Experimental Investigation on Process Capability & Process Capability Index in Grinding Machine

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Abstract – Quality is a state of a finished product, being free from defects, deficiencies and significant variations. This measure of an excellence can be brought about by the strict and consistent adherence to measureable and verifiable standards to achieve uniformity of output that satisfies specific customer or user requirements. This paper gives a proposed methodology for to increase the quality of a product manufactured in a grinding machine, using the various quality improvement tools like Cause and Effect diagram and Statistical Process Control Charts. The key note in using these tools is because of ease way to detect the problems and solutions for the same. The quality improvement is accompanied by the changes in machining parameters of a grinding machine and the optimization of those changes reflects as an increase in the acceptance level of the product in the world market.

Index Terms – Cause and Effect Diagram, Statistical Process Control Chart.

1. INTRODUCTION

1.1. POWER STEERING GEAR

Larger amount of torque is required to be applied by the driver for steering of vehicles. The power steering system provides automatic hydraulic assistance to the turning effort applied to the manual steering system. The power steering systems are operated by fluid under pressure. In the power steering the slight moment of the steering wheel actuates a valve so that the fluid under pressure from the reservoir enters on the appropriate side of a cylinder, thereby applying pressure on one side of a piston to operate the steering linkage, which steers the wheel in the appropriate direction.

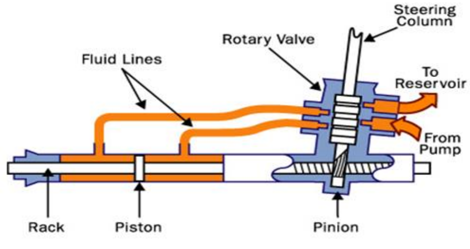

Fig 1.1.1 working of power steering gear

Fig.1.1.2. Photography assembly of steering gear

1.2 GRINDING MACHINE

A grinding machine is a machine, tool used for grinding, which is a type of machining using an abrasive wheel as the cutting tool. Each grain of abrasive on the wheel's surface cuts a small chip from the work piece via shear deformation.

Grinding is used to finish work pieces which must show high surface quality and high accuracy of shape and dimension. As the accuracy in dimensions in grinding is in the order of 0.000025mm, in most applications it tends to be a finishing operation and removes comparatively little metal, about 0.25 to 0.50mm depth. However, there are some roughing applications in which grinding removals high volumes of metal quite rapidly.

The grinding machine consists of a power driven grinding wheel spinning at the required speed and a bed with a fixture to guide and hold the work-piece. The grinding head can be controlled to travel across a fixed work piece or the work piece can be moved whilst the grind head stays in a fixed position. Very fine control of the grinding head or table's position is possible using a vernier calibrated hand wheel, or using the features of numerical controls.

In very high-precision grinding machines (most cylindrical and surface grinders) the final grinding stages are usually set up so that they remove about 200 nm (less than 1/100000 in) per pass - this generates so little heat that even with no coolant, the temperature rise is negligible

1.2.1. TYPES OF GRINDING MACHINE2 TY

Cylindrical grinder which include both the types that use centers and the Centre less types. A cylindrical grinder may have multiple grinding wheels. The work piece is rotated and fed past the wheel(s) to form a cylinder. It is used to make precision rods, tubes, bearing races, bushings, and many other parts.

Surface grinder which include the wash grinder. A surface grinder has a "head" which is lowered, and the work piece is moved back and forth past the grinding wheel on a table that has a permanent magnet for use with magnetic stock. Surface grinders can be manually operated or have CNC controls.

2. LITERATURE REVIEW

[1]Piyush kumar soni et.al., had discussed about the statistical process control, range and standard deviation, control charts, process capability in a paper named “process capability improvement by putting statistical process control’ into practice”. The value of Process Capability Index, as required by the customer, Delphi TVS, Chennai was greater than 2, and the process capability index we obtained after the implementation of SPC techniques is 2.71 which is greater enough than 2 therefore, we can say that the process is under control now and capable of producing all the components under the given specification limits with the very low normal distribution.

[2]K. Ghosh, imtiyaz khan et.al., in their work named “scrutinizing and improving process capability index by application of statistical process control and six sigma tools”, Statistical Process Control (SPC) is one of the tools to control the quality of products that practice in bringing a manufacturing process under control. The process capability (C_p) increased to 3.51 which show that implementation of SPC technique is proved to be successful in improving the performance of grinding process thereby making it more capable of producing the products with right dimensions. Capability Ratio (CR) is reduced to 0.28 which means that the process spread now occupies 28 % of the given tolerance. The lower is the CR the more is capable the process.

[3]Marija stanojeska et.al., in their wok is the replacement of existing dough divider with a new machine, provides reduction of the number of failures - 12,9% to2,3% of 1000 tested samples, so the process reached value of 5.99 Six Sigma.Introducing a statistical model of monitoring and quality control in the organization, will allow reducing variability in processes and products, which means reduction of waste, continuous improvement of the effectiveness of milling and baking processes and significantly enhance customer satisfaction.

[4]Goyat N.S et.al., ‘Introduction to quality engineering’ that says taguchi loss function concept is that whenever a product deviates from its target performance it generates a loss to society .This loss is minimum when performance is right on target, but it grows gradually as deviates from target.in this project the C_{pk} is increased from 1.67 to C_{pk}=2.1508 which is greater than 1 that means that the process variability is inside the range of specification. This means that the Process is capable of producing within specification and the process capability is excellent.

[5]R.Di Mascioa, et.al., ‘Premier on Taguchi Methods’ Taguchi concept says that manufacturer the best strategy is to produce as possible as close to the target as possible, rather than aiming at ‘being with specification’. The loss increases exponentially as the parameter value moves away from the target, and is at a minimum when the product (or) service is at target value.

3. PROCESS CAPABILITY STUDY

3.1. PROCESS CAPABILITY STUDY

A process is a unique combination of tools, materials, methods, and people engaged in producing a measurable output.

The Process Capability is a measurable property of a process to the specification, The output of this measurement is usually illustrated by a histogram and calculations that predict how many parts will be produced out of specification (OOS).

Formula for finding C_p= (USL-LSL)/6σ

Process capability is also defined as the capability of a process to meet its purpose as managed by an organization's management and process definition structures ISO 15504.

Process capability indices measure how much "natural variation" a process experiences relative to its specification limits and allows different processes to be compared with respect to how well an organization controls them.

If the upper and lower specification limits of the process are USL and LSL, the target process mean is T, the estimated mean of the process is μ and the estimated variability of the process is σ, then commonly-accepted process capability indices include:

Table 3.1 Interpretation of C_p & C_{pk}

Sl.no	Index	Description
1	$\hat{C}_p = \frac{USL - LSL}{6\hat{\sigma}}$	Estimates what the process is capable of producing if the process mean were to be centered between the specification limits. Assumes process output is approximately normally distributed.
2	$\hat{C}_{p,lower} = \frac{\hat{\mu} - LSL}{3\hat{\sigma}}$	Estimates process capability for specifications that consist of a lower limit only (for example, strength). Assumes process output is approximately normally distributed
3	$\hat{C}_{p,upper} = \frac{USL - \hat{\mu}}{3\hat{\sigma}}$	Estimates process capability for specifications that consist of an upper limit only (for example,

		concentration). Assumes process output is approximately normally distributed.
4	$\hat{C}_{pk} = \min\left[\frac{USL-\hat{\mu}}{3\hat{\sigma}}, \frac{\hat{\mu}-LSL}{3\hat{\sigma}}\right]$	Estimates what the process is capable of producing, considering that the process mean may not be centered between the specifications limits. (If the process mean is not centered, Cp overestimates process capability.) Cpk<0 if the process mean falls outside of the specification limits. Assumes process output is approximately normally distributed.

3.2. THE STUDY OF C_{pk}

The C_{pk} is a process capability index that measures the ability of process to produce product with in specification. The C_{pk} is the ratio of the distance between the actual process average and the closet specification limits over three times the standard deviation of the actual process. The process capability index measures degree of centering of the actual process spread with respect to the allowable spread.

The larger the index, the more stable the process is, the less likely that any item will be outside the specification. C_{PK} value of 1.33 is the industry standard of minimum acceptable level.

Formula for finding C_{pk}= MIN OF {(USL-μ)/3σ or (μ-LSL)/3σ}

Process Capability Study is considered the following 4M's:

1. Man
2. Machine
3. Method
4. Material

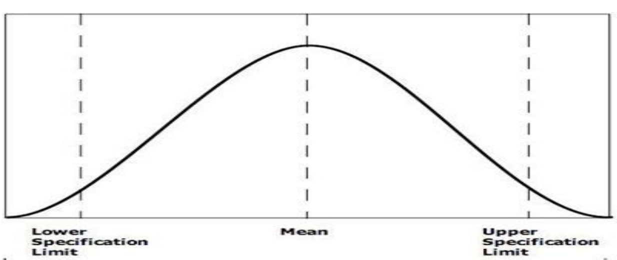

Fig3.1. Process Capability diagram

4. QUALITY CONTROL TECHNIQUES

4.1. QUALITY CONTROL TECHNIQUES

Quality control technique having following seven steps:

1) Problem: Identification of the problem.

2) Observation: Recognition of the features of the problem.

3) Analysis: Finding out the main causes.

4) Action: Action to eliminate.

5) Check: Confirmation of the effectiveness of the action.

6) Standardization: Permanent elimination of causes.

7) Conclusion: Review of the activities and planning for future work.

4.2. PROBLEM

4.2.1 Description

In the PR & P VALVE PLANT the outer diameter grinding of the input shaft component the C_p and C_{pk} value is less than the target in the Micromatic Grinding machine after the heat treatment.

4.2.2. Theme and Target

To improve C_p & C_{pk} >1.67 in the power rack & pinion valve Input Shaft outer diameter grinding in Microsmatic Grinding Machine.

4.3. OBSERVATION

Table 4.3 Machine Specification

Sl. no	MACHINE NAME	MICROMATIC OD GRINDING M/C
1	COMPONENT	POWER RACK & PINION INPUT SHAFT
2	COMPONENT DIMENSION	19.0550 mm ± 0.025 mm
3	WHEEL GRADE	19A60KVS3
4	WHEEL DIMENSION	550*80
5	WHEEL SPEED	1450 rpm
6	WORK HEAD SPEED	300 rpm R 180 rpm F
7	FEED RATE	0.08 R 0.05 F mm/min
8	COOLANT TYPE	WATER SOLUBLE COOLANT (QUACKER)
9	JOB HOLDING TYPE	TAILSTOCK ,DEAD CENTRE (hydraulic)
10	MEASURING EPQUIPMENT	Air GAUGE
11	SURFACE FINISH	Ra 0.2 TO 0.6 Rz 2 TO 6 micron

5. RESULTS & DISCUSSION

5.1. ANALYSIS

After the observations made about the component and analysis of problem should be done using some techniques.

5.1.1. Existing Condition

For the existing condition of the machine the statistical process control study is made to determine the C_p and C_{pk} value

COMPONENT	PR&P INPUT SHAFT
SIZE	19.055mm±0.0025mm
WORK HEAD FINISH SPEED	280rpm
FEED: ROUGH FINISH	 0.15mm/min 0.02mm/min

5.1.2 SPC Study in Existing Condition

S P C STUDY

MACHINE:	mic cnc od	PARAMETER:	Diameter
PART NAME:	Input shaft	SPECIFICATION: LSL=	19.0525
PART NUMBER:		USL=	19.0575
OPERATION:	Od Grinding	TARGET=	19.0550
MONTH:		DATE	

SAMPLE	OBSERVATIONS					MEAN	RANGE
1	19.0530	19.053	19.0540	19.0540	19.054	19.0536	0.0010
2	19.053	19.0540	19.0535	19.0545	19.0545	19.0539	0.0015
3	19.0535	19.0545	19.0540	19.0540	19.0540	19.0540	0.0010
4	19.0525	19.0545	19.0540	19.0540	19.0540	19.0538	0.0020
5	19.0530	19.0545	19.0540	19.0540	19.0540	19.0539	0.0015
6	19.0520	19.0540	19.0545	19.0545	19.0540	19.0538	0.0025

USL=19.0575 MAXIMUM=19.0545
LSL=19.0525 MINIMUM=19.0520 X bar= 19.0538
TOLE.=0.005 RANGE=0.003 R bar= 0.0016

CONTROL CHART COMPONENTS
A2=0.577 d2=2.326 D3=0.000 D4=2.114

USING STANDARD DEVIATION

STD.DEVIATION= 0.0006
SKEWNESS = -1.2709
KURTOSIS = 1.3295

Cp={USL-LSL}/6*SIGMA= **1.3138**
Cpu={USL-Xbar}/3*SIGMA= 1.9270
Cpl={Xbar-LSL}/3*SIGMA= 0.7007

Cpk=MINIMUM{Cpu,Cpl}= **0.7007**

PROBABILTY OF ACCEPTANCE= 98.22%

5.1.3.Program Changed to Standard Operating Procedure

We have found there is abnormality in the existing condition operating parameters when compared with the standard operating procedure so the program is changed to SOP and the SPC study is done for 30 numbers of the component.

COMPONENT	PR&P INPUT SHAFT
SIZE	19.055mm±0.0025mm
WORK HEAD FINISH SPEED	180rpm
FEED ROUGH FINISH	 0.08mm/min 0.05mm/min

S P C STUDY

MACHINE:	Mic cnc od	PARAMETER:	Diameter
PART NAME:	Input shaft	SPECIFICATION: LSL=	19.0525
PART NUMBER:		USL=	19.0575
OPERATION:	Od Grinding	TARGET=	19.0550
MONTH:		DATE	

SAMPLE	OBSERVATIONS					MEAN	RANGE
1	19.0540	19.054	19.055	19.0540	19.053	19.0539	0.0015
2	19.054	19.0550	19.0550	19.0550	19.054	19.0546	0.0010
3	19.0540	19.054	19.0540	19.054	19.0540	19.0540	0.0000
4	19.0530	19.0540	19.0550	19.055	19.0540	19.0541	0.0020
5	19.054	19.0540	19.0540	19.0545	19.054	19.0541	0.0005
6	19.0530	19.0540	19.0540	19.0535	19.0540	19.0537	0.0010

USL=19.0575 MAXIMUM=19.0550
LSL=19.0525 MINIMUM=19.0530 X bar= 19.0541
TOLE.=0.005 RANGE=0.002 R bar= 0.0010

CONTROL CHART COMPONENTS
A2=0.577 d2=2.326 D3=0.000 D4=2.114

USING STANDARD DEVIATION

STD.DEVIATION= 0.0005
SKEWNESS = -0.0869
KURTOSIS = 0.7719

Cp={USL-LSL}/6*SIGMA= **1.6000**

Cpu={USL-Xbar}/3*SIGMA= 2.1973
Cpl={Xbar-LSL}/3*SIGMA= 1.0027

Cpk=MINIMUM{Cpu,Cpl}= **1.0027**

PROBABILTY OF ACCEPTANCE= 99.87%

5.1.4. Hardening

In the machinig of input shaft component before the finish grinding the hardening takes place so we are checking whether the component has a growth in the specification itself.Induction hardening is a form of heat treatment in which a metal part is heated by induction heating and then quenched. The quenched metal undergoes a martensitic transformation, increasing the hardness and brittleness of the part. Induction hardening is used to selectively harden areas of a part or assembly without affecting the properties of the part as a whole.

5.1.4.1. Process

Induction heating is a non-contact heating process which utilizes the principle of electromagnetic induction to produce heat inside the surface layer of a work-piece. By placing a conductive material into a strong alternating magnetic field, electrical current can be made to flow in the material thereby creating heat due to the I^2R losses in the material. The current generated flows predominantly in the surface layer, the depth of this layer being dictated by the frequency of the alternating field, the surface power density, the permeability of the material, the heat time and the diameter of the bar or material thickness. By quenching this heated layer in water, oil or a polymer based quench the surface layer is altered to form a martensitic structure which is harder than the base metal.

5.1.4.2. Equipment

5.1.4.2.1. Power required

Power supplies for induction hardening vary in power from a few kilowatts to hundreds of kilowatts dependent of the size of the component to be heated and the production method employed i.e. single shot hardening, traverse hardening or submerged hardening.

5.1.4.2.2. Frequency

Induction heating systems for hardening are available in a variety of different operating frequencies typically from 1 kHz to 400 kHz. Higher and lower frequencies are available but typically these will be used for specialist applications. The relationship between operating frequency and current penetration depth and therefore hardness depth is inversely proportional. i.e. the lower the frequency the deeper the case.

DIMENSION OF THE COMPONENT BEFORE GRINDING

- **30 NO OF COMPONENT CHECKED FOR DIMENSIONS BEFORE AND AFTER HARDENING**

BEFORE HARDENING		AFTER HARDENING	
19.265	19.259	19.267	19.26
19.267	19.26	19.267	19.265
19.269	19.254	19.272	19.257
19.263	19.261	19.269	19.268
19.269	19.257	19.265	19.262
19.26	19.264	19.262	19.264
19.259	19.256	19.26	19.262
19.267	19.257	19.261	19.261
19.262	19.259	19.263	19.258
19.263	19.262	19.262	19.267
19.263	19.258	19.263	19.26
19.258	19.263	19.262	19.269
19.26	19.255	19.264	19.258
19.267	19.258	19.268	19.258
19.256	19.261	19.262	19.263

- **THE GROWTH OF THE COMPONENT AFTER HARDENING SO NEGLIGIBLE**

5.1.5. Analysed Result

- No assignable causes are found in the machine.
- No much growth in the hardening of the component.
- So in order to achieve the target value we are going to implement the DESIGN OF EXPERIMENT to achieve the target value.

Table 5.1.5 Analysed Result

CONDITION	C_p	C_{pk}
EXISTING	1.3138	0.7007
PROGRAM CHANGED AS PER STANDARD OPERATING PROCEDURE	1.60	1.0027

5.2. DESIGN OF EXPERIEMENTS

5.2.1 Reasons for Performing D.O.E:

While improving C_{pk}, the following response variables are taken into considerations. The combined action of these parameters has a great role in affecting the C_{pk} and also the surface finish. Hence one has to select the optimum machining parameters in order to improve the C_{pk} and reduced cycle time. The best operating parameters are selected by performing

5.2.2. Introduction

The study of most important variables affecting quality characteristics and a plan for conducting such experiments called "The Design of Experiments (DOE)". Taguchi method is used for solving our problem.

5.2.3. Response

It is the output of interest to be optimized. i.e Maximized , Minimized, Targeted etc. This can be qualitative or quantitative and this can be more than one.

5.2.4. Factor

A Factor is one of the variables being studied in the experiment. This can be qualitative or quantitative and this parameter which influences the response.

5.2.5. Level

Levels of the factor are values of the factor being examined in the experiments. It should be more than one and should make technological sense and statistical sense.

5.2.6. Interaction

It is defined as the joint effect of two or more factors. It can be under stood as; there is a joint effect if the contribution from one factor depends on the level of the other factor.

5.2.7. Treatment Combination

A Treatment combination is one set of levels for the factors in a given experimental run.

5.2.8. Degree of Freedom

It is the number of independent comparisons and formula is n-1 where n is the number of observation. For a factor it is the number of levels minus one. For an interaction it is the product of Degree Of Freedom of the respective factor.

5.3. D.O.E CALCULATION

5.3.1. Selection of Factors and Size of Array

Factors are selected from above observations and experience of shop floor people. From the factors we can find the size of the array. Below table establishes the factors and size of the array.

5.3.2. Cause & Effect Diagram

The cause & effect diagram is drawn by using the brain storming points to find the causes related for the problem

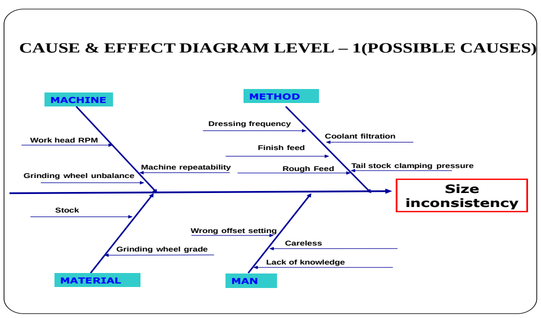

Fig 5.3.2 Cause & Effect Diagram 1

Table 5.3.2 Validation

Sl.no.	CAUSE	VALIDATION	RESULT
1	Tailstock clamping insufficient	5 bar noticed. OK as spec.	Insignificant
2	Wheel head grinding speed	Verified using tachometer. Found ok	Insignificant
3	Coolant filtration	Filter paper roll function verified. OK	Insignificant
4	Work head speed	Verified. Found not ok as per SOP 300 rpm R 180 rpm F Actual 300 rpm R 280 rpm F	Significant
5	Machine repeatability	Checked using dial stand. Found ok	Insignificant
6	Coolant flush	Coolant flow pipe position order. So, ineffective	Insignificant
7	OD Taper	No taper is found.	Insignificant
8	Dressing frequency	As per our regular practice 1 in 50 for dressing. It is as per procedure 50 is followed	Insignificant
9	Center Misalignment	Center misalignment verified using dial gauge. Found ok	Insignificant
10	Burr in center	In center area burr verified. No burr folded.	Insignificant
11	Feed	0.08 R 0.05 F mm/min Actual 0.15 R 0.02 F mm/min	Significant

Table 5.4.Experimental Table

S.NO	A (SPEED)	B (FINISH FEED)	C (FINISH STOCK)	AXB (INTERACTIONS)
1	165	0.04	0.04	1
2	195	0.04	0.04	2
3	165	0.06	0.04	2
4	195	0.06	0.04	1
5	165	0.04	0.06	1
6	195	0.04	0.06	2
7	165	0.06	0.06	2
8	195	0.06	0.06	1

5.5. EXPERIMENTS

5.5.1. Experiment 1

COMPONENT	PR&P INPUT SHAFT
SIZE	19.055mm±0.0025mm
WORK HEAD FINISH SPEED	165rpm
FEED ROUGH FINISH	 0.04mm/min 0.04mm/min

S P C STUDY

MACHINE:	Mic cnc od	PARAMETER:		Diameter
PART NAME:	Input shaft	SPECIFICATION:	LSL=	19.0525
PART NUMBER:			USL=	19.0575
OPERATION:	Od Grinding		TARGET=	19.0550
MONTH:			DATE	

SAMPLE	OBSERVATIONS					MEAN	RANGE
1	19.0555	19.0545	19.055	19.0555	19.0555	19.0552	0.0010
2	19.0550	19.0555	19.0565	19.0560	19.0560	19.0558	0.0015
3	19.0555	19.0555	19.0565	19.0560	19.0555	19.0558	0.0010
4	19.0560	19.0565	19.0555	19.0560	19.0565	19.0561	0.0010
5	19.0560	19.0565	19.0560	19.0560	19.0565	19.0562	0.0005
6	19.0555	19.0550	19.0565	19.0565	19.0560	19.0559	0.0015

USL=19.0575 MAXIMUM=19.0565
LSL=19.0525 MINIMUM=19.0545 X bar= 19.0558
TOLE.=0.005 RANGE=0.002 R bar= 0.0011

CONTROL CHART COMPONENTS

A2=0.577 d2=2.326 D3=0.000 D4=2.114

USING STANDARD DEVIATION

STD.DEVIATION= 0.0005
SKEWNESS = -0.4586
KURTOSIS = -0.3424

Cp={USL-LSL}/6*SIGMA= **1.5244**

Cpu={USL-Xbar}/3*SIGMA= 1.0162
Cpl={Xbar-LSL}/3*SIGMA= 2.0325

Cpk=MINIMUM{Cpu,Cpl}= **1.0162**

PROBABILTY OF ACCEPTANCE= 99.89%

5.5.2. Experiment 2

COMPONENT	PR&P INPUT SHAFT
SIZE	19.055mm±0.0025mm
WORK HEAD FINISH SPEED	195rpm
FEED ROUGH FINISH	 0.04mm/min 0.04mm/min

S P C STUDY

MACHINE:	Mic cnc od	PARAMETER:		Diameter
PART NAME:	Input shaft	SPECIFICATION:	LSL=	19.0525
PART NUMBER:			USL=	19.0575
OPERATION:	Od Grinding		TARGET=	19.0550
MONTH:			DATE	

SAMPLE	OBSERVATIONS					MEAN	RANGE
1	19.0530	19.055	19.053	19.0530	19.053	19.0532	0.0020
2	19.054	19.0540	19.0550	19.0550	19.055	19.0545	0.0015
3	19.0540	19.055	19.0540	19.055	19.0540	19.0543	0.0010
4	19.0540	19.0545	19.0550	19.0555	19.0550	19.0548	0.0015
5	19..0570	19.0550	19.0550	19.0550	19.055	19.0550	0.0000
6	19.0550	19.0550	19.0550	19.0550	19.0555	19.0551	0.0005

USL=19.0575 MAXIMUM=19.0555
LSL=19.0525 MINIMUM=19.0525 X bar= 19.0545
TOLE.=0.005 RANGE=0.003 R bar= 0.0011

CONTROL CHART COMPONENTS

A2=0.577 d2=2.326 D3=0.000 D4=2.114

USING STANDARD DEVIATION

STD.DEVIATION= 0.0008
SKEWNESS = -1.0091
KURTOSIS = 0.0385

Cp={USL-LSL}/6*SIGMA= **1.0262**

Cpu={USL-Xbar}/3*SIGMA= 1.2382
Cpl={Xbar-LSL}/3*SIGMA= 0.8141

Cpk=MINIMUM{Cpu,Cpl}= **0.8141**

PROBABILTY OF ACCEPTANCE= 99.26%

5.5.3. Experiment 3

COMPONENT	PR&P INPUT SHAFT
SIZE	19.055mm±0.0025mm
WORK HEAD FINISH SPEED	165rpm
FEED ROUGH FINISH	 0.06mm/min 0.04mm/min

S P C STUDY

MACHINE:	Mic cnc od	PARAMETER:	Diameter
PART NAME:	Input shaft	SPECIFICATION: LSL=	19.0525
PART NUMBER:		USL=	19.0575
OPERATION:	Od Grinding	TARGET=	19.0550
MONTH:		DATE	

SAMPLE	OBSERVATIONS					MEAN	RANGE
1	19.0565	19.0555	19.055	19.0555	19.0550	19.0555	0.0015
2	19.0550	19.0550	19.0565	19.0555	19.0565	19.0557	0.0015
3	19.0550	19.0555	19.0550	19.0540	19.0555	19.0550	0.0015
4	19.0555	19.0555	19.0550	19.0550	19.0550	19.0552	0.0005
5	19.0555	19.0555	19.0555	19.0555	19.0555	19.0555	0.0000
6	19.0560	19.0560	19.0555	19.0565	19.0565	19.0561	0.0010

USL=19.0575 MAXIMUM=19.0565
LSL=19.0525 MINIMUM=19.0540 X bar= 19.0555
TOLE.=0.005 RANGE=0.003 R bar= 0.0010

CONTROL CHART COMPONENTS
A2=0.577 d2=2.326 D3=0.000 D4=2.114

USING STANDARD DEVIATION

STD.DEVIATION= 0.0006
SKEWNESS = 0.1368
KURTOSIS = 0.4977

Cp={USL-LSL}/6*SIGMA= 1.4191

Cpu={USL-Xbar}/3*SIGMA= 1.1353
Cpl={Xbar-LSL}/3*SIGMA= 1.7029

Cpk=MINIMUM{Cpu,Cpl}= 1.1353

PROBABILTY OF ACCEPTANCE= 99.97%

5.5.4. Experiment 4

COMPONENT	PR&P INPUT SHAFT
SIZE	19.055mm±0.0025mm
WORK HEAD FINISH SPEED	195rpm
FEED ROUGH FINISH	 0.06mm/min 0.04mm/min

S P C STUDY

MACHINE:	Mic cnc od	PARAMETER:	Diameter
PART NAME:	Input shaft	SPECIFICATION: LSL=	19.0525
PART NUMBER:		USL=	19.0575
OPERATION:	Od Grinding	TARGET=	19.0550
MONTH:		DATE	

SAMPLE	OBSERVATIONS					MEAN	RANGE
1	19.0550	19.055	19.055	19.0550	19.055	19.0550	0.0000
2	19.054	19.0540	19.0565	19.0545	19.054	19.0546	0.0025
3	19.0550	19.054	19.0540	19.055	19.0555	19.0546	0.0015
4	19.0540	19.0535	19.0550	19.0550	19.0550	19.0545	0.0015
5	19.055	19.0550	19.0550	19.0550	19.056	19.0550	0.0010
6	19.0555	19.0545	19.0550	19.0550	19.0545	19.0549	0.0010

USL=19.0575 MAXIMUM=19.0565
LSL=19.0525 MINIMUM=19.0535 X bar= 19.0548
TOLE.=0.005 RANGE=0.003 R bar= 0.0012

CONTROL CHART COMPONENTS
A2=0.577 d2=2.326 D3=0.000 D4=2.114

USING STANDARD DEVIATION

STD.DEVIATION= 0.0006
SKEWNESS = 0.2799
KURTOSIS = 1.0760

Cp={USL-LSL}/6*SIGMA= 1.3613

Cpu={USL-Xbar}/3*SIGMA= 1.4884
Cpl={Xbar-LSL}/3*SIGMA= 1.2343

Cpk=MINIMUM{Cpu,Cpl}= 1.2343

PROBABILTY OF ACCEPTANCE= 99.99%

5.5.5. Experiment 5

COMPONENT	PR&P INPUT SHAFT
SIZE	19.055mm±0.0025mm
WORK HEAD FINISH SPEED	165rpm
FEED ROUGH FINISH	 0.04mm/min 0.06mm/min

S P C STUDY

MACHINE:	Mic cnc od	PARAMETER:	Diameter
PART NAME:	Input shaft	SPECIFICATION: LSL=	19.0525
PART NUMBER:		USL=	19.0575
OPERATION:	Od Grinding	TARGET=	19.0550
MONTH:		DATE	

SAMPLE	OBSERVATIONS					MEAN	RANGE
1	19.0550	19.0550	19.054	19.0550	19.0560	19.0550	0.0020
2	19.0560	19.0550	19.0550	19.0555	19.0555	19.0554	0.0010
3	19.0550	19.0545	19.0550	19.0550	19.0540	19.0547	0.0010
4	19.0545	19.0540	19.0550	19.0555	19.0555	19.0549	0.0015
5	19.0555	19.0550	19.0550	19.0555	19.0555	19.0553	0.0005
6	19.0545	19.0560	19.0555	19.0555	19.0560	19.0555	0.0015

USL=19.0575	MAXIMUM=19.0560		
LSL=19.0525	MINIMUM=19.0540	X bar=	19.0551
TOLE.=0.005	RANGE=0.002	R bar=	0.0013

CONTROL CHART COMPONENTS

A2=0.577 d2=2.326 D3=0.000 D4=2.114

USING STANDARD DEVIATION

STD.DEVIATION= 0.0006
SKEWNESS = -0.4175
KURTOSIS = -0.2105

Cp={USL-LSL} / 6*SIGMA= **1.4585**

Cpu={USL-Xbar} / 3*SIGMA= 1.3808
Cpl={Xbar-LSL} / 3*SIGMA= 1.5363

Cpk=MINIMUM{Cpu,Cpl}= **1.3808**

PROBABILTY OF ACCEPTANCE= 100.00%

5.5.6. Experiment 6

COMPONENT	PR&P INPUT SHAFT
SIZE	19.055mm±0.0025mm
WORK HEAD FINISH SPEED	195rpm
FEED ROUGH FINISH	 0.04mm/min 0.06mm/min

S P C STUDY

MACHINE:	Mic cnc od	PARAMETER:	Diameter
PART NAME:	Input shaft	SPECIFICATION: LSL=	19.0525
PART NUMBER:		USL=	19.0575
OPERATION:	Od Grinding	TARGET=	19.0550
MONTH:		DATE	

SAMPLE	OBSERVATIONS					MEAN	RANGE
1	19.0555	19.055	19.056	19.0555	19.0555	19.0555	0.0010
2	19.0565	19.0550	19.0550	19.0550	19.056	19.0555	0.0015
3	19.0560	19.055	19.0555	19.0555	19.0550	19.0554	0.0010
4	19.0550	19.0550	19.0555	19.0555	19.0555	19.0553	0.0005
5	19.0550	19.0550	19.0550	19.0550	19.056	19.0551	0.0005
6	19.0545	19.0555	19.0550	19.0560	19.0560	19.0554	0.0015

USL=19.0575	MAXIMUM=19.0565		
LSL=19.0525	MINIMUM=19.0545	X bar=	19.0554
TOLE.=0.005	RANGE=0.002	R bar=	0.0010

CONTROL CHART COMPONENTS

A2=0.577 d2=2.326 D3=0.000 D4=2.114

USING STANDARD DEVIATION

STD.DEVIATION= 0.0005
SKEWNESS = 0.5771
KURTOSIS = -0.0740

Cp={USL-LSL} / 6*SIGMA= **1.8372**

Cpu={USL-Xbar} / 3*SIGMA= 1.5677
Cpl={Xbar-LSL} / 3*SIGMA= 2.1066

Cpk=MINIMUM{Cpu,Cpl}= **1.5677**

PROBABILTY OF ACCEPTANCE= 100.00%

5.5.7 Experiment 7

COMPONENT	PR&P INPUT SHAFT
SIZE	19.055mm±0.0025mm
WORK HEAD FINISH SPEED	165rpm
FEED ROUGH FINISH	 0.06mm/min 0.06mm/min

S P C STUDY

MACHINE:	Mic cnc od			PARAMETER:				Diameter
PART NAME:	Input shaft			SPECIFICATION:		LSL=		19.0525
PART NUMBER:						USL=		19.0575
OPERATION:	Od Grinding					TARGET=		19.0550
MONTH:						DATE		

SAMPLE	OBSERVATIONS					MEAN	RANGE
1	19.0550	19.0555	19.055	19.0550	19.0550	19.0551	0.0005
2	19.0550	19.0555	19.0560	19.0555	19.0555	19.0555	0.0010
3	19.0555	19.0545	19.0560	19.0550	19.0555	19.0553	0.0015
4	19.0560	19.0550	19.0560	19.0550	19.0555	19.0555	0.0010
5	19.0550	19.0555	19.0545	19.0550	19.0555	19.0551	0.0010
6	19.0555	19.0555	19.0555	19.0560	19.0555	19.0556	0.0005

USL=19.0575 MAXIMUM=19.0560
LSL=19.0525 MINIMUM=19.0545 X bar= 19.0554
TOLE.=0.005 RANGE=0.002 R bar= 0.0009

CONTROL CHART COMPONENTS
A2=0.577 d2=2.326 D3=0.000 D4=2.114

USING STANDARD DEVIATION

STD.DEVIATION= 0.0004
SKEWNESS = -0.1211
KURTOSIS = -0.4380

Cp={USL-LSL}/6*SIGMA= **1.9920**

Cpu={USL-Xbar}/3*SIGMA= 1.7132
Cpl={Xbar-LSL}/3*SIGMA= 2.2709

Cpk=MINIMUM{Cpu,Cpl}= **1.7132**

PROBABILTY OF ACCEPTANCE= 100.00%

5.5.8. Experiment 8

COMPONENT	PR&P INPUT SHAFT
SIZE	19.055mm±0.0025mm
WORK HEAD FINISH SPEED	195rpm
FEED ROUGH FINISH	 0.06mm/min 0.06mm/min

S P C STUDY

MACHINE:	Mic cnc od			PARAMETER:				Diameter
PART NAME:	Input shaft			SPECIFICATION:		LSL=		19.0525
PART NUMBER:						USL=		19.0575
OPERATION:	Od Grinding					TARGET=		19.0550
MONTH:						DATE		

SAMPLE	OBSERVATIONS					MEAN	RANGE
1	19.0555	19.055	19.055	19.0555	19.055	19.0552	0.0005
2	19.0555	19.0555	19.0555	19.0555	19.0550	19.0554	0.0005
3	19.0555	19.0555	19.0560	19.0560	19.0555	19.0557	0.0005
4	19.0555	19.0560	19.0550	19.0550	19.0560	19.0555	0.0010
5	19.0560	19.0550	19.0550	19.0555	19.0555	19.0554	0.0010
6	19.0555	19.0555	19.0555	19.0555	19.0550	19.0554	0.0005

USL=19.0575 MAXIMUM=19.0560
LSL=19.0525 MINIMUM=19.0550 X bar= 19.0554
TOLE.=0.005 RANGE=0.001 R bar= 0.0007

CONTROL CHART COMPONENTS
A2=0.577 d2=2.326 D3=0.000 D4=2.114

USING STANDARD DEVIATION

STD.DEVIATION= 0.0003
SKEWNESS = 0.1702
KURTOSIS = -0.7148

Cp={USL-LSL}/6*SIGMA= **2.4458**

Cpu={USL-Xbar}/3*SIGMA= 2.0218
Cpl={Xbar-LSL}/3*SIGMA= 2.8697

Cpk=MINIMUM{Cpu,Cpl}= **2.0218**

PROBABILTY OF ACCEPTANCE= 100.00%

Table 5.5.9 Summary

FACTORS			EXPERIMENT	
A (SPEED)	B(FINISH FEED)	C(FINISH STOCK)	C_p	C_{pk}
165	0.04	0.04	1.5244	1.0162
195	0.04	0.04	1.0262	0.8141
165	0.06	0.04	1.4191	1.1353
195	0.06	0.04	1.3613	1.2343
165	0.04	0.06	1.4585	1.3808
195	0.04	0.06	1.837	1.567
165	0.06	0.06	1.9920	1.7132
195	0.06	0.06	2.4458	2.0218

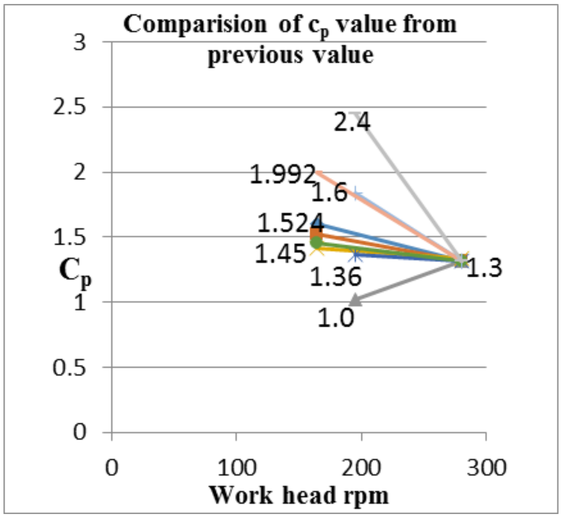

Fig5.5.9 comparison of cpk value from previous value

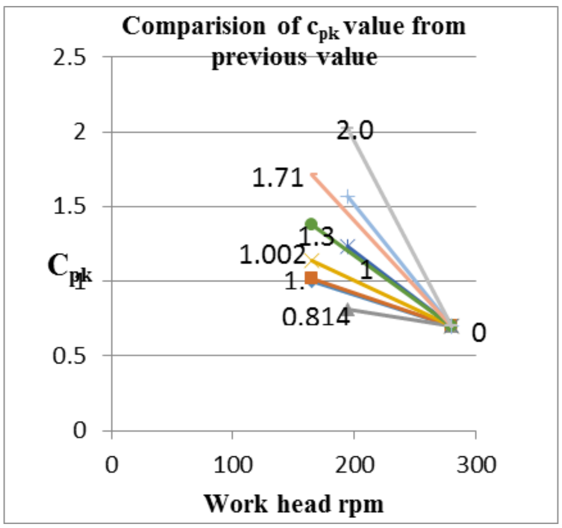

Fig5.5.9 comparison of cpk value from previous value

5.6. SURFACE FINISH & CYCLE TIME

5.6.1 Surface Finish

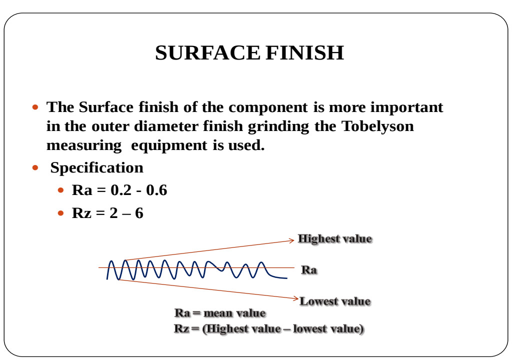

Fig. 5.6.1.Surface Finish Description

The cycle time and surface finish value is shown in the above tabulation for the experiments

5.7. CHECK

Now we are going to check for the experiment 7 & 8 because both the value is greater than the target value we are doing another 30 no reading for both the experiments to find the optimal combination.

Table 5.6.1 Surface Finish & Cycle Time Value

FACTORS			SURFACE FINISH		CYCLETIME
A(SPEED)	B(FINISH FEED)	C(FINISH STOCK)	Ra	Rz	Sec
165	0.04	0.04	*0.42*	*2.5*	58
195	0.04	0.04	*0.32*	*2.3*	63
165	0.06	0.04	*0.38*	*2.6*	57
195	0.06	0.04	*0.44*	*2.8*	42
165	0.04	0.06	*0.38*	*2.9*	52
195	0.04	0.06	*0.36*	*2.6*	54
165	0.06	0.06	*0.46*	*3.5*	55
195	0.06	0.06	*0.5*	*3.6*	53

Table 5.7 Comparison of 165rpm and 195rpm

FACTORS			EXPERIMENT1		EXPERIMENT2	
A (SPEED)	B(FINISH FEED)	C(FINISH STOCK)	C_p	C_{pk}	C_p	C_{pk}
165	0.06	0.06	1.9920	1.7132	1.8528	1.6798
195	0.06	0.06	2.4458	2.0218	2.1790	2.0192

For the experiment 7 the Cp and Cpk value is get lowered and the values are very nearer to the target value. The value will go down below target value after a period of time.

For the experiment 8 the Cp and Cpk value is far greater than the target value so the optimum combination of parameter is choosing from the experiment 8.

5.8. ESTABLISHING OF OPTIMAL PARAMETERS

Table5.8. Optimal Parameters

OPTIMAL PARAMETERS	
WORK HEAD FIINISH SPEED	195 rpm
FINISH FEED	0.06mm/min
FINISH STOCK	0.06mm

5.9. STANDARDIZATION

It gives the maintenance techniques to get the continuous Cpk of 1.67 throughout process.

- Change the work head finish speed to 195 rpm.
- Change the finish feed to 0.06mm/min
- Change the finish stock to 0.06mm
- Check the diameter after the power cut and idle time and set to the target
- Start the process with the value of 19.0450 to 19.0555 mm.
- Monitor the grinded date of the centers in the SOP

6. CONCLUSION

The control limits obtained after the remedial actions taken for the grinder are within specification limits and the diameter produced in all the components of every sample lie under the control limits. The diameter of all the components is located very close to the process mean. All these results are positive by which we conclude that the process is under control.

The concept of DOE and SPC is used to determine the effect and influence of process parameters namely work speed, feed rate, dressing frequency and dressing depth of cut is studied on output responses, and found that the developed model is significant. The model predicted in the present work is useful for selecting the right set of process parameters variables for optimal value of the Cp and Cpk values.

For work head speed of 195 rpm, finish feed 0.06mm/min and finish stock of 0.06 mm, the process capability (Cp) is increased from 1.3138 to 2.44 and Cpk is increased from 0.7007 to 2.0192. Which show that implementation of SPC technique is proved to be successful in improving the performance of grinding process there by making it more capable of producing the products with right dimensions.

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