Building A Computerize System for Controlling and Monitoring Manufacturing Operations Based on Statistical Quality Control

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Abstract: Statistical process control techniques are extensively used to describe statistics data to monitor and satisfy the specifications of product and process. This approach capable to decide the amount of the variations in the case of frequent mistakes of the production process. Consequently, this approach can be monitored the production process and keep sure that the production locates inside this acceptable range and indicate directly that the process became under control. This means that the SPC considered an active method to monitor, examine and control variation in processes. In this paper, a computerized system is constructed to determine the manipulate charts and process capability which representing the predominant tool to monitor the rotational mechanical parts product machined by turning machine. A critical quality characteristic (variables) used in the work is dimensions to be measure and examining this process.

1. Introduction
One of the most important methods used for the purpose of survive and remain competitive in the markets is increase the quality and efficiency of process and product. Quality is the appropriateness of a service or product to meet its design purposes [1]. For increasing quality, the control charts are commonly used. A control chart is an important graphical tool attempt to identify and eliminate special causes of variation. Essential in the process common cause and control charts to track process statistics over time and to detect the presence of special causes. This chart illustrates the relation between two variables quality characteristic and the number of samples against time [2]. The chart consists from sample numbers or points in time Positioned on the horizontal axis, and measurements made from these samples Located on a vertical axis. The control limits of charts are upper and lower representative the suitability limits around the process average line, representing centre line. A chart depends on collecting the data through the process. Data be required collected and plotted on a chart. If the points of the chart are inside and within the control limits, the process considered as controlled. If there are points remote the control limits, the process is considered uncontrolled [3].

After completing the inspection process, the next stage is to monitor and analyse the inspection data to determine the variation in control limits. This statistical method used to optimize the process in real-time to determine the efficiency of this process, as shown in figure (1).
Chang-Hsien Hsu and Chun-Ming Yang (2010) studied the process capability for the multi-process procedure produced by the sewing machine based on the Cpk chart. The Six-Sigma technique used in three-phase to locate influential quality characteristics. This method considered suitable for a process that has many quality characteristics [4]. Marija Karajović et al (2011) described the application of software as a tool in the quality control, and highlights the benefits of using software to improve the quality through their considerations of time-saving and reduce cost [5].

Fahim. A et al (2014) this study includes three variables that analysis using a developed X bar chart, S and Range control chart. In addition, they used the Estimated Weighted Moving Average (EWMA) to detect for small shifts, and multivariate to monitor the height and diameter of the bolt. Based on these approaches, the process identifies if the process in control or out of control and gives the reasons and gives necessary procedures to overcome these variations [6].

Manish. Y and Manoj. K (2016) in this study many Statistical tools used to analysis a process that produces piece of equipment and spare parts. Statistical tools as cause and effect diagram arranges to determine the source reason of variant in diameter of piece as for the use of control chart is to found the process positioned at the control limits. Process capability specifies if processes are appropriate for company qualifications while decrease the process variation [7]. O.A. Adeoti1 and J.O. Olaomi (2017) focused on the use of a single control chart that can monitor and evaluate process capability for variables, depending the use of the process capability index C, by estimating the process standard deviation. The proposed chart is using to compare the performance of the using chart with the usual two-stage technique of using control charts (X and R) and the Cp index [8].

Teuku. M et al (2019) applying techniques of quality improvement in molding machine, via statistical process control which improved the capability of the process from 0.63 to 1.65. The results shown that reducing in variation of inner contact rubber will be increasing in the quality [9]. In this work, a computerized system executed to constructed analyse the quality chart and process capability to monitor the rotational mechanical parts product machined by turning machine. Dimensions considered as a critical quality characteristic (variables) to improve the process capability.

2. The principal concepts of control chart
There are different types of control charts, these charts include variables data and attribute data. The first type of control chart is the variable data, which shows data that result from measurement. Process data includes different variables such as length, pressure, dimensions and so on. In the other hand, another type of control chart called attributes control charts, which displays data that obtained from counting the number of items or occurrences in a single type of similar items or occurrences. These data may be expressed as pass/fail, yes/no, or presence/absence of a defect this chart plot data, such as
the number of defects or defective unit. Variables data can be analysing by using control charts (X-bar and R-charts). These charts usually used to give a clearer picture of case study [10].

The X-bar chart represents a mean control chart. This chart examines changes in the mean of a process. In the first stage to construct this chart, several samples are taken to find the mean for each one. Then determine the mean of all samples to locate the centre line of the chart [11].

$$\bar{X} = \frac{\sum_{i=1}^{n} \bar{x}}{n}$$  \hspace{1cm} (1)

Applies the following to compute the upper and lower limits of the control charts:

$$\text{Upper control limit (UCL)} = \bar{X}+A_2\bar{R}$$  \hspace{1cm} (2)

$$\text{Lower control limit (LCL)} = \bar{X} - A_2\bar{R}$$  \hspace{1cm} (3)

As the following represents:

$$\bar{X} = \text{the average of the sample means}$$  \hspace{1cm} (4)

$$\bar{R} = \text{average range of the samples}$$  \hspace{1cm} (5)

$$A_2 = \text{factor obtained from index (A)}.$$  \hspace{1cm} (6)

Figure (2) illustrates different ranges of standard deviation

For variables data, the R-charts can be used which represents a range. Whereas x-bar charts measure shift in the central tendency of the process, range charts display the variability or dispersion or of the process. The centre line of the control chart is the average range, and the upper and lower control limits computed as follows [12]. The factors of the charts obtained from index (A),

$$\text{LCL} = D_3 \bar{R}$$  \hspace{1cm} (7)

$$\text{UCL} = D_4 \bar{R}$$  \hspace{1cm} (8)

$$CL = \bar{R}$$  \hspace{1cm} (9)
3. Process-capability

Process capability is an effective method to explore the statistical data and then represented in the curve of control charts to analyse and determine the variation in the process. Therefore, using this method can improve the quality and efficiency of the process and gives a good vision in decision-making. This method consists of two-phases, finding the variation of the process and compare it with the proposed specifications in the product design stage. The output specifications produced from the process under control compared with the specification limits using process indices. This method can prevent the defects in the early stage of production [13].

3.1. Process-capability Index

The process capability index considered as a tool to decide if the performance of the process in control or out of control. Generally, these indices relate to customers specification, therefore, these indices compare the process or product with the engineering specifications. The process capability defined as the ratio of the distance from the process centre to the nearest specification limit divided by a measure of the process variability. The function of index Cp measures the ratio of the process consistency distribution spread to the process precision. The index defines only the consistency of the product quality characteristics. The mathematical structure [13].

\[
C_p = \frac{USL - LSL}{6\sigma}
\]  

Cp equal to 1: The process is just meet the specifications.

Cp less than 1: Cp value below 1 indicates that the process variability is not capable to meet specifications, and the process must be improved.

Cp greater than 1: The process has strongly capable to meet specifications.

To overcome comes some of the weaknesses of Cp when its value locates outside of the specification limits. In this case, minimum process capability index Cpk provides lower bounds on process yield by considering the process location [13].

\[
C_{pk} = \min(C_{pl}, C_{pu})
\]

4. Research methodology

In this research, the proposed methodology was built to estimate the process quality control that has an ability to monitor and analyse the effective parameter represented by the dimensional characteristics of rotational parts (motor shaft) formed by turning machines, as illustrated in figure (3).
5. Implementation of program
The execution of quality control and process capability that manufactured in the general company of electrical industries as shown in figure (4). In this research, the proposal system built using visual basic software. This system provides a fast and accurate tool that help the user for creation the control chart, also calculation of process capability indexes $C_p$ and $C_{pk}$. Consequently, can be analyse the values of these indexes and inform the user that process capable or not capable to produce the product with present specifications ranges.

![Diagram](image)

**Figure 3.** Research methodology flow chart.

**Figure 4.** Rotational Parts (Shaft of Motors)
In the beginning, the problem specification enters the sample size (observations) and the number of samples (k) and the engineering dimensions of the product. The next step, inputting Statistical data of shifts diameters shown in figure (5) which is representing the raw data of motor shaft diameter which are collected in spread time periods from the mass production line produced by using the turning process as form of samples.

![Figure 5. Statistical quality characteristic](image-url)
The system calculates the limits of both X and R charts and calculates and analysis the process capability based on the values of the process capability indexes by processing the data and the equations built in the program which shown in figure (6, 7 and 8).

![Image showing output results of the program](image_url)

**Figure 6.** The output results of the program
Figure 7. The X-chart

Figure 8. The R-chart
6. Conclusions
Process capability analysis is an effective approach for determinate the stability of the process to manufacture the products with proposed design specifications during the manufacturing stages. The Process capability analysis is not enough to consider that the process is in control, even although this generally done the use of quality control charts. However, these charts give a prediction of the behaviour of the process. In this work, it consists of building and implementation a program that can supplies a fast and accurate tool to sure that the process under control depending on the control charts. The results show that the turning process is capable to meet the requirements specification according to the values obtained from Cp and Cpk. Moreover, the Cpk is supposed to use with processes that are in control, which gives the employer a measure of whether this process is capable to satisfy the product specifications. On the other side, the process in this state needs to accelerate to meet specifications and continuous enhancement although the process capability achieved.

| Sample Size n | Factors for X-Chart | Factors for R-Chart |
|---------------|---------------------|---------------------|
|               | A2                  | D3                  | D4                  |
| 2             | 1.88                | 0                   | 3.27                |
| 3             | 1.02                | 0                   | 2.57                |
| 4             | 0.73                | 0                   | 2.28                |
| 5             | 0.58                | 0                   | 2.11                |
| 6             | 0.48                | 0                   | 2.00                |
| 7             | 0.42                | 0.08                | 1.92                |
| 8             | 0.37                | 0.14                | 1.86                |
| 9             | 0.34                | 0.18                | 1.82                |
| 10            | 0.31                | 0.22                | 1.78                |
| 11            | 0.29                | 0.26                | 1.74                |
| 12            | 0.27                | 0.28                | 1.72                |
| 13            | 0.25                | 0.31                | 1.69                |
| 14            | 0.24                | 0.33                | 1.67                |
| 15            | 0.22                | 0.35                | 1.65                |
| 16            | 0.21                | 0.36                | 1.64                |
| 17            | 0.20                | 0.38                | 1.62                |
| 18            | 0.19                | 0.39                | 1.61                |
| 19            | 0.19                | 0.40                | 1.60                |
| 20            | 0.18                | 0.41                | 1.59                |
| 21            | 0.17                | 0.43                | 1.58                |
| 22            | 0.17                | 0.43                | 1.57                |
| 23            | 0.16                | 0.44                | 1.56                |
| 24            | 0.16                | 0.45                | 1.55                |
| 25            | 0.15                | 0.46                | 1.54                |
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