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Research Paper

QUALITY IMPROVEMENT OF A GRINDING OPERATION USING PROCESS CAPABILITY STUDIES

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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 Process monitoring techniques, Cause and Effect diagram, Why-Why analysis 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 optimisation of those changes reflects as an increase in the acceptance level of the product in the world market.

Keywords: Quality improvement techniques, Process capability studies, Statistical process control, Process monitoring chart, Process capability index

INTRODUCTION

Manufacturing processes are often met with lot of variations in a product from the customer specified limits during the machining process and it is characterised by the strong effect on the quality of a product. The variations in a product are an inevitable one. No two products are identical in nature. The variations on a machine are due to either special (assignable) causes or chance (natural) causes (Mahajan, 2004). Sometimes, the variation occurs due to both of these causes, which affects the quality of a product severely. In a grinding operation, variations which arise as a result of these causes play a vital role in acceptance level of a product. These causes are detected using various quality improvement tools and finding remedies in a simply way. Process Monitoring Charts and Statistical Process Control techniques find to be a simplest

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method among various quality improvement tools for detecting the variations in a product.

The Process Monitoring charts are used for the purpose of identifying the chance and assignable causes. It gives a well-defined warning signal, if the process is going out of control. By using this technique, the reoccurrence of the defects or variations in a product can be rectified. The Statistical Process Control are the charts, where the average, range, standard deviations, process capability values can be determined by statistical approach.

These tools use the Process Capability index value as a major technique to verify whether any variations occurred on the grinding operation or not (Gijo, 2005).

Process Capability Calculation

Process Capability index value (Cpk) is calculated statistically using Statistical Process Control sheet and it is validated against the Sigma value to determine the rejection level of a product. The Cpk calculation is done with the use of Upper Specification Limit (USL), Lower Specification Limit (LSL) of a product, given from the customer side. By using these specification limits, USL and LSL, the Cpu and Cpl are calculated. Cpu is nothing but a statistic, which related the difference between USL and the centre line to the Standard deviation (σ) (Gijo, 2005). Cpl is also a statistic which relates the difference between the centre line and LSL to the Standard deviation (σ). The formula for calculating Cpu and Cpl is given below:

$Cpu = (USL - \overline{X})/3 * Sigma$ (http://www.quality-control-plan.com/spc-definitions.html) and

$Cpl = (\overline{X} - LSL)/3 * Sigma$ (http://www.quality-control-plan.com/spc-definitions.html)

Sigma is the standard deviation value (σ) and $\overline{X}$ is the average of the sum of all the values, i.e., mean of all observed values. From the calculated *Cpu* and *Cpl* values, one can determine the *Cpk* value from the formula, shown below:

Cpk = *Minimum*(*Cpu*, *Cpl*) (http://www.quality-control-plan.com/spc-definitions.html)

The minimum value is taken for the *Cpk* calculation because, it indicates whether or not the process being analysed is capable of producing little or no defects. The higher the number, the less likely it will be defectives are produced.

Each company is focusing to implement Six Sigma (6σ) quality on a product for to achieve nil (0.05 PPM) rejection level. Based on the Process Capability Index value, the rejection percentage is determined. As the variations is high, due to any one of those causes, affects the *Cpk* value and hence results in decline of the Sigma level. So, the Six Sigma quality level can be achieved in a grinding operation only when the variations on the grinding process are eliminated. This methodology not only suits grinding operations, but it is meant for all kind of machining processes like turning, milling, shearing, etc.

ANALYSIS

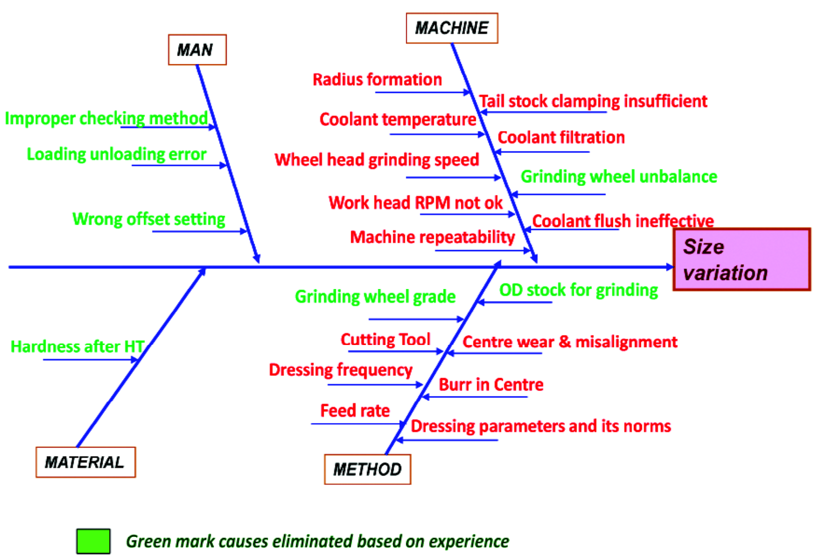
In grinding operations, the variation takes place during the machining process is majorly due to the parameters with in the machine and these parameters can be acknowledged by brainstorming method. By brainstorming, the motives for the causes occurred on a grinding machine are thoroughly analysed from various angles, to determine the significant and insignificant causes. From this method, the recognised possible causes for the variations are Tail stock clamping insufficient, Grinding wheel unbalance, Wheel head grinding speed, Work head rpm, Dressing frequency, Grinding wheel grade, Coolant flush ineffective, Coolant temperature, Coolant filtration, Improper checking method, Centre wear and misalignment, radius formation, Feed rate, Outer Diameter stock for grinding, Machine repeatability, Burr in centre, Hardness of the material, Dressing parameters and its norms, Wrong offset settings, Loading and unloading error and last but not least the cutting tool.

The above described possible causes are the main reasons for the occurrence of the variations in a product during grinding operation. Hence, these possible causes are scrutinised to find the significant and insignificant causes. From the above mentioned various possible causes, some may be eliminated by proper training to the personnel and by experience. This can be done by using Cause and effect diagram, a major quality tool, which differentiates the causes into 4M categories, namely Man; Materials; Machine; Methods (http://www. isixsigma.com/tools-templates/capability-indices-process-capability/process-capability-cp-cpk-and-process-performance-pp-ppk-what-difference/).

Cause and Effect Diagram

The cause and effect diagram clearly denotes the causes in 4 M s for a single effect of Size variation (Figure 1). These causes are labelled in green and red colors, where green color causes can be eliminated by proper training and experience and red color causes plays an important role in size variations of a product. By eliminating the green color labelled causes from the Cause and Effect diagram, we get both significant and insignificant causes, for the variations to occur in a grinding machine.

Figure 1: Cause and Effect Diagram for the Size Variation by Considering the 4M's



From the mentioned causes in the Cause and Effect diagram, the Significant and Insignificant causes has to be determined. The Significant causes are the main reason for the variations in a grinding operation to happen. The Significant causes are taken into account for total elimination.

Possible Causes

When examine the possible causes after the removal of green marks from the Cause and Effect diagram (Figure 2), some causes are seems to be insignificant for the effect on a grinding machine to occur. The causes like Coolant temperature, Tailstock clamping insufficient, Wheel head grinding speed, Coolant temperature, Machine repeatability, Coolant flush ineffective, Centre misalignment and Burr in centre are termed to be insignificant because nowadays the CNC grinding machine are made to eliminate these causes before it

Figure 2: Cause and Effect Diagram for the Size Variation by Considering Both Significant and Insignificant Causes as Possible Causes

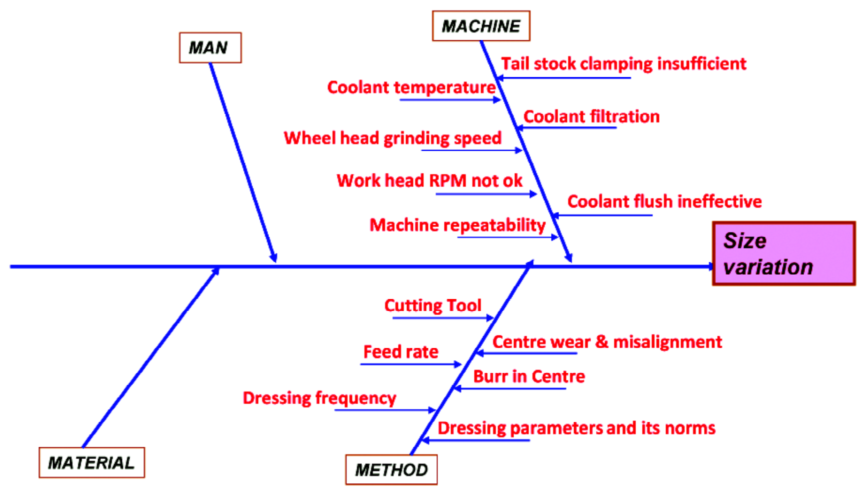
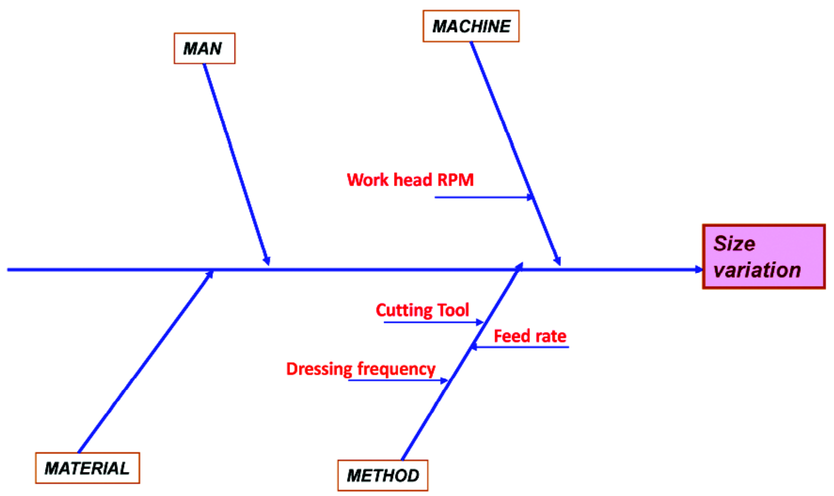


Figure 3: Cause and Effect Diagram Showing the Significant Causes for the Size Variation



comes to existence. By using various techniques like Poke Yoke, building of Servo motors with an encoder, the minor causes are totally eliminated to avoid the variations of a product. Hence, apart from these causes, rest of them are considered to be Significant and responsible for the variations in a grinding process to happen. The Significant causes are clearly demonstrated in by Cause and Effect diagram (Figure 3).

So, "a systematic analysis on these four causes, namely Work head speed, Feed rate, Dressing frequency, Cutting tool, may eliminate the variations occur on the product during grinding operations". The analysed results needed to be optimized for the continuous improvement in a grinding machine, if not; the outcome products will have defects and leads to rejection. To prove this statement a detailed analysis should be made on a grinding machine.

EXPERIMENTATION

The four major causes, Work head rpm, Dressing frequency, Feed rate and Cutting tool are responsible for the variations to occur on a product during the grinding operation. So, an Industrial experimentation is carried out on a grinding machine to eliminate the variations occurring on a product by making some changes on these causes. These four causes are the key parameters in a grinding machine. Hence, an effect can be surely achieved, once a change is made on these causes.

The experimentation is carried out in a firm, where a numerous products are being manufactured. In that firm, a product is manufactured with more variations in size and they are facing lots of rejection. This situation in that firm is merely due to a single operation out of various operations at various stages on the product. The variation occurs only during machining of the same product, after the heat treatment process. The operation is grinding and it is performed in a grinding machine. Hence, this can be taken as an experimental approach to prove the statement.

OBSERVATION

Initial Condition

The Worm shaft is the product being manufactured in the firm as a part of Hydraulic Power Steering. In that product, an operation of seal groove making is done in the grinding machine. The grinding machine is a FANUC programming one.

Initially, when observation is made on the grinding machine (HMT K130 U2), the process capability index (Cpk) was found to be 0.49 by using Process Monitoring Chart (PMC) and Statistical Process Control (SPC) with work head rpm of 170, feed rate of 1.1 mm/min throughout the depth, dressing frequency is done once in 10 components, cutting tool of open grain 19A 80 L8 VS. The Cpk value of 0.49 in that machine is due to the assignable causes.

The assignable causes can be eliminated by making changes in the four main significant causes in a grinding machine. So, a comprehensive analysis is done on the machine for to improve the Cpk value and reduce the rejection level in the grinding machine, using only the four main significant causes.

The PMC for the initial observation taken in the machine clearly shows the variations of the product (Figure 4). The SPC analysis for the initial observation, which uses the statistical approach, is used to find the Standard deviation (Sigma) value. The SPC analysis for the value of Cpk 0.4911 is explained in detail using the SPC chart. The chart uses the formula for the calculation of X bar, Standard deviation and Process Capability index, generates as the value enters in the column. The SPC analysis clearly shows the values for 30 observations taken continuously on the product in the grinding machine (Figure 5).

The Cpk improvement in the machine will be carried out using showed Process Monitoring Chart (Figure 4), to find the point of occurrence of the variation and Statistical Process Control (Figure 5) for statistical approach to determine the process capability index (Cpk) value.

Figure 4: PMC Shows the Observations at the Initial Condition of the Machine

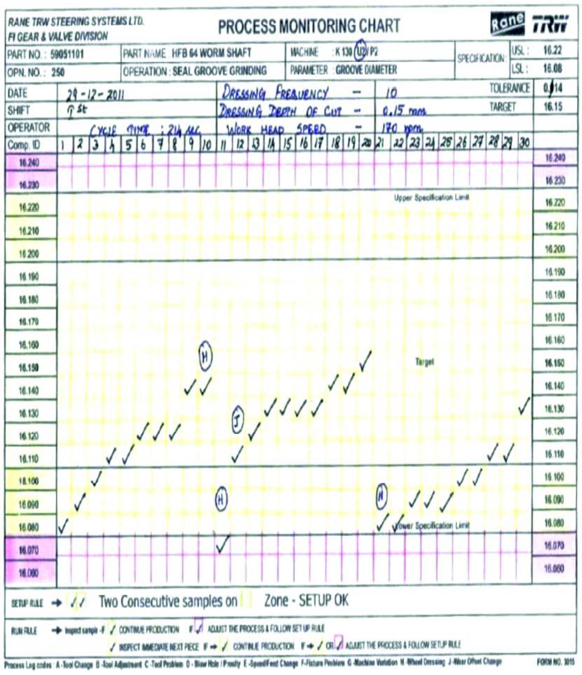
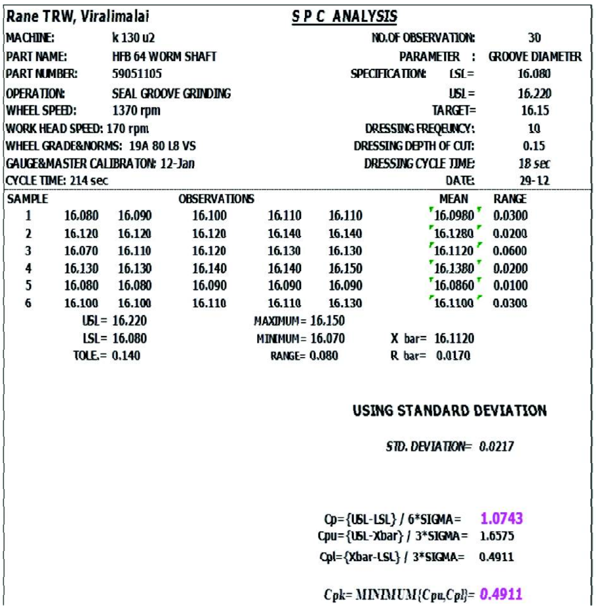


Figure 5: SPC Chart Analysis for the Observations Made in PMC at the Initial Condition of the Machine



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S P C ANALYSIS

MACHINE:	k 130 u2	NO.OF OBSERVATION:	30
PART NAME:	HFB 64 WORM SHAFT	PARAMETER :	GROOVE DIAMETER
PART NUMBER:	59051105	SPECIFICATION: LSL=	16.080
OPERATION:	SEAL GROOVE GRINDING	USL=	16.220
WHEEL SPEED:	1370 rpm	TARGET=	16.15
WORK HEAD SPEED:	170 rpm	DRESSING FREQEUNCY:	10
WHEEL GRADE&NORMS:	19A 80 L8 VS	DRESSING DEPTH OF CUT:	0.15
GAUGE&MASTER CALIBRATON:	12-Jan	DRESSING CYCLE TIME:	18 sec
CYCLE TIME:	214 sec	DATE:	29-12

SAMPLE	OBSERVATIONS					MEAN	RANGE
1	16.080	16.090	16.100	16.110	16.110	16.0980	0.0300
2	16.120	16.120	16.120	16.140	16.140	16.1280	0.0200
3	16.070	16.110	16.120	16.130	16.130	16.1120	0.0600
4	16.130	16.130	16.140	16.140	16.150	16.1380	0.0200
5	16.080	16.080	16.090	16.090	16.090	16.0860	0.0100
6	16.100	16.100	16.110	16.110	16.130	16.1100	0.0300

USL= 16.220 MAXIMUM= 16.150

LSL= 16.080 MINIMUM= 16.070 X bar= 16.1120

TOLE.= 0.140 RANGE= 0.080 R bar= 0.0170

USING STANDARD DEVIATION

STD. DEVIATION= 0.0217

Cp={USL-LSL} / 6*SIGMA= 1.0743

Cpu={USL-Xbar} / 3*SIGMA= 1.6575

Cpl={Xbar-LSL} / 3*SIGMA= 0.4911

Cpk= MINIMUM{Cpu,Cpl}= 0.4911

ACTION

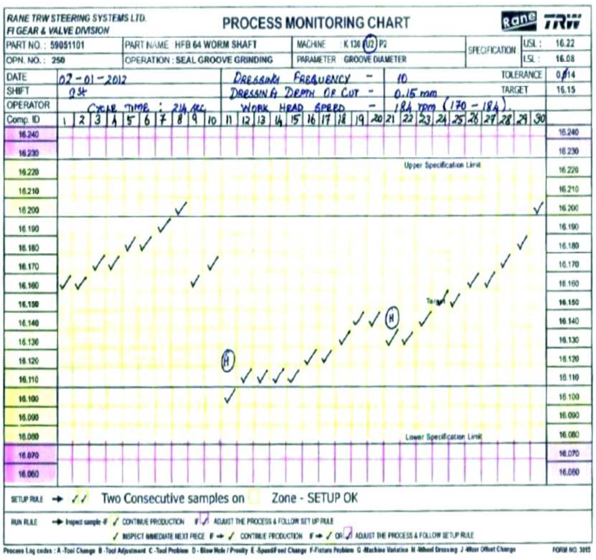
The four significant causes are to be modified in the grinding machine for the sake of improvement in the Cpk value.

Work Head Speed

The initial action on a machine is taken to modify the work head speed from 170 rpm to 184 rpm. By using the quality tools such as Process Monitoring chart (PMC), the observation is monitored in the form of graph and it is validated in Statistical Process Control (SPC) analysis charts for to find the Cpk value. The result for the monitored observations can be attained, only after the observations are fed into the SPC analysis chart. The PMC for the monitored observations are clearly demonstrating the variations are occurred only due to chance causes (Figure 6).

The SPC analysis briefly explains the X bar, Standard deviation and Cpk values for the Cpk

Figure 6: PMC for the Increased Work Head Speed of 184 rpm from the Initial Condition of 170 rpm



improvement from the initial condition of the machine (Figure 7). The result becomes positive as the work head speed increases and Cpk value increases from 0.4911 to 0.8179. Hence the modification has a positive approach towards the Cpk value. Therefore, as there is a sign of increase in Cpk value as the work head rpm increases, because as the work speed increases the 'arc of contact' between the cutting tool and the work piece decreases. This decrease in arc of contact, leads to creation of less variations in size (Pankaj and Arunesh, 2009).

Figure 7: SPC Chart Analysis for the Observation Made in PMC at a Work Head Speed of 184 rpm

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MACHINE: k 130 u2
PART NAME: HFB 64 WORM SHAFT
PART NUMBER: 59051105
OPERATION: SEAL GROOVE GRINDING
WHEEL SPEED: 1370 rpm
WORK HEAD SPEED: 184 rpm
WHEEL GRADE&NORMS: 19A 80 L8 VS
GAUGE&MASTER CALIBRATON: 12-Jan
CYCLE TIME: 214 sec
Workhead Speed Increased From 170>184 rpm

NO.OF OBSERVATION: 30
PARAMETER : GROOVE DIAMETER
SPECIFICATION: LSL= 16.080
USL= 16.220
TARGET= 16.15
DRESSING FREQEUNCY: 10
DRESSING DEPTH OF CUT: 0.15
DRESSING CYCLE TIME: 18 sec
DATE: 2-Jan

SAMPLE	OBSERVATIONS					MEAN	RANGE
1	16.160	16.160	16.170	16.170	16.180	16.1680	0.0200
2	16.180	16.190	16.200	16.160	16.170	16.1800	0.0400
3	16.100	16.110	16.110	16.110	16.110	16.1080	0.0100
4	16.120	16.120	16.130	16.140	16.140	16.1300	0.0200
5	16.130	16.130	16.140	16.150	16.150	16.1400	0.0200
6	16.160	16.160	16.170	16.180	16.200	16.1740	0.0400

USL= 16.220 MAXIMUM= 16.200
LSL= 16.080 MINIMUM= 16.100 X bar= 16.1500
TOLE.= 0.140 RANGE= 0.100 R bar= 0.0150

USING STANDARD DEVIATION

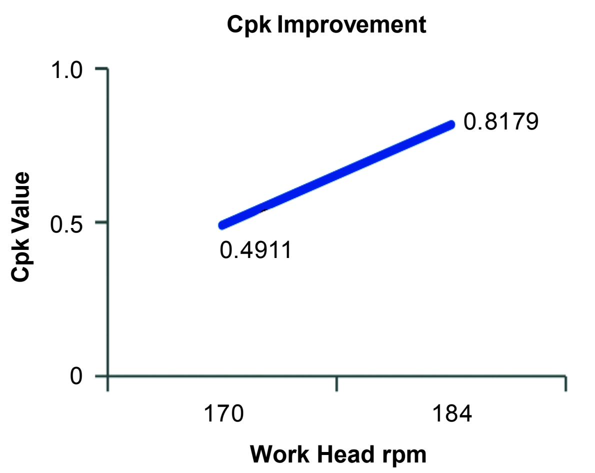
STD. DEVIATION= 0.0285

Cp={USL-LSL} / 6*SIGMA= 0.8179
Cpu={USL-Xbar} / 3*SIGMA= 0.8179
Cpl={Xbar-LSL} / 3*SIGMA= 0.8179

Cpk= MINIMUM{Cpu,Cpl}= 0.8179

The graph shows the improvement in the Cpk value from the initial condition, i.e., 170 rpm, to the increase in the work head speed, i.e., 184 rpm, of the machine (Figure 8).

Figure 8: The Comparison of Cpk Values from the Previously Operating Condition



As there is a positive approach towards the Cpk value, as work head speed increases, further improvement in Cpk value, can be done by still increasing the work head rpm. So, the work speed is further increased from 184 rpm to 200 rpm, to see the effect of variation of the product.

The observations of the product at work head speed of 200 rpm are monitored using PMC and the variations are observed (Figure 9). The variations of the products falls on the

Figure 9: The PMC for the Increased Work Head Speed from 184 rpm to 200 rpm

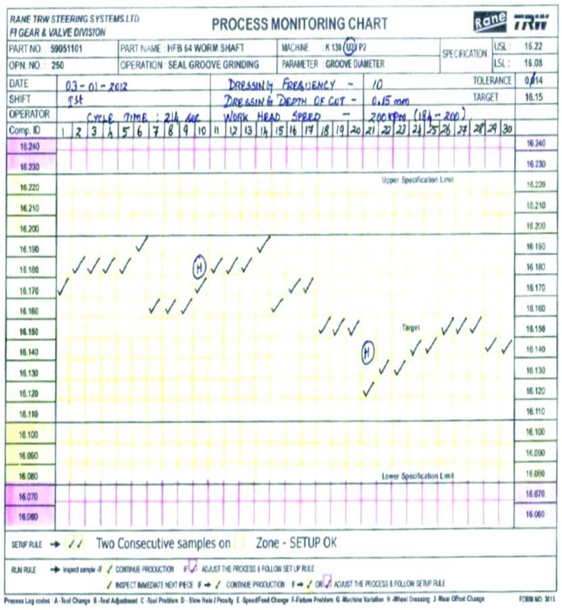
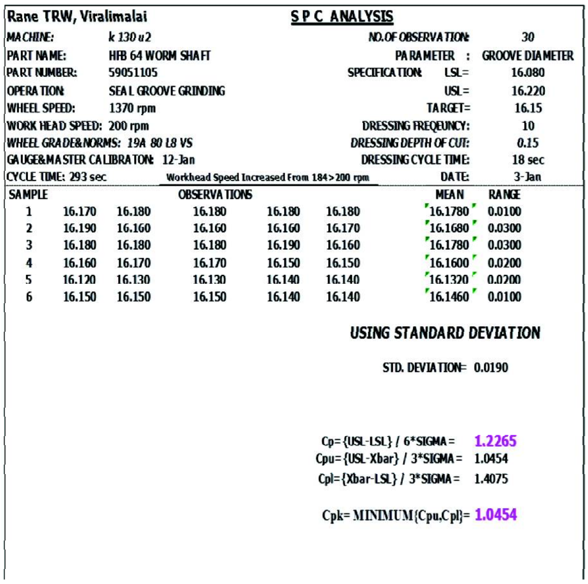


Figure 10: SPC Chart Analysis for the Observed Values Under the Work Head Speed of 200 rpm



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S P C ANALYSIS

MACHINE: k 130 u2 — NO.OF OBSERVATION: 30
PART NAME: HFB 64 WORM SHAFT — PARAMETER : GROOVE DIAMETER
PART NUMBER: 59051105 — SPECIFICATION: LSL= 16.080
OPERATION: SEAL GROOVE GRINDING — USL= 16.220
WHEEL SPEED: 1370 rpm — TARGET= 16.15
WORK HEAD SPEED: 200 rpm — DRESSING FREQEUNCY: 10
WHEEL GRADE&NORMS: 19A 80 L8 VS — DRESSING DEPTH OF CUT: 0.15
GAUGE&MASTER CALIBRATON: 12-Jan — DRESSING CYCLE TIME: 18 sec
CYCLE TIME: 293 sec — Workhead Speed Increased From 184>200 rpm — DATE: 3-Jan

SAMPLE	OBSERVATIONS					MEAN	RANGE
1	16.170	16.180	16.180	16.180	16.180	16.1780	0.0100
2	16.190	16.160	16.160	16.160	16.170	16.1680	0.0300
3	16.180	16.180	16.180	16.190	16.160	16.1780	0.0300
4	16.160	16.170	16.170	16.150	16.150	16.1600	0.0200
5	16.120	16.130	16.130	16.140	16.140	16.1320	0.0200
6	16.150	16.150	16.150	16.140	16.140	16.1460	0.0100

USING STANDARD DEVIATION

STD. DEVIATION= 0.0190

Cp={USL-LSL} / 6*SIGMA= 1.2265
Cpu={USL-Xbar} / 3*SIGMA= 1.0454
Cpl={Xbar-LSL} / 3*SIGMA= 1.4075

Cpk= MINIMUM{Cpu,Cpl}= 1.0454

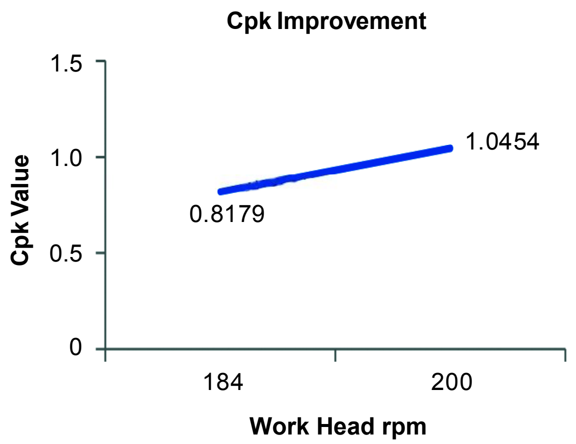
green zone, from PMC, means as the work speed increases, the variations are being controlled within the limits and also results in continuous improvement. As the variations are controlled, gives rise to the Cpk values as well.

The SPC chart shows the Sigma values and the corresponding result in Cp and Cpk values (Figure 10). As the work speed increases, the Cpk value again increases from 0.8179 to 1.0454. This also shows a positive attitude towards the Six sigma quality.

The Cpk improvement after the change in work head speed from 184 rpm to 200 rpm is clearly demonstrated using the graph (Figure 11).

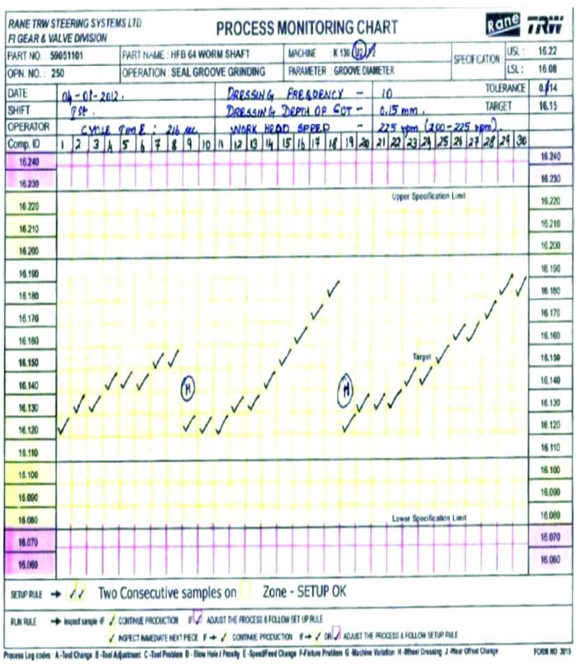
The Cp and Cpk value are increased as the work speed increases and this also favour the objectives. Hence, the speed can be further increased to see the changes on the product variations and as well as in the Cp and Cpk values.

Figure 11: The Chart Showing the Improvement in Cpk Value from the Previous Operating Condition



So, the work head rpm is increased to 225 rpm from 200 rpm and notice the changes. As the speed increases, as mentioned earlier, the contact point between the work piece and the cutting tool decreases, results in the decline of the range in variations. This can be seen from the monitored observations in PMC, at the work head speed of 225 rpm (Figure 12). The PMC shows the variations falls on the green zone, which denotes 100% acceptance of the product. The recording of data of each product on PMC is an easy process to find the deviations from the recommended specification limits of the product. By knowing this, the employer can make some changes to bring back the component into the green zone only if the deviation reaches yellow or red zone of PMC. Otherwise, the processes need not to be disturbed.

Figure 12: The PMC for the Increased Work Head Speed of 225 rpm from 200 rpm



The SPC chart analysis shows an increase in the Cpk value from 1.0454 to 1.1806, when the machine is operated under the work head speed of 225 rpm (Figure 13). So, the work head speed works well for the improvement in quality of the product by reducing the variations. The Cpk improvement from the previously operating condition is shown

Figure 13: The SPC Chart Analysis for the Observed Values Under the Condition of Work Head Speed 225 rpm

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MACHINE:	k 130 u2	NO.OF OBSERVATION:	23
PART NAME:	HFB 64 WORM SHAFT	PARAMETER :	GROOVE DIAMETER
PART NUMBER:	59051105	SPECIFICATION: LSL=	16.080
OPERATION:	SEAL GROOVE GRINDING	USL=	16.220
WHEEL SPEED:	1370 rpm	TARGET=	16.15
WORK HEAD SPEED:	225 rpm	DRESSING FREQUENCY:	10
WHEEL GRADE&NORMS:	19A 80 L8 VS	DRESSING DEPTH OF CUT:	0.15
GAUGE&MASTER CALIBRATION:	12-Jan	DRESSING CYCLE TIME:	8sec
CYCLE TIME: 216 sec	Workhead Speed Increased From 200>225 rpm	DATE:	4-Jan

SAMPLE	OBSERVATIONS					MEAN	RANGE
1	16.1200	16.1300	16.1300	16.1400	16.1400	16.1320	0.0200
2	16.1400	16.1500	16.1500	16.1200	16.1200	16.1360	0.0300
3	16.1200	16.1300	16.1300	16.1400	16.1500	16.1340	0.0300
4	16.1600	16.1700	16.1800	16.1200	16.1300	16.1520	0.0600
5	16.1300	16.1300	16.1400			16.1333	0.0100

USING STANDARD DEVIATION

STD. DEVIATION= 0.0162

Cp={USL-LSL} / 6*SIGMA= 1.4381

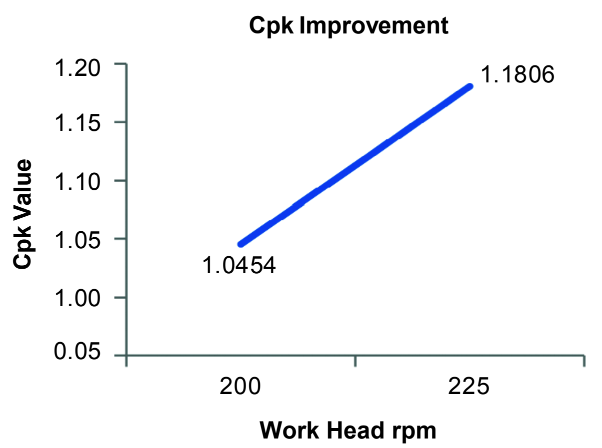
Cpu={USL-Xbar} / 3*SIGMA= 1.6956

Cpl={Xbar-LSL} / 3*SIGMA= 1.1806

Cpk= MINIMUM{Cpu,Cpl}= 1.1806

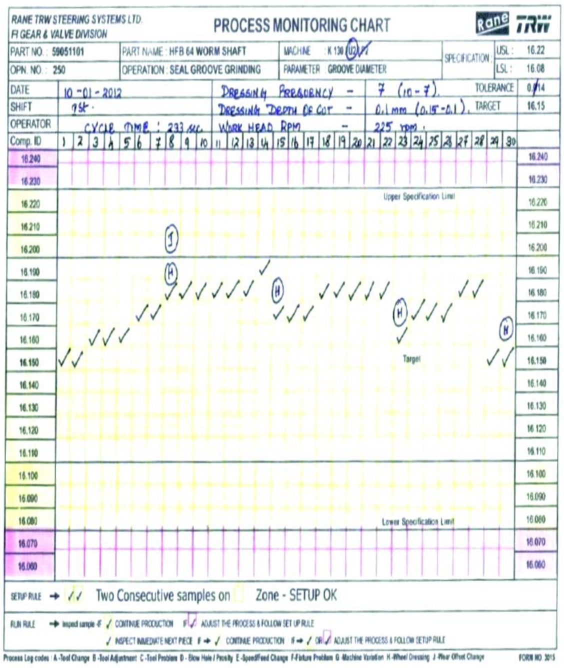
through graph (Figure 14). The increase in work head speed results in the improvement of both Cp and Cpk values. Hence, the speed has been decided to increase further to visualize the changes in the variation of the product.

Figure 14: The Graph Shows the Cpk Improvement from the Previously Operating Condition



Therefore the work head speed is increases from 225 rpm to 250 rpm, and monitored the changes of the machine in PMC (Figure 15).

Figure 15: The PMC for the Condition of Change is Dressing Frequency from 10 to 7 Components



As the speed increases to 250 rpm from 225 rpm, the variation in the product is in control, but the vibration of the machine begins to increase and this ends in the formation of chatters on the product which leads to rejection of the component (http://www.nortonindustrial.com/uploadedFiles/SGindnortonabrasives/Documents/Toolroom%20Selection%20Chart%207505.pdf). This chattering formation is noticed on the first product after the change of speed from 225 rpm to 250 rpm. So, further process on this speed is stopped and the work head rpm of 225 is optimised in that machine.

From the four significant causes, one cause, i.e., the work head rpm has been altered and the changes are visualized. The next action is to take any of those remaining significant causes for alteration and see the changes reflect on the product.

Dressing Frequency

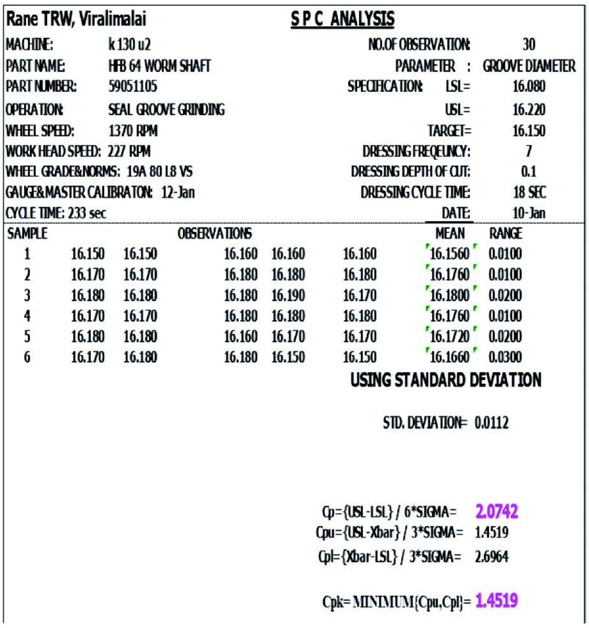
The dressing frequency is taken for further discussion and changes on the dressing frequency is done by keeping the optimised work head speed, i.e., 225 rpm in the machine. From the PMC of the product at various work speed, the variation of the component is high only after the 7th component in a dressing cycle of 10 components. Hence, the 8th, 9th and 10th component of the dressing cycle shows a high variation from the target value. So, the dressing frequency is made to change from 10 components to 7 components. As the dressing frequency is decreases, the dressing depth of cut needs to be decrease (Linke, 2008). So, the depth of cut is changed from 0.15 mm to 0.1 mm radially.

By implementing the above specified changes in that machine and data are collected. The PMC for the monitored observations at a dressing frequency of 7 components is demonstrated clearly (Figure 16).

The PMC shows the variations are fall on the green zone and denotes 0% rejection. But at the same, the cycle time of the process increases due to the reduction in the dressing frequency

The SPC chart analysis for the variations of the product under the condition of dressing frequency 7 components is shown in Figure 17, with the Cp and Cpk values and standard deviations. The change in dressing frequency shows an improvement in Cpk value from

Figure 16: SPC Analysis Observed Values of Dressing Frequency of 7 Components



Rane TRW, Viralimalai — **S P C ANALYSIS**

MACHINE: k 130 u2 | NO.OF OBSERVATION: 30
PART NAME: HFB 64 WORM SHAFT | PARAMETER : GROOVE DIAMETER
PART NUMBER: 59051105 | SPECIFICATION: LSL= 16.080
OPERATION: SEAL GROOVE GRINDING | USL= 16.220
WHEEL SPEED: 1370 RPM | TARGET= 16.150
WORK HEAD SPEED: 227 RPM | DRESSING FREQEUNCY: 7
WHEEL GRADE&NORMS: 19A 80 L8 VS | DRESSING DEPTH OF CUT: 0.1
GAUGE&MASTER CALIBRATON: 12-Jan | DRESSING CYCLE TIME: 18 SEC
CYCLE TIME: 233 sec | DATE: 10-Jan

SAMPLE	OBSERVATIONS					MEAN	RANGE
1	16.150	16.150	16.160	16.160	16.160	16.1560	0.0100
2	16.170	16.170	16.180	16.180	16.180	16.1760	0.0100
3	16.180	16.180	16.180	16.190	16.170	16.1800	0.0200
4	16.170	16.170	16.180	16.180	16.180	16.1760	0.0100
5	16.180	16.180	16.160	16.170	16.170	16.1720	0.0200
6	16.170	16.180	16.180	16.150	16.150	16.1660	0.0300

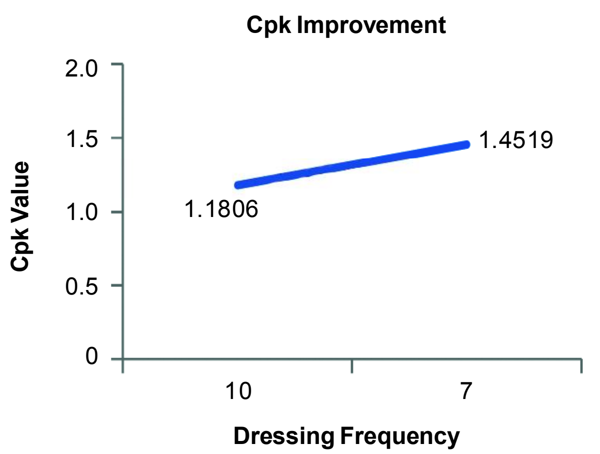
USING STANDARD DEVIATION

STD. DEVIATION= 0.0112

Cp={USL-LSL} / 6*SIGMA= 2.0742
Cpu={USL-Xbar} / 3*SIGMA= 1.4519
Cpl={Xbar-LSL} / 3*SIGMA= 2.6964

Cpk= MINIMUM{Cpu,Cpl}= 1.4519

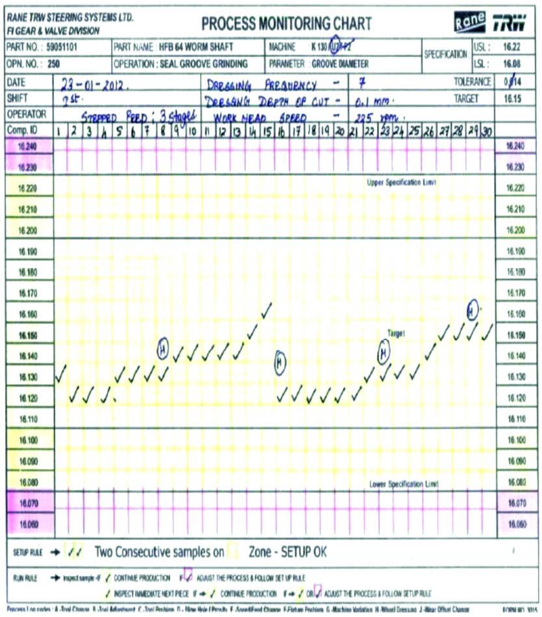
Figure 17: The Cpk Comparison of Effects of Both Dressing Frequencies



1.1806 to 1.4519 and the value of Cpk is very nearer to the objective of Six sigma quality, i.e., Cpk of 1.67.

The Cpk improvement for the change in the dressing frequency from 10 components to 7 components on the machine is shown by graph (Figure 17).

Figure 18: The PMC for the Variations at Stepped Feed Rate Condition



But, due to increase in the cycle time of the whole process, further changes on the dressing frequency is stopped by optimising the changes in that machine and look for changing any of the remaining two significant causes.

Feed Rate

We take the feed rate concept for the further improvement in Cpk value. When the work piece is examined, the hardness of the material changes as the depth of the component increases due to the heat treatment process on it. The hardness of the component is about 1.1 mm along the depth in the total depth of 2.9 mm. Hence, the single feed rate of 1.5 mm/min is not sufficient for the removal of material of the whole depth of the component. So, stepped feed needs to be implement for the efficient removal of material.

Stepped feed in 3 stage as 1.7, 1.6, 1.4 mm/min is to be implement by keeping all other changed process constant and the observations are carried out using the PMC (Figure 18). The PMC shows the values are inside the green zone and there are no possibilities of rejection of the component. Hence, the feed rate change gives a positive result for the objective.

Figure 19: SPC Analysis on the Observed Values Under the Condition of Stepped Feed Rate

Rane TRW, Viralimalai — **S P C ANALYSIS**

MACHINE:	k 130 u2	NO.OF OBSERVATION:	30
PART NAME:	HFB 64 WORM SHAFT	PARAMETER :	GROOVE DIAMETER
PART NUMBER:	59051105	SPECIFICATION: LSL=	16.080
OPERATION:	SEAL GROOVE GRINDING	USL=	16.220
WHEEL SPEED:	1370 RPM	TARGET=	16.150
WORK HEAD SPEED:	227 RPM	DRESSING FREQEUNCY:	7
WHEEL GRADE&NORMS:	19A 80 L8 VS	DRESSING DEPTH OF CUT:	0.1
GAUGE&MASTER CALIBRATON:	Jan-12	DRESSING CYCLE TIME:	18 sec
CYCLE TIME:	233 sec	DATE:	01/23/12

SAMPLE	OBSERVATIONS					MEAN	RANGE
1	16.13	16.12	16.12	16.12	16.13	16.1240	0.0100
2	16.13	16.13	16.13	16.14	16.14	16.1340	0.0100
3	16.14	16.14	16.14	16.15	16.16	16.1460	0.0200
4	16.12	16.12	16.12	16.12	16.12	16.1200	0.0000
5	16.12	16.13	16.13	16.13	16.13	16.1280	0.0100
6	16.14	16.15	16.15	16.15	16.15	16.1480	0.0100

USL= 16.220 MAXIMUM= 16.160
LSL= 16.080 MINIMUM= 16.120 X bar= 16.1333
TOLE.= 0.140 RANGE= 0.040 R bar= 0.0060

USING STANDARD DEVIATION

STD. DEVIATION= 0.0118

Cp={USL-LSL} / 6*SIGMA= **1.9704**
Cpu={USL-Xbar} / 3*SIGMA= 2.4396
Cpl={Xbar-LSL} / 3*SIGMA= 1.5013

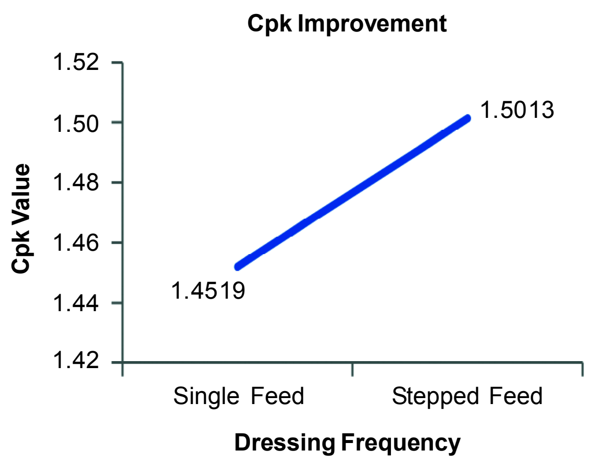
Cpk= MINIMUM{Cpu,Cpl}= **1.5013**

The SPC chart for the changed feed rate process reveals an improvement in the Cpk value from 1.4519 to 1.5013. The SPC chart shows an improvement in the Cp and Cpk values from the previous process and the change enhances the process further.

The increase in Cpk value is clearly shown through graph by comparing the previous changes with the change in the feed rate (Figure 20).

Further change in the feed rate cannot be done, because the supplementary change in feed rate affects the surface finish and optimise the change on the machine. Hence take the final significant cause, i.e., cutting tool. The feed rate of stepped feed is optimised in the machine and looks for any making any change in the cutting tool.

Figure 20: The Cpk Comparison of the Effects of Both Feed Rates



Cutting Tool

Cutting tool in grinding machine is an abrasive and it is an important significant cause than others. The analysis on the cutting tool is a tedious process, since lot of parameters are involved in this such as abrasives, grid size, grade, structure and bond type. In all the previous process, the grinding wheel used is A 80 L8 VS.

This grinding wheel A 80 L8 VS has various explanations for each letters and numbers. The 'A' denotes the Aluminium oxide abrasive; '80' denotes the fine grain size; 'L' denoted the Medium grade; '8' denotes the Open structure; 'V' for the vitrified bond; 'S' for bond modification (http://metalwebnews.com/machine-tools/ch5.pdf).

In the above mentioned grinding specification, the structure is an open structure and during removal of huge depth more wear occurs, results in minimum life of the wheel. So, the structure is taken as a defective parameter in that grinding wheel and it is to be replaced with a dense structure (http://www.grindwellnorton.co.in/GrindingTech/pdfs/FactorsAffectSelection.pdf).

As per the analysis, the dense structure wheel available in the inventory of the company is taken to replace this wheel for to examine any change is occurring in the variation of the component.

So, the dense structure wheel of specifications DA 80 K5 V10 is made to replace the previous cutting tool. The new wheel has a dense structure, '5' . Other than that, no other parameters are changed. By keeping the previously changed significant causes as optimised one and changing the new grinding wheel for the examination.

The observations are monitored and the data are noted in the PMC (Figure 21). The variations of the product fall within the green zone and hence the probability of rejection is 0%. Some process shows nil variations in the product and it falls exactly at the target value.

The product variations are very nearer to the target value. This may give raise to both Cp and Cpk value from the previous process. This can attained from the SPC chart analysis.

The SPC chart analysis (Figure 22) shows the Cpk value of 1.9359, which exceeds the objective of 1.67. This Cpk value denotes that the rejection of the product being manufactured in this machine is about 0.5 PPM. Hence, Six Sigma quality is implemented in HMT machine by improving the four major significant causes in a grinding machine.

The increase in the Cpk value from the previously operated condition to the change

Figure 21: The PMC for the Variations in a Product at Dense Structure Cutting Tool Operating Condition

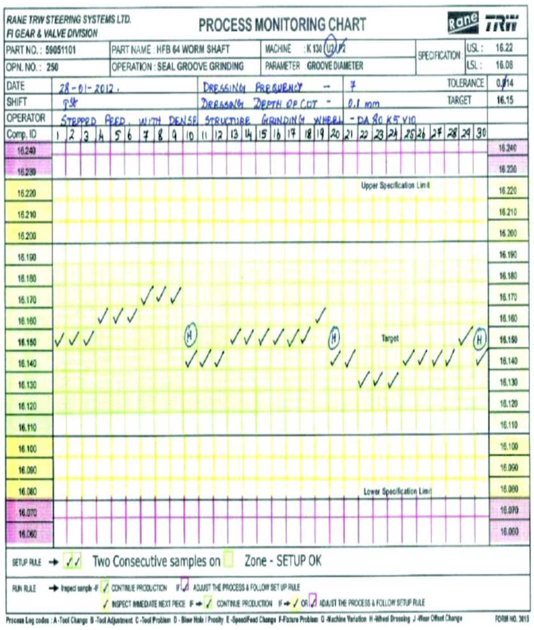
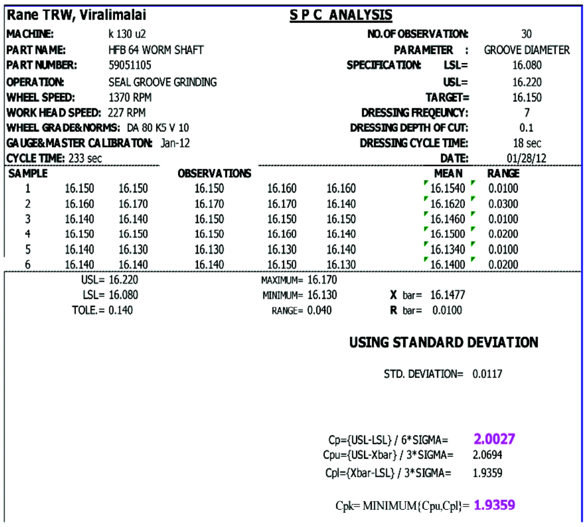


Figure 22: The SPC Analysis for the Observed Values on the Operating Condition of Dense Structure Cutting Tool



Rane TRW, Viralimalai **S P C ANALYSIS**

MACHINE: k 130 u2
PART NAME: HFB 64 WORM SHAFT
PART NUMBER: 59051105
OPERATION: SEAL GROOVE GRINDING
WHEEL SPEED: 1370 RPM
WORK HEAD SPEED: 227 RPM
WHEEL GRADE&NORMS: DA 80 K5 V 10
GAUGE&MASTER CALIBRATON: Jan-12
CYCLE TIME: 233 sec

NO.OF OBSERVATION: 30
PARAMETER : GROOVE DIAMETER
SPECIFICATION: LSL= 16.080
USL= 16.220
TARGET= 16.150
DRESSING FREQEUNCY: 7
DRESSING DEPTH OF CUT: 0.1
DRESSING CYCLE TIME: 18 sec
DATE: 01/28/12

SAMPLE	OBSERVATIONS					MEAN	RANGE
1	16.150	16.150	16.150	16.160	16.160	16.1540	0.0100
2	16.160	16.170	16.170	16.170	16.140	16.1620	0.0300
3	16.140	16.140	16.150	16.150	16.150	16.1460	0.0100
4	16.150	16.150	16.150	16.160	16.140	16.1500	0.0200
5	16.140	16.130	16.130	16.130	16.140	16.1340	0.0100
6	16.140	16.140	16.140	16.150	16.130	16.1400	0.0200

USL= 16.220 MAXIMUM= 16.170
LSL= 16.080 MINIMUM= 16.130 X bar= 16.1477
TOLE.= 0.140 RANGE= 0.040 R bar= 0.0100

USING STANDARD DEVIATION

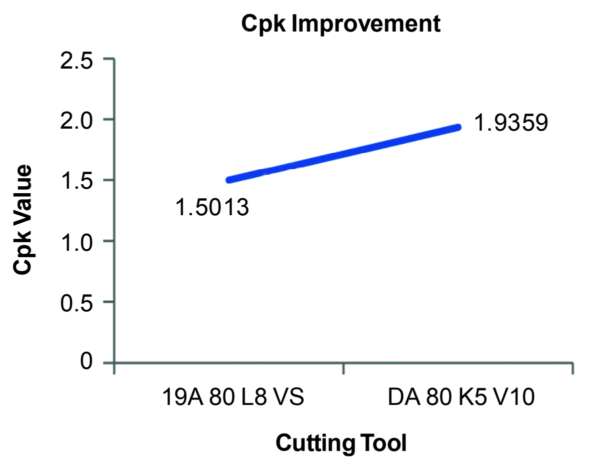
STD. DEVIATION= 0.0117

Cp={USL-LSL} / 6*SIGMA= 2.0027
Cpu={USL-Xbar} / 3*SIGMA= 2.0694
Cpl={Xbar-LSL} / 3*SIGMA= 1.9359

Cpk= MINIMUM{Cpu,Cpl}= 1.9359

in the cutting tool is clearly demonstrated using the line graph (Figure 23).

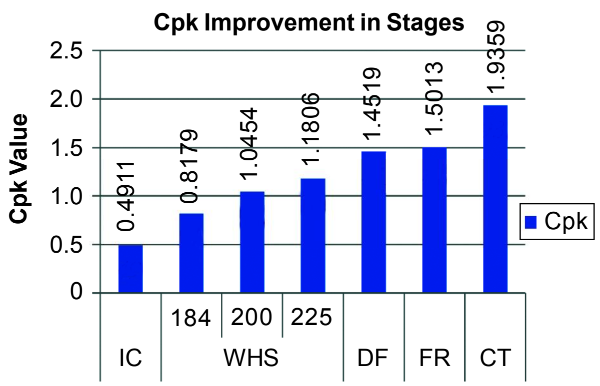
Figure 23: The Cpk Comparison of Cutting Tool from the Previously Operated Condition



RESULTS AND DISCUSSION

The Process Monitoring Chart and Statistical Process Control are the helping tools for performing such a huge process. The every improvement in the process cycle is noticed and implemented for the permanent achievement in the quality of the product.

Figure 24: The Cpk Improvement on Every Actions and Optimization of the Each Completed Action



Note: IC – Initial Condition; WHS – Work Head Speed in rpm; DF – Dressing Frequency; FR – Feed Rate in mm/min; CT – Cutiing Tool (abrasive).

Finally, the work head speed of 225 rpm; dressing frequency of 7; stepped feed rate of 1.7, 1.6, 1.4 mm/min; dense structure cutting tool of specification DA 80 K5 V10 are optimised in the machine for the defects less and variations less product output. The total result of the project is shown with different stages of action of the corresponding Cpk value (Figure 24).

CONCLUSION

This improvement in the quality not only gives customer satisfaction, it also gains more profit to the organisation. The back tracking of the finished product is minimum hence this makes a way for reducing the time constraints.

The available time increases as a result of reduction in the re-work and backtracking of the products, the productivity increases rapidly. If all these are achieved in the machine, the cost of a product will play a major role. The organisation can give a product at a competitive price, than other firms and at the same time, deliver at a world class products.

This methodology is applicable for any kind of grinding machine for to improve the quality of the product. The four significant causes can be made into insignificant, if the analysis and approach to the existing problem in a right way. This method has to be done with careful premeasures and with the knowledge of the employer.

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