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PROCESS CAPABILITY ANALYSIS OF BALL BEARING INNER RACE: A CASE STUDY

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Abstract

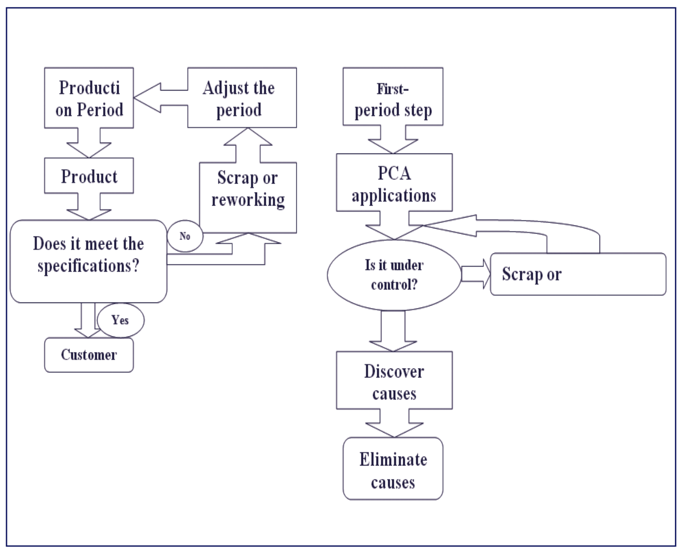
Process capability analysis (PCA) is shown a capacity of the process to meet up a pre-specified required value. PCA defines that how a product specification relates to the common variations occur in the process. PCA has been usually applied in various companies and processes i.e. an automobile, air conditioning, manufacturing, ordinance factories, medical industries etc. Among these industries, bearing manufacturing firms hold a special value, as bearings are an integral part of all prime movers. In this paper, PCA has been applied on the inner race of ball bearings to attain success in terms of productivity, quality control, improvement plans and their successful implementation. The work is focused on the computation of process capability indices (PCIs) with the help of collected data and to provide solutions to identified problems. In this work, PCA was done with the help of MINITAB 18.0 and the results were obtained in the form of graphs and control charts. Based on these findings, strategies for quality improvement were developed and suggested to the concerned firm.

Keywords: Process Capability Analysis (PCA), Statistical Process Control (SPC), Process Capability Indices (PCIs).

1. INTRODUCTION

Quality has been an extremely important management strategy for achieving competitive advantages and improvements [1]. Quality and variability both are inversely proportional to each other and as variability can simply be describe into statistical terminology; the fundamentals of statistical method are regular enhancement of the process [2]. Production with good quality has some benefits like minimize rate of rejection, scrap, rework and increases the market value of the product with customer satisfaction. For achieving a quality production used statistical stage techniques at each and every stage of production. When process is statistically control the process can carry-on without any change into the process until organization don't want improve their current process. On the other hand, if the process is not statistically control, then responsible causes must be revealed and minimized. Statistical quality control (SQC) and conventional approaches are relatively different from each other; SQC contribution is much important for improvement in bearing manufacturing industries and other also. In conventional approach, manufacture the product first, and after that check whether it fulfils the required quality or not. When the product not satisfies the expected quality requirement than product discarded and reverts for improvement. If discarded products were to a large in quantity, corrective actions required for minimizing the assignable causes by examining the production stage (Fig. 1a). SQC is a very important part of the production, instead of investigating the finished product. SQC applied at each stage of the production. If current stage is under statistical control, then the subsequent stage is considered; or else, causes exposed and minimised [3].

Figure 1. Quality control methods: (a) traditional quality control method; (b) statistical quality control method [2].



(a) (b)

SPC is not just a tool for analysing quality improvements. Although using as a technique for assessing the ability of a process to manufacture good quality products continually. The ability of the process is to provide the products dimensions within the pre-specified limits. The control charts were used to ensure nonconformist products were reduced during the ongoing process [4]. A steady process, in general, is a process of which all the causes of variations are known and are acted upon and the process is the ruled by common roots of variations, where the output of the process is relatively expectable. Management decision required to further enhance the ability of the process. In the theory of probability as well as statistics, normal distribution is a regular probability distribution so as to describe statistics those groups more or less a mean. The related curve of the probability density function be normal with a peak at the mean, this is acknowledged "Gaussian function" or bell-shaped curve [5]. Capability index (C_p and C_{pk}), were invented before some decades to compute this assessment among control as well as specified limits. The capability index is a quotient so as to compares spread of the process and tolerance, also results within single digit [6]. The PCIs were generally used in the new processes to inspect the product according to specified limits in manufacturing practice. These capability indices are helpful to reduce variations of the product [7]. C_p index indicates the distribution of dimension of the manufacturing quality features of the product inside the specific region that defined by the designer, whereas C_{pk} indicate the process is perform at the mid-point or else closer to upper or lower tolerance limits [8]. When process production is closure to the given target and minimum spread, than the process to be more capable. PCI provides a tremendous value than the process is more competent. We have assumed in this work the process was under statistical control also the features under analysis occur on or after a normal distribution. Likewise, the value of the target occupied to be present at mid-point of the specified restrictions [9]. PCIs cover expected significant consideration in quality assertion to do research as well as amplified practice in process evaluation [10]. Individual PCI gives standard quantitative events on production ability in addition to manufacturing excellence. Seller and buyer mention these when they sign a deal so; these indices are attractive, commanding tools in favor of the quality description [11]. The control chart was used to monitor mean of the process and process variation. The purpose of the control chart is to differentiate among the common and assignable cause of deviation [12].

2. PROCESS CAPABILITY INDICES (PCIS): CP, CPK AND CPM

In the manufacturing process PCIs was generally used for measure the process capability. PCIs are considered to compute the relation among the real process performance with its specific desires. In case of two-sided intervals industries are specifically used PCIs are

$$C_p = \frac{USL-LSI}{6\sigma},\ C_{pk} = \frac{\min(USL-\mu, \mu-LSL)}{3\sigma} \text{ and } C_{pm} = \frac{C_p}{\sqrt{1+\left(\frac{\bar{X}-T}{\sigma}\right)^2}}$$

3. CONTROL CHARTS TYPE X BAR-R

Control charts are used to examine variation of the manufacturing process. It is useful tool for the appearance of statistics. They seek to find out if an order of statistics possibly use for prediction of upcoming results [13]. In the control chart, X represents the performance as well as capability of the operator. R represents reflection of administration work sheet as well as competence of firm.

Table 1. Characteristic of chart type X bar-R [14]

X-bar R chart	Characteristic
	The control charts are used while controlling aspects were computable with a continuous programme. Assets: provision of submission, tiny sampling option.

4. EXTENSIONS AND APPLICATIONS: A CASE STUDY

In this part, useful applications of PCIs are introduced. A medium scale bearing manufacturing industry is considered in this study. The comparison of PCIs is performed using MINITAB 18.0. The objective is to minimize the variability of the product dimensions. The target value is 34.40 mm. The upper and lower specified limits are 34.43 mm and 34.37 mm respectively. Samples are collected by measuring the dimensions of 80 ball bearings inner race every day, therefore collect 200 observed data. The mean is 34.397 mm and value of SD is 0.0153 mm as the process capability report.

5. STEPS OF WORK

Figure 2. Steps of work

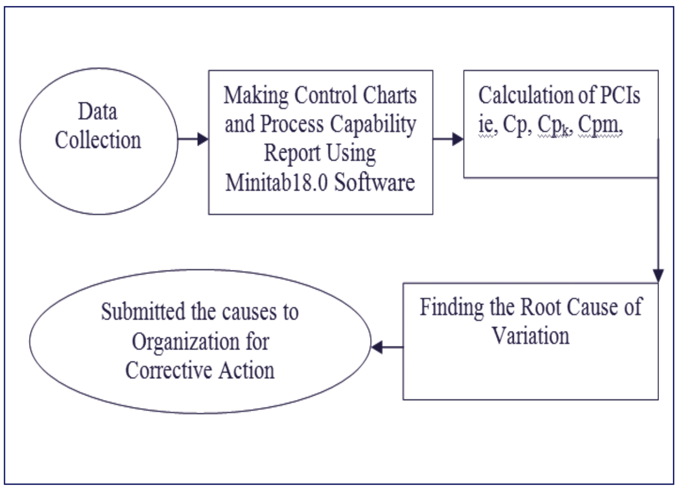


Table 2 shows that the data collected after the machining process on the inner race of bearing with 40 samples are considered; each sample contains five observations also calculate process mean and process range. The drawing dimension is 34.40±0.03 mm.

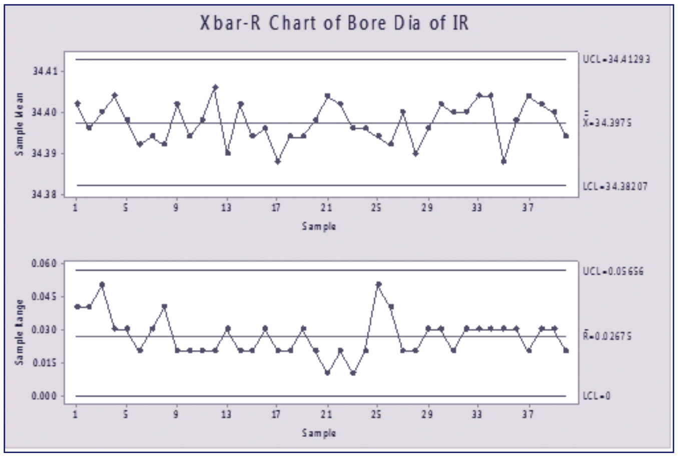
Table 2. Collected data of Bore Diameter of Inner Race

Bore Diameter of inner Race (IR)							
Tolerance = 34.40 ± 0.03 mm							
S. No.	**1**	**2**	**3**	**4**	**5**	**X Bar**	**Range**
1	34.40	34.41	34.38	34.40	34.42	34.402	0.04
2	34.41	34.40	34.39	34.38	34.40	34.396	0.03
3	34.40	34.40	34.40	34.37	34.39	34.392	0.03
4	34.42	34.41	34.39	34.40	34.40	34.404	0.03
5	34.38	34.39	34.38	34.42	34.41	34.396	0.04
6	34.40	34.40	34.40	34.40	34.40	34.400	0.00
7	34.37	34.39	34.38	34.41	34.41	34.392	0.04
8	34.41	34.40	34.40	34.37	34.39	34.394	0.04
9	34.40	34.38	34.39	34.40	34.42	34.398	0.04
10	34.40	34.40	34.40	34.38	34.40	34.396	0.02
11	34.43	34.39	34.38	34.40	34.38	34.396	0.05
12	34.40	34.40	34.40	34.41	34.37	34.396	0.04
13	34.39	34.41	34.41	34.40	34.39	34.400	0.02
14	34.40	34.40	34.40	34.39	34.40	34.398	0.01
15	34.38	34.39	34.38	34.40	34.40	34.390	0.02
16	34.40	34.40	34.41	34.39	34.40	34.400	0.02
17	34.41	34.42	34.40	34.40	34.38	34.402	0.04
18	34.39	34.40	34.39	34.38	34.40	34.392	0.02
19	34.40	34.41	34.40	34.40	34.41	34.404	0.01
20	34.42	34.40	34.39	34.38	34.40	34.398	0.04
21	34.40	34.38	34.40	34.40	34.41	34.398	0.03
22	34.40	34.40	34.41	34.38	34.39	34.396	0.03
23	34.38	34.37	34.40	34.39	34.41	34.390	0.04
24	34.41	34.40	34.41	34.40	34.40	34.404	0.01
25	34.40	34.40	34.40	34.41	34.41	34.404	0.01
26	34.38	34.39	34.41	34.40	34.40	34.396	0.03
27	34.40	34.40	34.40	34.39	34.39	34.396	0.01
28	34.39	34.41	34.39	34.40	34.40	34.398	0.02
29	34.40	34.40	34.40	34.42	34.40	34.404	0.02
30	34.39	34.41	34.41	34.40	34.42	34.406	0.03
31	34.38	34.40	34.40	34.41	34.41	34.400	0.03
32	34.40	34.39	34.39	34.40	34.40	34.396	0.01
33	34.41	34.40	34.40	34.39	34.38	34.396	0.03
34	34.38	34.38	34.39	34.40	34.40	34.390	0.02
35	34.40	34.40	34.40	34.40	34.41	34.402	0.01
36	34.37	34.38	34.41	34.39	34.40	34.390	0.04
37	34.38	34.39	34.39	34.40	34.40	34.392	0.02
38	34.40	34.40	34.40	34.42	34.39	34.402	0.03
39	34.41	34.41	34.39	34.39	34.40	34.400	0.02
40	34.40	34.40	34.39	34.40	34.38	34.394	0.02
						$\bar{\bar{X}} = 34.398$	$\bar{R} = 0.0267$

According to Montgomery, establishment of process control could be iterative, along with limits to be generally view as check limit. The process was functioning approximately hit the target with a few common causes of variability without any other reason.

The process capability calculated by a control chart, in figure 3 below.

Figure 3 X-bar R charts of bore diameter of the inner race



According to control chart results, the entire samples are in between both control limits, the process is under statistical control. Mathematical calculations of control chart as follows:

6. CONTROL LIMITS

Control limits for X-bar chart for machining of bore diameter

Upper control limit: $UCL = \bar{\bar{X}} + A_2\bar{R}$

UCL = 34.398 + (0.577*0.026) = 34.412 mm

Centre line $\bar{\bar{X}} = 34.398$ mm

Lower control limit: $LCL = \bar{\bar{X}} - A_2\bar{R}$

LCL = 34.399 – (0.057*0.037) = 34.382 mm

Control limits for R chart for machining of bore diameter

Upper control limit: $UCL = D_4\bar{R} = 2.114 * 0.0267 = 0.0565$

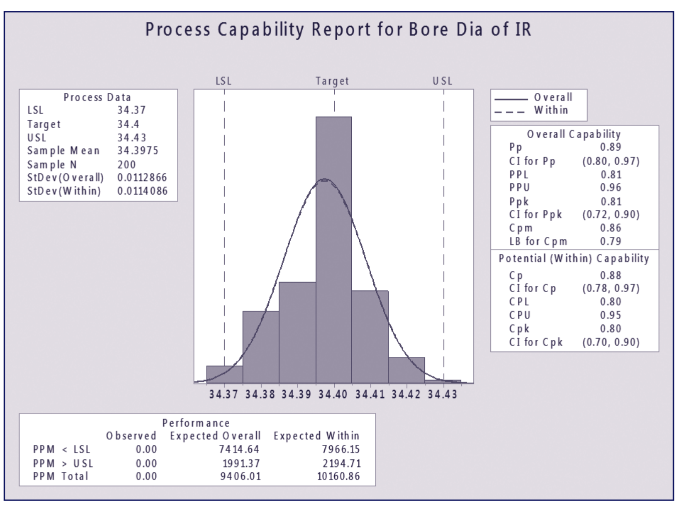
Centre line = $\bar{R}$ = 0.0267

Lower control limit: $LCL = D_3\bar{R} = 0$

In the above section A_2 =0.577, D_4=2.114 and D_3=0 are constants [5].

Process capability report for bore diameter of inner race of ball bearing shows in fig. 4 below generated by MINITAB18.0 software. In this report 200 machined work piece data's are used.

Figure 4 Process capability report of bore diameter of the inner race



PCIs Calculation:

$$C_p = \frac{USL-LSL}{6\sigma},\ C_{pk} = \frac{\min(USL-\mu, \mu-LSL)}{3\sigma} \text{ and } C_{pm} = \frac{C_p}{\sqrt{1+\left(\frac{\bar{X}-T}{\sigma}\right)^2}}$$

$$Cp = \frac{34.43mm - 34.37mm}{6 * 0.0114mm} = 0.88$$

$$Cpku = \frac{34.43mm - 34.3975mm}{3 * 0.0114mm} = 0.95$$

$$Cpkl = \frac{34.3975mm - 34.37mm}{3 * 0.0114mm} = 0.80$$

Cpk=min ($Cpku$; kl)= 0.80

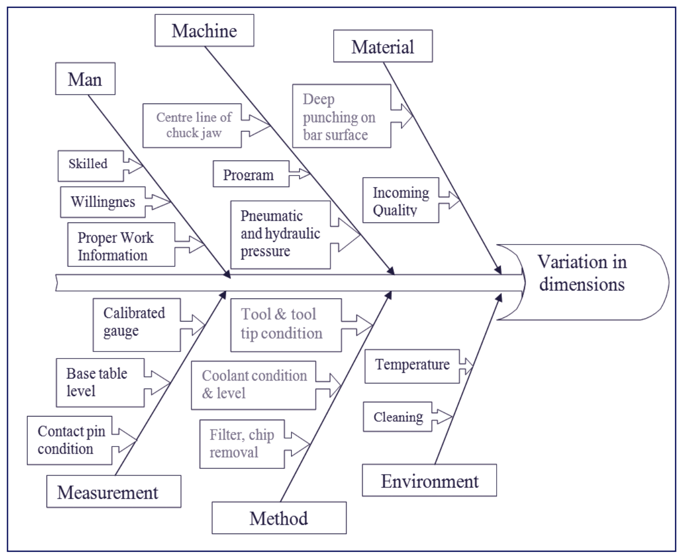
$$C_{pm} = \frac{0.88}{\sqrt{1+\left(\frac{34.398-34.40}{0.0114}\right)^2}} = 0.86$$

Above values of process capability indices, C_p and C_{pk} are less than 1.33 then immediate improvement needed. But the process is under statistical control.

7. FINDING ROOT CAUSES FOR VARIATION

The values of PCIs were not appropriate; therefore it is essential to discover the causes accountable for the variation in dimension of the product. The feasible causes for variation are mentioned in Figure 5

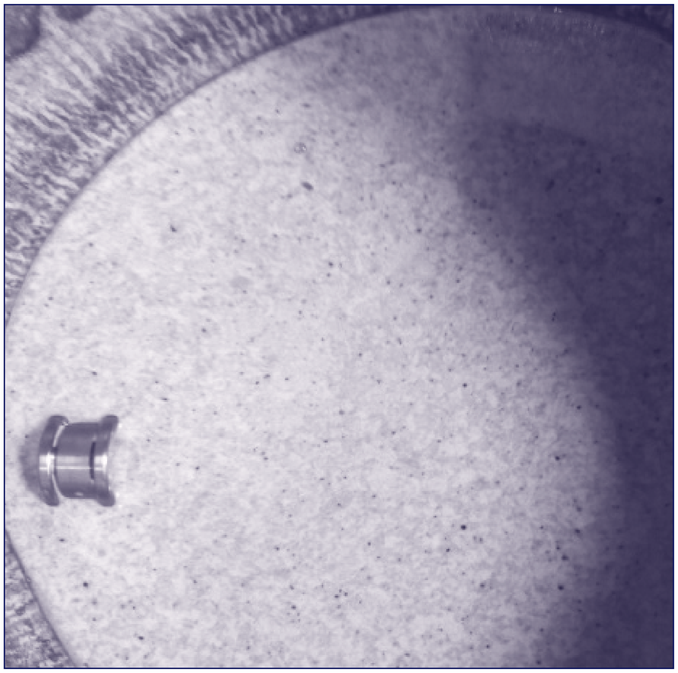
Figure 5. Cause and effect diagram



Possible reasons of variability in the dimensions of the process mainly owe machine as well as operate causes. Sometimes cutting tool, the coolant category and life source errors occur during the machining process.

- Proper removal of chips from cutting tool and chuck jaws after every machined product.
- The tool life should be closely monitored. Tool should be changed not after ongoing production batch, in between the ongoing production batch to minimize the possible variation.
- Replacement of existing coolant filters with smaller mesh size. The coolant and coolant filter changed after specified duration or machine run time. Also clean the coolant filter after every production batch and check the level of coolant in tank.

Figure 6 Tiny chip particles found in coolant



- Before start the production check all the setting of machine every day. Specifically check chuck jaws were centered or not to prevent ovality.
- Use sticker on raw material steel round bar for specifications.

Figure 7 After suggestion raw material with stickered specification

After analysing above points, it was observed that the variability could be minimised by eliminating these causes.

8. RESULT AND DISCUSSIONS

PCA is applying mathematical regulations and technique in every stage of plan, production and deal. Among these methods to assure, the quality for the duration of manufacturing is to concern the SPC technique to each phase of manufacturing for the duration of or later than production. PCA have much improvement in manufacturing with mass level production. PCA help us to find out capability for production among both acceptance and specified limits. PCA be able to apply to the manufacturing era, machines and its tool. PCA give data concerning change moreover tendency of the system in manufacturing duration. Control charts like X-bar and R charts were used to examine existing process if the process is under statistical control. In the present study, process is under statistical control excluding process capability. From the analysis using MINITAB 18.0, it can be concluded that during the PCIs calculation the value of C_p , C_{pk} and C_{pm} are <1.The main responsible causes were identified with the help of root and cause diagram. The suggestions were suggested to concern firm for taking remedial actions on the recent process for improvement.

Because of present learning, the employees understand the requirement of quality, economic loss owed to low quality. This work minimizes the low-quality cost throughout production; firm administration supports this study. From the study, PCA methods are useful to find out and minimize the quality related trouble of manufacturing and other industries that produce machined products.

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