ABSTRACT
Surface grinding is the most common process used in the manufacturing sector to produce smooth finish on flat surfaces. Surface quality is the important performance characteristics to be considered in the grinding process. The economics of the grinding process is affected by several factors such as, machining speed, depth of cut, feed and material properties. Quality control helps industries in improvement of its product quality and productivity. Statistical Process Control (SPC) is one of the tools to control the quality of products that practice in bringing a manufacturing process under control. In this paper, the process control of Spacer tube manufactured at TRUE FIT PRECISION is vendor of TATA Motors discussed. The varying measurements have been recorded for a number of samples of a spacer tube obtained from a number of trials with the Grinder. SPC technique has been adopted, by which the process is finally brought under control and process capability is improved. In order to produce any product with desired quality by machining, proper selection of process parameters is essential. Process capability is to be assessed by using statically process control techniques like control charts, it reduces the variability in delivery times, completion times control chart in is an important tool for robust design, which offers a simple and systematic approach to optimize a design for performance, quality and cost. Quality achieved by means of process optimization is found by many manufacturers.

1. INTRODUCTION
This paper describes use and steps of Statistical process control, specific range and surface grinding parameters like cutting speed, feed rate and depth of cut to optimize the critical to quality parameter values of response variables like surface finish (roughness), parallelism (flatness) in surface grinding of spacer tube of FG 260 gray cast iron Material. Process Currently in Trufit Precision, Karad, Dist.-Satara is a small scale industry which is doing surface grinding machining operation of 600 spacer tube casting components per day for Tata motors. Grinding process is carried on vertical spindle surface grinder having the grinding capacity (250*500mm). During the surface grinding machining the important input parameters are feed, speed, and depth of cut, properties of work piece material such as hardness which affects on the output parameters of surface grinding machine such as majorly work piece parallelism, flatness and surface roughness (surface finish) of spacer tube increase in time of production, increase the cost of production. So this type of variation due to men, material and machine, so there is need to study the process and for consistent performance of grinding machine need to identify the factors which contribute to variability and the effect of variations in various parameters on work piece parallelism flatness, surface finish (surface roughness) of spacer tube in grinding. Surface grinding machine cannot gives the require process capability for total production process improvement so there is need to study the statically process control and to implement. Spacer tube having tube hardness: 180- BHN is used between hub inner and outer bearings in automobile at Tata motors. Composition of work piece of spacer tube [ FG:260 ] cast iron is as given below after grinding was found to be out of tolerance limits asked by TATA MOTOR, the process capability found to be less than the standard value. This required the idea of SPC implementation and the techniques been practiced. This process enables a company to meet four main objectives: higher quality, more effectiveness, produces products of optimum quality. SPC tools can be used by operators to monitor their part of production or service process for the purpose of making improvements.

2. METHODOLOGY

A. Goals of SPC:
1. Understand the process
2. Eliminate special cause variation
3. Reduce common cause variation and maintain a process that is in "statistical control" and has high "process capability".

B. Errors and variation can arise from two kinds of causes:
1. Special Causes: (assignable, local Variation), special cause, e.g., miscalibrated instrument. It can be detected by running known standards and recalibrating [3].
2. Common Causes: (random, system variation) due to unknown causes. e.g., normal fluctuations in instruments, natural variation in raw materials. Statistics is more applicable to measuring and controlling variation from common cause (random) than from special causes [3].

C. Variations can be reduced by:
1. Fundamental Point: Special causes and random causes of variation are treated differently.
2. Process Capability Improvement by Putting ‘Statistical Process Control’ into Practice. 15% of variation is special cause and is fixable by the worker.

D. Usefulness of Control Charting:
Control charts are also known as process-behavior charts. Variable control charts are used to study a process when characteristics is a measurement, for example, cycle time, processing time, waiting time, detects special causes of variation, measures and monitors common causes of variation.

E. Steps in an SPC Program:
1. Identify the cause of variation in order to remedy it. This is not always obvious;
2. Remove special causes, e.g., recalibrate the instrument, store standards to minimize Deterioration, etc. Once a process is free of special causes, it is said to be STABLE even Though it still has variation due to random causes.
4. Establish and carry out a plan to monitor, improve and assure the quality of the process, e.g., charting, maintenance, training and record keeping, in order to constantly and forever reduce variation [3].
5. Normally the values cluster about the average value
\[
\text{Average } \bar{x} = \frac{(x_1 + x_2 + \ldots + x_n)}{n} = \frac{\sum x_i}{n}
\]
Where, n refers to number of data points (usually called the population), xi refers to the measured dimension of a component of a sample, and \(\bar{x}\) refers to the average (usually called the population or process mean). When all parts are measured, the standard deviation Where, (\(x_i - \bar{x}\)) is the difference between an individual datum and the sample average.

calculation becomes:
1. \(\bar{x}\) is the standard deviation of the sample. (Pronounced sigma).
2. The arithmetic average (mean) of ranges
3. Process (or population) Standard Deviation, \(\sigma = \frac{R}{D_2}\) (5)

Where, \(D_2\) is the factor obtained from tables of constants used in constructing control charts.
4. Standard Deviation of the sample mean, \(\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{N}}\) (6)
5. Average \(\bar{x}\) (Process mean), \(\bar{x} = \frac{\sum x_i}{n}\) (7)
6. Upper Control Limit, UCL\(\bar{x}\) = \(\bar{x} + 3\sigma_{\bar{x}}\) (8)
7. Lower Control Limit, LCL\(\bar{x}\) = \(\bar{x} - 3\sigma_{\bar{x}}\) (9)
8. Range, \(R = \text{[Highest value – Lowest value]}\) (10)
   - Upper Control Limit, UCLR = \(D_4 R\) (11)
   - Lower Control Limit, LCLR = \(D_3 R\) (12)

Where, \(D_3\) and \(D_4\) are the factors obtained from tables used in constructing control charts.[5]

Process Capability (Capability Index): Process capability (Cp) is simply the ability of a process to meet a customer's product specification. A process must be in control before Cp is calculated. Capability Ratio (CR) is simply the inverse of Process Capability. The lower is the CR the more capable is the process.

Process Capability Index (Cpk) is equal to the lower of \(\text{Cpu}\) (upper process capability) and \(\text{Cpl}\) (lower process capability). Cpk is a better measure of process capability than \(\text{Cp}\) or \(\text{CR}\) since Cpk takes into account the actual process center compared to the target

III. METHODOLOGY
1) Record: Recorded component details. At first, component details were taken as furnished below:
Component Name: Spacer Tube
Customer Name: TATA MOTOR PUNE, India.
Specifications: 106.200 + 0.025 (as per the customer drg).

Upper Specification Limit (USL): 106.225 mm
Lower Specification Limit (LSL):106.200 mm

Several measurements of thickness ground by the Manual operated Grinder in different trials have been recorded for every component in the observation tables. One of the observation tables (trial no. 8) is given as under:

3. EXPERIMENTATION DETAILS
Suppose that three factors, A, B, and C, each at two levels, are of interest.
The design is called \(2^3\) factorial designs three factors and two levels, which is taken for present process optimization. So, as per the \(2^3\) design, numbers of trial runs are eight.

A notation to represent high and low levels of the factors is done by using the +1 and -1 respectively.
The eight runs in the \(2^3\) design sometimes called the design matrix which is prepared by using Minitab15 software are as shown in table.
(2) Feed: In this process the feed have less steep slope therefore it has less effect on process & results. The low level of feed (0.01 mm/min) resulting in less flatness (0.017 mm) & the high level of feed (0.03 mm/min) resulting in more flatness (0.018 mm). From this graph we have value of flatness is 0.0175 mm.

(3) Depth of cut: In this process the depths of cut have steeper slope therefore it has larger effect on process & results. The low level of depth of cut (0.02 mm) resulting in more flatness (0.0215 mm) & the high level of depth of cut (0.04 mm) resulting in less flatness (0.0135 mm). From this graph we have value of flatness is 0.0175 mm.

INTERACTION PLOT FOR FLATNESS:
At low speed (2600 rpm) feed goes on increasing the flatness also goes on slightly increasing. At high speed (3000 rpm) feed goes on increasing the flatness also slightly increasing. At low speed (2600 rpm) depth of cut goes on increasing the flatness value slightly increasing. At high speed (3000 rpm) depth of cut increases the flatness value increases rapidly. At low feed value (0.01 mm/min) depth of cut increases the flatness value rapidly increases. At high feed (0.03 mm/min) depth of cut increases the flatness creases rapidly.

RESULTS AFTER THE ANALYSIS:
OBSERVATION AFTER ANALYSIS:
The graph shows process capability six pack. In this include sample mean, sample range, values, capability histogram, normal probability plot, capability plot. Sample mean shows the all readings and UCL, LCL and sample mean i.e. X bar. The sample mean is 106.22 for this graph. Sample range chart shows the range of readings which we conducted. The sample range R of bar of this process 0.001800. The values chart shows the all actual values of readings which we had taken from the dial gauge indicator. Capability plot shows the bell shaped curve which shows process capability of entire process. The process capability (Cp) of this process is 1.19 & process capability index (Cpk) of this process is 0.94. The normal probability plot shows the readings scattered between two curves tilted vertically. These readings scattered between 106.218 to 106.224 which are lower control limit & upper control limit of the process. The capability plot shows the all process capability indices. The process capability (Cp) of this process is 1.19 & process capability index (Cpk) of this process is 0.94, Pp=1.09 & Ppk=0.86.
Remove special causes, e.g., recalibrate the instrument, store standards to minimize deterioration etc. Once a process is free of special causes, it is said to be STABLE even though it still has variation due to random causes. Estimate the Process Capability. Establish and carry out a plan to monitor, improve and assure the quality of the process e.g. charting, maintenance, training and record keeping, in order to constantly and forever reduce variation. Normally the values cluster about the ‘average value’.

\[ \text{Average} = \bar{x} = \frac{(x_1 + x_2 + \ldots + x_n)}{n} = \frac{1}{n} \sum x_i \]

Where, 
\( n \) refers to number of data points (usually called the population), \( x_i \) refers to the measured dimension of a component of a sample, and \( x \) refers to the average (usually called the population or process mean).

When all parts are measured, the standard deviation\( \sigma \) calculation becomes,
\[ \sigma x = \sqrt{\frac{\sum (x_i - \overline{x})^2}{n}} \]

Where,
(xi - x) is the difference between an individual datum and the sample average.
x is the standard deviation of the sample.
The arithmetic average (mean) of ranges,
\[ \bar{R} = \frac{\sum R_i}{n} \]
k. Process (or population) Standard Deviation, 
\[ \sigma = \frac{R}{\bar{R}} \]
Where, D2 is the factor obtained from tables of constants used in constructing control charts.
Standard Deviation of the sample mean, 
\[ \sigma_x = \frac{\sigma}{\sqrt{n}} \]
Average xi (Process mean), 
\[ x = \frac{\sum x_i}{n} \]
Upper Control Limit, 
\[ UCL_x = x + 3\sigma_x \]
Lower Control Limit, 
\[ LCL_x = x - 3\sigma_x \]
Range charts are constructed immediately below the xi or x chart. When more than 1 data point per day is analyzed and x values are plotted on a x chart, the range is the difference between the highest and lowest xi in that period (subgroup).
Range, 
\[ R = \text{[Highest value} - \text{Lowest value}] \]
Upper Control Limit, 
\[ UCLR = D4 \cdot R \] (11)
Lower Control Limit, 
\[ LCLR = D3 \cdot R \] (12)
As per calculation we are calculated the all values
Where, 
D3 and D4 are the factors obtained from tables used in constructing control charts. Process Capability (Capability Index): Process capability (Cp) is simply the ability of process to meet a customer’s product specification. A process must be in control before Cp is calculated. Capability Ratio (CR) is simply the inverse of Process Capability. The lower is the CR the more capable is the process.

**OBSERVATION BEFORE THE ANALYSIS**

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**RESULTS AFTER THE ANALYSIS**

**Table Result after analysis**

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5. RECOMMENDATION
In the present investigation which carried out to focus on the root sources which limit bearings efficiency and then leading to bearings failure. A proactive approach is to eliminate the following sources of failures in order to avoid and remedy such causes and then increase life time of bearings, as bearing failure has a great impact on industry economy. After grinding the no. of components 8000 to 8500 the bearing should calibrate or replace from the machine. After every batch (100 components) the speed of the machine should measure with the tachometer equipments and note down the variation if any. Select the best combination of input parameters. From these all consideration company will get the continuous improvement in the process with results improve in efficiency with better quality.

6. CONCLUSION
In present work grinding of spacer tube by vertical spindle surface grinder components such as spacer tube is used in rear wheel hub in between spindle to fill the gap. This spacer tube product is used in the trucks of model number starting from M-1213 to keep the gap and reduce the friction and wear resistance has been done and following conclusions are drawn.

The control limits obtained after the remedial actions taken for the grinder are within specification limits and the flatness produced in all the components of every sample lie under the control limits. The flatness 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.

1. The process capability (Cp) increased from 0.46 to 1.19 which shows 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.
2. The productivity increased from 94% to 99% which show that implementation of SPC technique is proved to be successful in improving the performance of grinding process.
3. Capability Ratio (CR) is reduced from 2.17 to 1.06 which means that the process spread now occupies 20 % of the tolerance. The lower is the CR the more is capable the process.
4. Cp is a better measure of process capability than Cpk or CR since Cp takes into account the actual process center compared to the target. Here, we got Cp as 1.19 which is greater than 0.46 was required by the customer.
5. Optimum parameters such as speed, feed and depth of cut which is critical to quality for vertical spindle surface grinder are 2800rpm, 0.02mm/min and 0.03mm after technical suggestion i.e. after recommendation to quality control department.

7. SCOPE OF FUTURE WORK
These all become possible with the implementation of an SPC technique. Likewise, the SPC tools can be implemented to solve so many real life problems of grinding machine and processes in future that may come up with meeting the demand of higher quality and productivity of vertical spindle surface grinding machine in production process.

REFERENCES:
