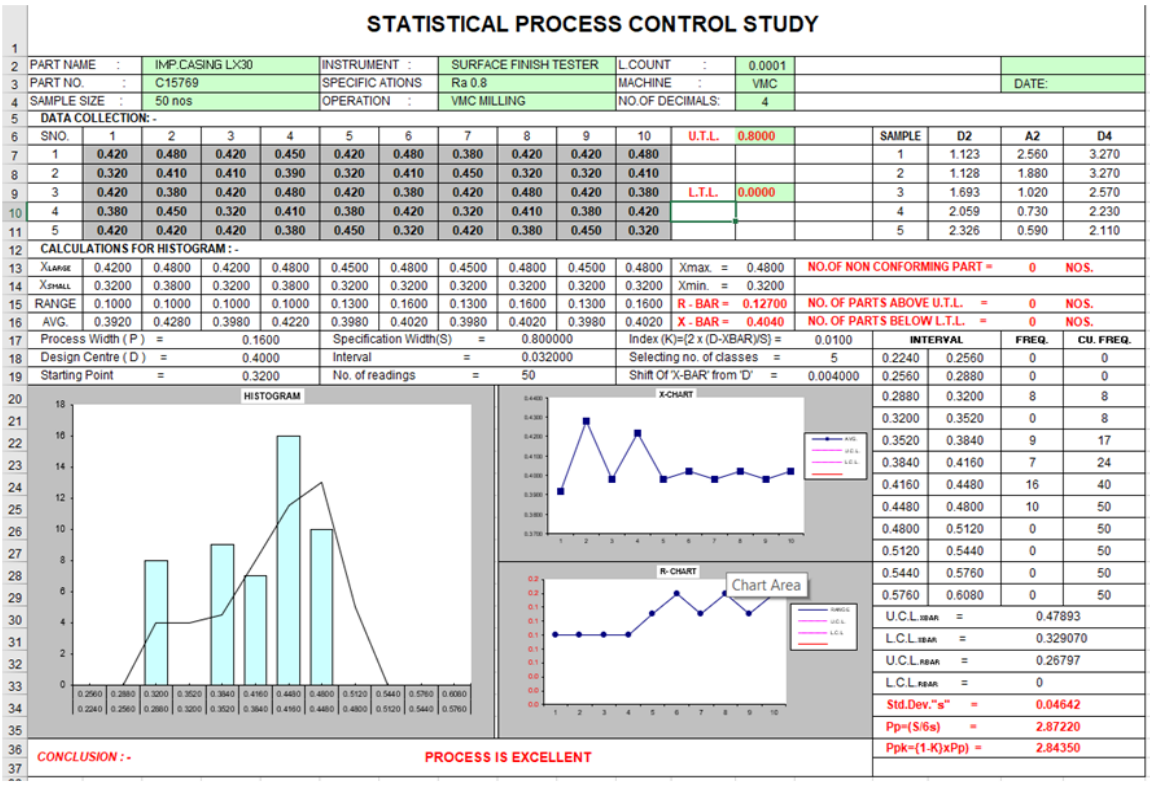


Figure 6 A. Burnishing tool pass through impeller **B.** Impeller Casing rest on the table

4. Burnishing tool improved the required surface finish of impeller casing.SPC analysis of the process is done after adding burnishing tool in the process. The values of Pp and Ppk are 2.87 and 2.84 which shows the process is operating in limit with high product quality and process stability.[9]

Table 3 Readings of Impeller Casing Surface Finish after SPC Tool Implementation

PART NAME: - IMP CASING LX 30B CRITICAL PARAMETER: -SURFACE FINISH Ra 0.8					
SR.NO.	SUBGROUP 1	SUBGROUP 2	SUBGROUP 3	SUBGROUP 4	SUBGROUP 5
1	0.420	0.320	0.420	0.380	0.420
2	0.480	0.410	0.380	0.450	0.420
3	0.420	0.410	0.420	0.320	0.420
4	0.450	0.390	0.480	0.410	0.380
5	0.420	0.320	0.420	0.380	0.450
6	0.480	0.410	0.380	0.420	0.320
7	0.380	0.450	0.420	0.320	0.420
8	0.420	0.320	0.480	0.410	0.380
9	0.420	0.320	0.420	0.380	0.450
10	0.480	0.410	0.380	0.420	0.320



STATISTICAL PROCESS CONTROL STUDY

PART NAME :	IMP.CASING LX30	INSTRUMENT :	SURFACE FINISH TESTER	L.COUNT :	0.0001		
PART NO. :	C15769	SPECIFIC ATIONS	Ra 0.8	MACHINE :	VMC		DATE:
SAMPLE SIZE :	50 nos	OPERATION :	VMC MILLING	NO.OF DECIMALS:	4		

DATA COLLECTION: -

SNO.	1	2	3	4	5	6	7	8	9	10		
1	0.420	0.480	0.420	0.450	0.420	0.480	0.380	0.420	0.420	0.480	U.T.L.	0.8000
2	0.320	0.410	0.410	0.390	0.320	0.410	0.450	0.320	0.320	0.410		
3	0.420	0.380	0.420	0.480	0.420	0.380	0.420	0.480	0.420	0.380	L.T.L.	0.0000
4	0.380	0.450	0.320	0.410	0.380	0.420	0.320	0.410	0.380	0.420		
5	0.420	0.420	0.420	0.380	0.450	0.320	0.420	0.380	0.450	0.320		

SAMPLE	D2	A2	D4
1	1.123	2.560	3.270
2	1.128	1.880	3.270
3	1.693	1.020	2.570
4	2.059	0.730	2.230
5	2.326	0.590	2.110

CALCULATIONS FOR HISTOGRAM : -

	1	2	3	4	5	6	7	8	9	10		
X_{LARGE}	0.4200	0.4800	0.4200	0.4800	0.4500	0.4800	0.4500	0.4800	0.4500	0.4800	Xmax. =	0.4800
X_{SMALL}	0.3200	0.3800	0.3200	0.3800	0.3200	0.3200	0.3200	0.3200	0.3200	0.3200	Xmin. =	0.3200
RANGE	0.1000	0.1000	0.1000	0.1000	0.1300	0.1600	0.1300	0.1600	0.1300	0.1600	R - BAR =	0.12700
AVG.	0.3920	0.4280	0.3980	0.4220	0.3980	0.4020	0.3980	0.4020	0.3980	0.4020	X - BAR =	0.4040

NO.OF NON CONFORMING PART = 0 NOS.
NO. OF PARTS ABOVE U.T.L. = 0 NOS.
NO. OF PARTS BELOW L.T.L. = 0 NOS.

Process Width (P) =	0.1600	Specification Width(S) =	0.800000	Index (K)={2 x (D-XBAR)/S} =	0.0100
Design Centre (D) =	0.4000	Interval =	0.032000	Selecting no. of classes =	5
Starting Point =	0.3200	No. of readings =	50	Shift Of 'X-BAR' from 'D' =	0.004000

INTERVAL		FREQ.	CU. FREQ.
0.2240	0.2560	0	0
0.2560	0.2880	0	0
0.2880	0.3200	8	8
0.3200	0.3520	0	8
0.3520	0.3840	9	17
0.3840	0.4160	7	24
0.4160	0.4480	16	40
0.4480	0.4800	10	50
0.4800	0.5120	0	50
0.5120	0.5440	0	50
0.5440	0.5760	0	50
0.5760	0.6080	0	50

$U.C.L._{XBAR}$ =	0.47893
$L.C.L._{XBAR}$ =	0.329070
$U.C.L._{RBAR}$ =	0.26797
$L.C.L._{RBAR}$ =	0
Std.Dev."s" =	0.04642
Pp=(S/6s) =	2.87220
Ppk={1-K}xPp) =	2.84350

CONCLUSION : - PROCESS IS EXCELLENT

Figure 7: SPC Analysis of Impeller Casing surface finish after SPC Tool Implementation

4.1 Graphical representation of Impeller Casing LX30B surface finish results before and after SPC Tools Implementation

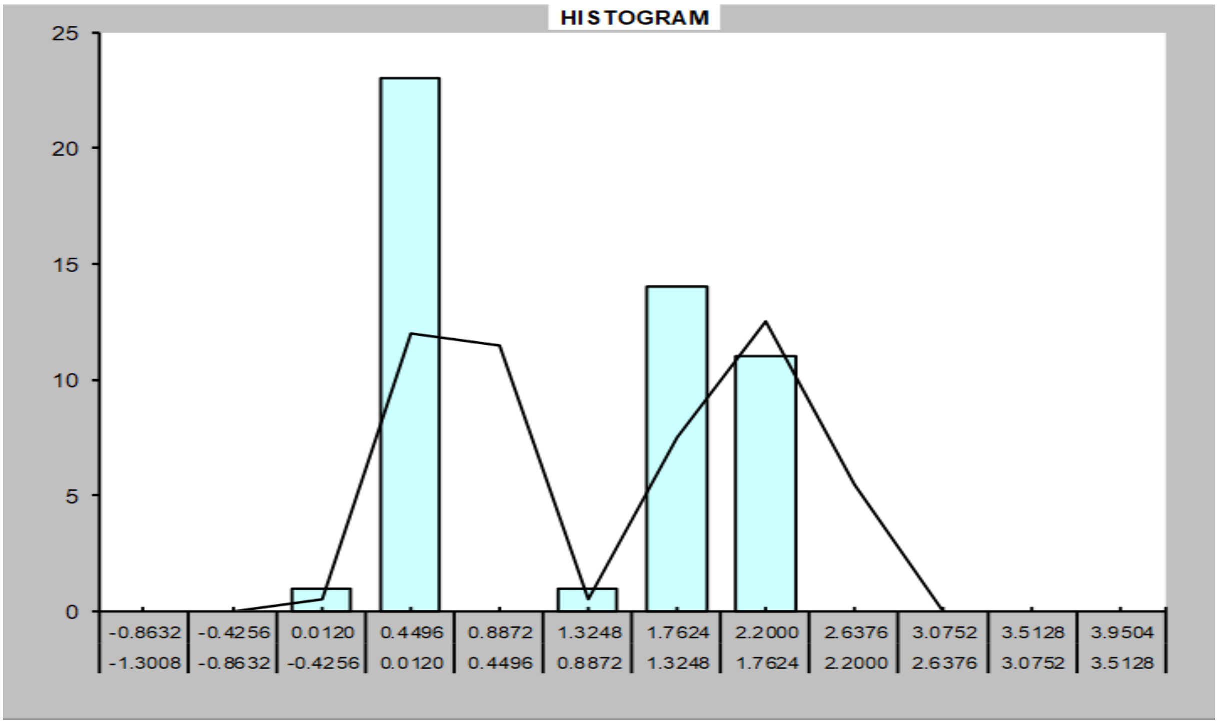


Figure 8: Impeller Casing LX30B Surface Finish Results before SPC Tools Implementation

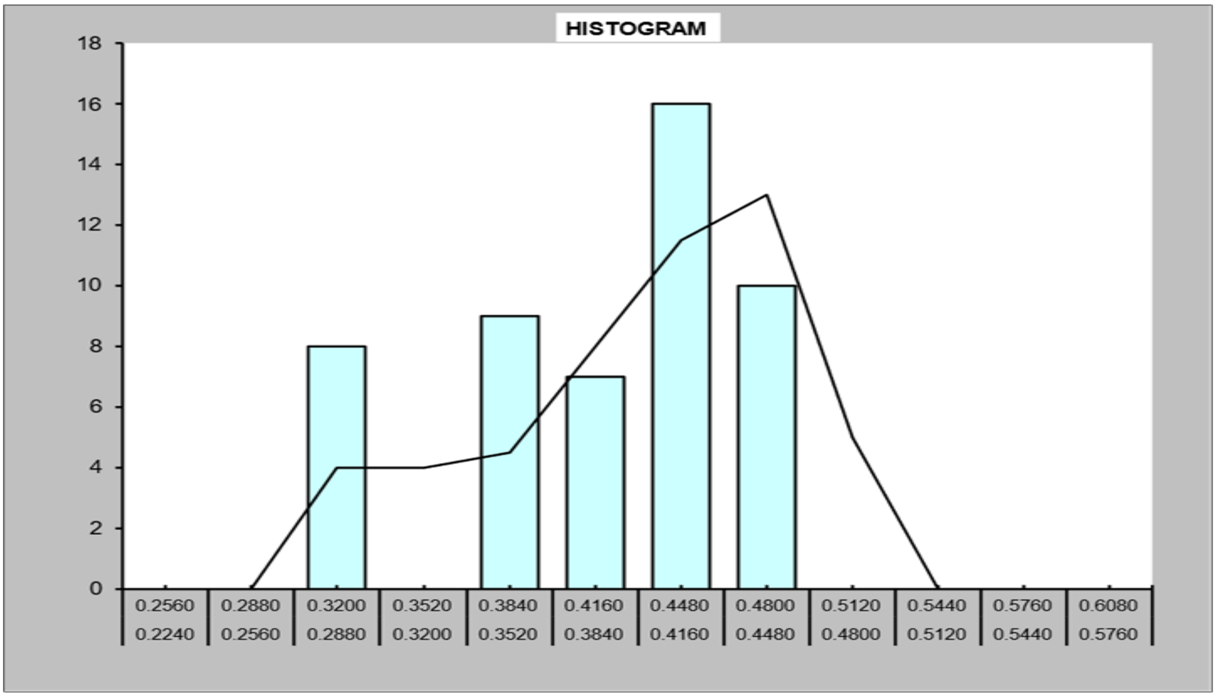


Figure 9: Impeller Casing LX30B Surface Finish Results after SPC Tools Implementation

4.2 Photograph of surface roughness measurement instrument used

Figure 10: Mitutoyo Surface Roughness Tester used for surface roughness measurement

V. Conclusion: -

- Before SPC Tools Implementation surface finish of Impeller casing LX 30B was very poor. Process capability (Pp) was 0.1550 which shows process is unstable and operating out of limit.SPC Tool Implementation increased the surface finish of the impeller casing LX 30B to the great extent with high quality, reduced process variability and having process capability 2.8720.
- During SPC Tools Implementation Fishbone Diagram was used to find out the root cause of the problem. The problem was observed under 4M points (Man, Machine, Material and Method) to find out causes of the problem. Burnishing Tool was added in the process as no any special surface finish method was used after bore finish. SPC results showed that the process was stable with high quality surface finish.
- From the above case study, it can be concluded that process conformity to require standards can be achieved using SPC Tools. SPC can be part of overall product quality improvement program. Top management involvement and employee support is the need of implementing SPC Tools.

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