# Application of Statistical Process Monitoring and Control (SPC) for Quality Control of Front Axle Component in Truck Vehicle

**Yuyun Hidayat, Neneng Sunengsih, Lusyana Leonita, Titi Purwandari**
Department of Statistics, Faculty of Mathematics and Natural Sciences, Universitas Pdjadjaran, Indonesia
yuyun.hidayat@unpad.ac.id; nenks.stat@gmail.com; lusyleo7@gmail.com; titipurwandari@yahoo.com

**Sukono**
Department of Mathematics, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran, Indonesia.
sukono@unpad.ac.id

**Abdul Talib Bon**
Department of Production and Operations, University Tun Hussein Onn Malaysia, Malaysia
talibon@gmail.com

## Abstract

The Quality Control (QC) Department of PT. Mitsubishi Krama Yudha Motors and Manufacturing (PT. MKM) is responsible for producing products which prioritizes safety, function, and government regulations. The QC Department establishes the quality characteristics of each components and specifications in the early stage of the production process. A stable process and capable of meeting specifications can enhance the quality and business development. The process improvement methodologies, like six-sigma, etc., can improve the capability of the process. When the process is highly capable with minimum variability, sometimes it may not sense to monitor the process using traditional control charts, it is unable to detect the non-conforming product. Therefore, modified control chart is needed and allow the process mean to vary over a small interval provided the fraction non-conforming is within a pre-specified value. This study uses the method of adding data period to avoid violating the normality distribution assumption. The result shows there are 73 of the 240 plotted point is outside the modified control limits.

**Keywords:**
Statistical Process Control, Modified Control Chart, Non-normal Characteristics

## 1. Introduction

PT. Mitsubishi Krama Yudha *Motors and Manufacturing* (MKM) is one of the companies that engaged in the field of manufacturing automotive that produce vehicle components materials. PT. MKM has a vision into a company that can survive in a competitive global, manage factories that safe to carry out control QCD (*quality, cost, delivery*), as well as be responsible towards the environment and placing priority primary to gain the trust of customers.

Quality Control (QC) Department of PT. MKM is responsible for producing products in accordance with the company's mission, that’s are prioritizing safety, function and government regulations. QC department should define the quality characteristics of each component of the vehicle, as well as the specifications on the beginning of the production processes. Product specifications are standards that are set as references for companies in producing daily components. The component specification limits that have been set by PT. MKM for the work program in 2019 can be seen in Table 1.

**Table 1.** Production Performance at PT. MKM July 2019

| No. | Vehicle Components | 2019 Work Program Specifications | July 2019 Production Accuracy (%) |
|---|---|---|---|
| 1. | Front Axle | 0 - 0.021 mm | 68.27 |
| 2. | Extension Housing | 0 - 0.025 mm | 99.99 |
| 3. | Clutch Housing | 0 - 0.05 mm | 86.80 |
| 4. | TM | | |
| | TM axis X | ± 0.2 mm | 68.27 |
| | TM axis Y | ± 0.2 mm | 68.27 |
| | TM Flatness | 0 - 0.3 mm | 68.27 |
| | TM Parallelism | 0 - 0.028 mm | 68.27 |
| 5. | FC Ø 50 | (-0.1) - 0 mm | 99.99 |
| 6. | MC | | |
| | Hole R4 0 | ± 0.1 mm | 90.11 |
| | Hole R4 9 | ± 0.08 mm | 86.80 |
| | Hole R4 20 ° | ± 30 ' | 99.99 |
| | Hole R5 9 | ± 0.08 mm | 86.80 |
| | Hole R5 40.5 | ± 0.1 mm | 95.45 |
| | Hole R6 9 | ± 0.08 mm | 96.43 |
| | Hole R6 64 | ± 0.1 mm | 86.80 |
| | MC Parallelism | 0 - 0.05 mm | 68.27 |
| 7. | DC | | |
| | DC R / Out Flange | 0 - 0.03 mm | 68.27 |
| | DC Ø 70 | 0.043 - 0.065 mm | 68.27 |

Based on Table 1, the percentage of production accuracy of Front Axle Components is 68.27%, *Extension Housing* Components 99.99%, and so on for other components. The level of production accuracy is varying for each component, as well as the level of tolerance or specification limits. So that each process has a different level of difficulty. In the production process of vehicle components on July 2019, front axle component has the lowest percentage with the most stringent range of tolerance, so the effort to reduce the variability of production become more stringent.

The tools used by the company in monitoring the production process is an ordinary control chart without paying attention to the normality distribution assumption of the data. Using traditional control chart usually give non accurate results of the analysis, when data variability is very small with high capability. That makes the control chart is not able to detect non appropriate quality characteristics. The same is true for violations normality distribution assumption of the data.

The quality of vehicle component productions at PT. MKM is determine by measuring its quality characteristics. Based on the description, required a statistics method that is suitable for controlling the process of production and can be used in making the right decisions during evaluation and the company can improve the quality of production.

## 2. Literature Review

Quality control of the manufacturing automotive company is an effort to maintain the quality of the vehicle components that is manufactured in order to conform with the specifications, that have been defined by the policy and work program of the company. There are three methods of quality control which are *designed experiment*, SPC, and *acceptance sampling*. The method that will be used in this research is *Statistical Process Control* (SPC) (Wheeler and Chambers, 1992).

SPC is a powerful collection of problems-solving useful in achieving process stability and improving capability of production through the reduction variability. SPC has become one of the greatest technological developments of the 20th century because it is based on basic principles, easy to use, has a significant impact, and can be applied to any process (Montgomery, 2005; 2009).

The main purpose of SPC is to detect the assignable cause(s) quickly in the process, so the company can investigate and done the corrective action before increasing the number of production units that are not accordance with the specification (Fouad and Mukattash, 2010; Sultana and Islam, 2009).

**Modified control chart**

Many of the modern process operates with high level capability. Application of process performance improvement and reducing variabilities methodologies with lean, *six-sigma,* and other methods can improve the process capability significantly, that generate value Cp and Cpk > 1 (John and S. Subhani, 2020). The values of Cp and Cpk can be determined by the following equation:

$$Cp = \frac{USL - LSL}{6\sigma}$$
$$Cpk = \min(Cpl, Cpu) \tag{1}$$
$$Cpu = \frac{USL-\mu}{3\sigma} \text{ dan } Cpl = \frac{\mu-LSL}{3\sigma}$$

*Six-sigma* focus on reducing activities that do not have a value-added and the variability of the process to get the idea of an increase in the quality (Antony, 2004). It is an orientation of the project based on the data in the control process and lowers the level of disability products and the value of the variability of the process (Montgomery and Woodall, 2008).

When the process is highly capable, the spread of the specification limits will be higher than the natural variability of process ($\pm 3\sigma$). Hence even if the process of production is out of control, the process may still meet the standard specifications, however the control chart is not capable to detecting failure of the production. These situations are sometimes ignored, so that the process of production resumed and occur shifting the average process without attention to the impact on the performance of the process as a whole. Modified control chart can be used to analyze the problems that, to make sure the average process ($\mu$) is a way such that a process that does not produce fractions do not correspond more than chance nonconformity that has been set ($\delta$) (Grigg et al., 2003). On average the process can vary in intervals little that is set by the limit specification as equation follows:

$$\mu_L = LSL + z_\delta \sigma \tag{2}$$
$$\mu_U = USL - z_\delta \sigma \tag{3}$$

where is the point 100 (1- $\delta$) the upper percentage of the standard normal distribution.

Next, determine the LCL and UCL limits of modified control chart. In general, $2\sigma$ is recommended for modified control chart as may suppress the risk of consumers without increasing the risk of manufacturers are significantly (Freund, 1957; Ab-Rahman et al., 2009). Modified control limit $2\sigma$ can be calculated using the following equation:

$$LCL = LSL + \left(z_\delta - \frac{2}{\sqrt{n}}\right)\sigma \tag{4}$$
$$UCL = USL - \left(z_\delta - \frac{2}{\sqrt{n}}\right)\sigma \tag{5}$$

**Data screening**

Almost all studies require normality distribution assumptions, including the SPC method, especially in the use of modified control charts. But in reality, it is rare to find the measurement data in a normally distribute. In order not violate the normality assumption, then needed a method to resolve violations of the assumptions of normality such as, transformation of data, pruning outliers, the addition of data observation, or by increasing the period of data observation. Transformation of data can be done in the form of roots of quadratic, natural logarithm, inverse, Boxcox transformation, or Tukey transformation depend on the data suitability. In the study's authors do a screening of data by detection of outliers and add the period of observation data (Johnson and Wichern, 2001).

## 3. Research Methodology

The suggested methodology for developing a modified control chart for monitoring non normal characteristics in the study, *x* is as follows: outliers' detection, adding the period of the data to meet the normality assumptions, and testing the process capability. Once the process is highly capable, then modified control limits can be determined using equations (4) and (5):

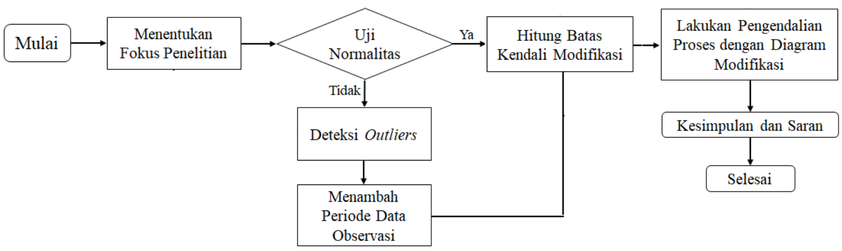


**Figure 1.** Suggested Methodology

## 4. Result and Discussion

**Data**

The data used in this study is the Kingpin Diameter of the Front Axle Components on PT. Mitsubishi Krama Yudha *Motors and Manufacturing,* in July 2019. The data consists of 240 observations.

**Data screening**

The first assumptions that must be met is normality distribution of data, QQ-plot can be used as the early detection or visually testing [6] as in Figure 3. Besides, normality testing of the data also can be done by Shapiro Wilks test. Shapiro test was carried out using the statistics software R and obtained the p-value $1{,}224e^{-09}$. With 5% significant level, obtained the *p-value* < α, so that $H_0$ is rejected. That means with 95% confidence level, it is concluded that the Kingpin Diameter of the Front Axle Components are not normally distributed.

It is known that the data is not normally distributed, then do the outliers detection. By using boxplot to detect the point of outliers, we obtained the results as in Figure 3. As we can see that there is no point of observation detected as an outlier, thus it doesn't change the data of analysis. Furthermore, increasing the period of observation data can be done to overcome violations of the normality assumption.

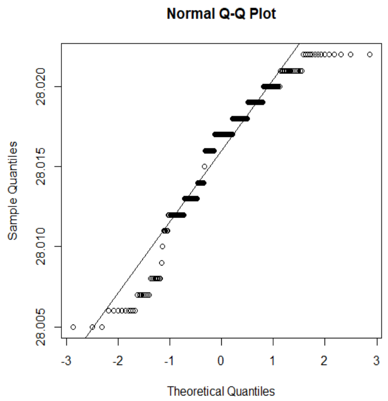


**Figure 2**. QQ-Plot Kingpin Diameter

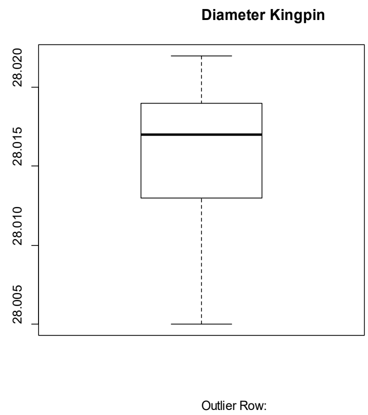


**Figure 3**. Boxplot Kingpin Diameters

Because it is not able to perform the addition of data observations, and not suitable to use the transformation of data so the research is carried out method of adding the period of data to avoid violations of the normality assumptions. The following is the process of adding an observation data period using statistics software R:

a. A period of 30 minutes (the data results of the measurement of the company)
   *p-value* $1{,}224e^{-09}$ < α then the 30 minutes observation period is not normally distributed.
b. an hour periods
   *p-value* $2{,}53e^{-06}$ < α, then with a 95% confidence level, an hour period is not normally distributed.
c. 2 hours period
   *p-value* 0.0008105 < α, then with a 95% confidence level, two hours period is not normally distributed.
d. 3 hours period
   *p-value* 0.04326 < α, then with a 95% confidence level, three hours period is not normally distributed.
e. 4 hours period
   *p-value* 0.4566 > α, then with a 95% confidence level, four hours period normally distributed.

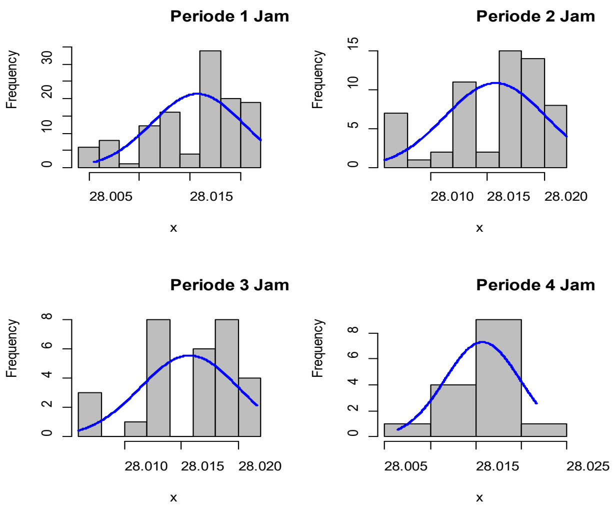


**Figure 4.** Histogram of each period

After getting the results that the data is normally distributed over a 4 hours period, the analysis can be continued by making a modified control chart using the 4 hour period.

**Modified Control Chart**

To do verification on the data Kingpin Diameters whether already meet the standards specifications that have been determined, then the first step to do is analysis of process capability. The results of the analysis are shown in the following table below:

**Table 2.** Capability Process Analysis

| Statistics | Value |
|---|---|
| USL | 28,021 |
| LSL | 28,000 |
| Mean (CL) | 28,016 |
| Standard deviation | 0,002 |
| Cp = Cpk | 1,75 |

Table 2. shows the value of the process capability is 1.75 > 1.33 that can be said that the process is capable of producing Front Axle components in accordance with the specifications. Then the data on the production of Front Axle Components can be monitored using modified control chart and to detect points that do not meet specifications. The control limit value for the modified control chart is calculated using equations (4) and (5) with the $3\sigma$ limit. Using the standard normal distribution, the probability of failure or the fraction defective according to Cp = 1.3 is identified as $\delta$ = 0.0000481. Hence, the value $z_\delta$, the upper 100 (1 - $\delta$) percentage point of the standard normal distribution is taken as 3.9 while calculating the control limits. The control limit values for the modified control chart are as follows:

| Statistics | Value |
|---|---|
| UCL | 28,019 |
| Mean (CL) | 28,016 |
| LCL | 28,002 |

The following is a modified control chart for Kingpin Diameters data from Front Axle Components:

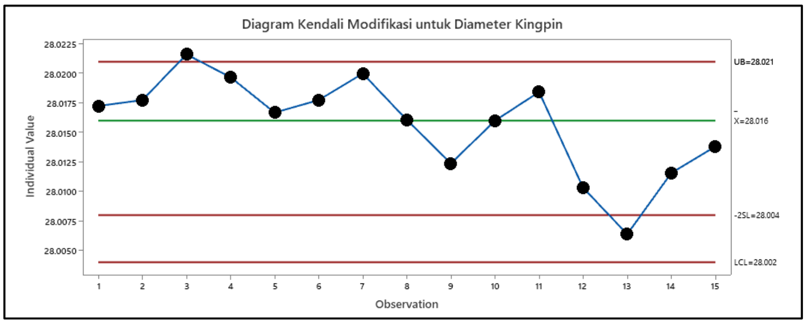


**Figure 5.** Modified Control Chart of Kingpin Diameters from Front Axle Component

The companies can use the modified control chart in the monitoring process of the production of components Front Axle for accurate results. As long as the plotted point is within the control limits, no action is needed and the process can continue to proceed. In this situation, the process will be capable of producing Front Axle components in accordance with the standards specifications and the value of Cpk ≥ 1.33.

But in the production process in this research, there are some points which are beyond the control limits of the specification 28.021 as the Figure 5 above. It detected that the production does not meet standard specifications. Hence, action is needed to handle this overcoming shift average to make sure the order does not affect the production process significantly as a whole in the period length.

## 5. Conclution

Based on the analysis using modified control chart, control limit values are obtained as follows:

**Table 3.** Comparison of Control Limit Values

| Statistics | Traditional Control Chart | Modified Control Chart |
|---|---|---|
| UCL | 28,021 | 28,019 |
| CL | 28,016 | 28,016 |
| LCL | 28,010 | 28,002 |

Table 3 shows the values of the limits for traditional control chart which is calculated without involving the limits of the specification and the chances of disability products. This control limit is unable to detect non-conformity of the product with its specifications. While the value of the modified control chart limits on the right column which is calculated based on the specifications of products and takes into account the value of the opportunity of disability products have been able to detect non-conformity of products with the specification. If spread of the natural variability process is smaller than spread of the specification products, it is technically Cp and Cpk will be worth more than 1, or the process is highly capable. But in reality, that process conditions are not able to detect quality characteristics data that are not in accordance with the specification standard. Thus, in this study a modified control chart is used to determine which points of the data are out of control. From the analysis it can be seen that there is data on the Kingpin Diameters of Front Axle Components that do not meet the standard specification 28.021. Using a modified control chart is expected the company to apply the defect prevention in accordance with its mission, as well to improve the quality of its production until Front Axle Components do not produce defect products more than chances of failure were determined by the company.

**Suggestion;** PT. Mitsubishi Krama Yudha Motors and Manufacturing (PT. MKM) can use modified control chart to monitoring the production process with regard the distribution of the quality characteristics. The method is able to be applied in general for quality characteristics with small variability and highly capable of the process. Thus, in monitoring the quality of production can be detected assignable cause(s) quickly with the right way. For this reason, it is hoped defect prevention and customer specific requirements (CSR) can be achieved in accordance with the company's vision and mission

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**Biographies**

**Yuyun Hidayat** is a lecturer in the Department of Statistics, Faculty of Mathematics and Natural Science, Universitas Pdjadjaran, Indonesia. He received his PhD in the University of Malaysia, Trengganu, Malaysia. He has published more then 20 papers in national and international journals and participated in many national and international conference. Currently initiated accurate predictions about Covid-19 case data in Indonesia

**Neneng Sunengsing** is a lecturer in the Department of Statistics, Faculty of Mathematics and Natural Science, Universitas Pdjadjaran, Indonesia. She has published more than 20 papers in national and international journals.

**Lusyana Leonita** is a student in Faculty of Mathematics and Natural Sciences, Universitas Pdjadjaran, Indonesia. Research interest in Industrial Quality Control at PT. Mitsubishi Krama Yudha Motors and Manufacturing, Indonesia

**Titi Purwandari** is a lecturer in the Department of Statistics, Faculty of Mathematics and Natural Science, Universitas Pdjadjaran, the field of applied statistics, with a field of economic statistics.

**Sukono** is a lecturer in the Department of Mathematics, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran. Currently as Chair of the Research Collaboration Community (RCC), the field of applied mathematics, with a field of concentration of financial mathematics and actuarial sciences.

**Abdul Talib Bon** is a professor of Production and Operations Management in the Faculty of Technology Management and Business at the Universiti Tun Hussein Onn Malaysia since 1999. He has a PhD in Computer Science, which he obtained from the Universite de La Rochelle, France in the year 2008. His doctoral thesis was on topic Process Quality Improvement on Beltline Moulding Manufacturing. He studied Business Administration in the Universiti Kebangsaan Malaysia for which he was awarded the MBA in the year 1998. He’s bachelor degree and diploma in Mechanical Engineering which his obtained from the Universiti Teknologi Malaysia. He received his postgraduate certificate in Mechatronics and Robotics from Carlisle, United Kingdom in 1997. He had published more 150 International Proceedings and International Journals and 8 books. He is a member of MSORSM, IIF, IEOM, IIE, INFORMS, TAM and MIM.