Comparative analysis of inline quality control system process capability with offline lab QC against product specification by MSPC method

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Abstract. The similarity of values shown by the two methods of reading paper specifications, namely Quality Control System (QCS) and QC Lab (controlling offline in Quality Control lab) to the attention of PT Bukit Muria Jaya (BMJ). The QCS is an online control process while QC Lab is offline control process. The company wants to change the offline control process online, but there is no analysis to show whether the output given by both methods is the same. The study involved Grade A paper measured at once by five paper specification parameters, i.e. paper weight, porosity, CaCo3 content, opacity, and paper strength. However, after normality testing was found, the data is not multivariate normal distribution. Therefore, this study aims to answer the problem with a multivariate free distribution procedure. The study was conducted in two stages, firstly by looking at the median equality of both outputs of the paper specification reading method, and the second is by looking at the similarity of characteristic capability. A preliminary study was conducted to see whether the two methods of reading the Grade A paper specifications had the same median. This test is done by Kruskal Wallis Multivariate method. The results of the analysis received a null hypothesis which means the median of the two outputs generated QCS and QC Lab for each Grade A paper are equal. Furthermore, based on a capability comparison analysis where the value of this capability is derived from the sample without observation out of control, out of control process control is assisted in the range of T² Hotelling Control Free Distribution. It can be concluded that Grade A paper capability of QCS does not show the same result as QC Lab, i.e. Porosity variable, where Porosity is capable in QC Lab but not QCS, so manual process control for Grade A paper cannot yet be replaced online.

Keywords: Grade A paper, normality testing, Kruskal Wallis multivariate method, T² Hotelling

1. Introduction

Paper in this company using Popereel Machine (PM), currently there are three PM PM1, PM2, and PM3. In this case the researcher will take data from PM3. On the PM is installed software paper controller that is being produced. Control with this software is a control that is done online. One of the installed software is Quality Control System (QCS) which focuses on reading the paper specification being processed. Control is also done manually in QC Lab, which is a place to analyze product specifications through manual sampling using a calibrated tool. The research data was taken from PM3 in November 2016 with Grade A. In that month, there was a gap between QCS and QC Lab, the gap indicated that
the value of gap exceeded the company's tolerance limit. The largest gap is in the porosity variable of 3.88 points [14; 15].

Taken the average of each variable as shown in Table 1, it turns out that the average value gap given by both paper specification methods indicates that there are variables that tend to exceed the tolerance limit i.e. porosity variable of 2.0830 points.

Table 1. Average Gap Value of each Variable in Each Popereel Machine (PM)

| PM3 (Grade A) | Contents CaCo₃ | Paper Weight | Paper Strength | Opacity | Porosity |
|---------------|----------------|--------------|----------------|---------|----------|
|               | 0.253241       | 0.427701     | 1.983982       | 0.716505| 2.083039 |

Is this company's tolerance limit a good benchmark for concluding differences in data to be of interest to the researcher. Since these variables come from the same observation of reels or rolls of paper, the variables must be tested by multivariate analysis whether QCS significantly gives different output to the QC Lab for the gap. Currently there is no research that conducted the test on PT Bukit Muria Jaya (BMJ). Yet this gap is a concern for companies to use QCS data as data used to describe the company's production process [14; 15].

Leoni et al. [9], investigates the effect of correlation and autocorrelation in the Hotelling $T^2$ graph when there are two quality characteristics of X and Y, whose autocorrelation structure and correlation are represented by the VAR model (1). Their research is done by using Mahalanobis distance and geometric approach with ellipse. The results of his research indicate that the presence of autocorrelation reduces the performance of $T^2$ charts, and limits the ability of diagrams to provide specific cause information applicable in the process. A higher or lower degree of autocorrelation is the performance of the graph in detecting the cause of the change in value on the average vector. Several examples have been presented to illustrate the adverse effects of $T^2$ charts when there is autocorrelation in the process.

Ramzan et al. [11], conducting quality control studies and activities with a special focus on offline inspection. In his research various models and methodologies were developed for offline inspection under different manufacturing and inspection conditions. Their studies are classified into six groups based on their research objectives, developed models, adopted methodologies, and research results. In their research also provides a brief overview of offline inspection to propose future research opportunities and emerging trends. The proposed research may assist in the development of new models or modify existing models to improve offline inspection performance. Similar research on the capability of the process of quality control system has been done by Ferrer [5], Hadad & Alsmadi [6], Kormaz et al. [7], Lee [8], Hidayat et al. [14; 15] and Zhan et al. [16].

Therefore, based on the above description, the researcher is interested to analyze whether there is significant difference of output from QCS when compared with QC Lab. While the purpose of this research is to replace the control of offline production into online that is by using QCS. So from this research for PT Bukit Muria Jaya is can be used as material evaluation of QCS (Quality Control System) that is being applied company. If the QCS and QCS Labs show the average similarity and show the similarity of variations based on the customers' specifications then QCS is feasible to be used as a trusted process control.
2. Methodology

Based on the background of research in the previous chapter, it is known that mathematically there is a difference in the output given between QCS software and QC Lab analyst. This difference does not indicate a good or bad thing for the company when viewed mathematically. Therefore this difference will be tested statistically in order to provide useful information for the company. The supporting theories to conduct an analysis of the problem will be described as follows.

2.1. Description of research data

Data obtained from Grade A paper produced in PM 3 in November 2016, sampling carried out every 30,000 meters of paper length. The sample is taken from the paper in production, i.e. at the last 4 meters before the length to 30,000 meters. The paper specifications of this sample are then calculated by two methods, namely QCS and QC Lab. In each paper specification variable taken 3 points of observation. The first sample is computed into the first subgroup.

Involved five of the same paper characteristic variables in the two paper reading methods as follows: $X_1$ = paper weight/grammature (in gr/m$^2$); $X_2$ = paper strength/size press moisture (in %); $X_3$ = CaCo3/ash titration content (in %); $X_4$ = opacity/opacity (in %); and $X_5$ = porosity/permeability (in coresta).

2.2. Assumption testing

Assumption tests performed in this section include: correlation testing with Bartlett sphericity, and assaying multivariate normality assumptions.

- Correlation test with Bartlett sphericity

This correlation test aims to show whether there is a significant correlation between the five variables involved in both paper readout methods. According to Lim et al. [10]. This test can be performed using Bartlett sphericity testing with the following steps.

Develop a statistical hypothesis that is $H_0: R = I$ and $H_1: R \neq I$; then calculate chi-square test statistic according to equation as follows:

$$
\chi^2_{hitung} = -m - 1 - \frac{2p+5}{6} \ln |R|
$$

where $m$ is the number of observations, and $R$ is the correlation matrix of $x$ with as many variables $p$.

The testing criterion is rejecting the null hypothesis if the value $\chi^2_{hitung} \geq \chi^2_{\alpha;1/2p(p-1)}$ or $p$-value $\leq \alpha$, meaning that the correlation matrix obtained is not the identity matrix so that the characteristic variable of paper specification correlates each other. Therefore the use of multivariate methods is feasible to use.

- Testing multivariate normality assumptions

Testing the assumption of normality is assisted by using package "MVN" in application R with hypothesis as follows:

$H_{01}: b_{1,p} = 0$ (data is normally distributed)

$H_{11}: b_{1,p} \neq 0$ (data is not normally distributed)

$H_{02}: b_{2,p} = 0$ (data is normally distributed)

$H_{12}: b_{2,p} \neq 0$ (data is not normally distributed)

Mardia's MVN test is an assay method of normal multivariate distribution based on the skewness extension $b_{1,p}$ and kurtosis $b_{2,p}$ with skewness test statistics $z_1$ and kurtosis test statistics $z_2$ as follows:

$$
z_1 = \frac{(p+1)(m+1)(m+3)}{6[(m+1)(p+1)-6]} b_{1,p}
$$

(2)
Develop a statistical hypothesis find whether there is a difference of distribution between QCS and QC Lab. The steps to perform this test is performed if the assumption of normal distribution cannot be met. This test is conducted to show whether the distribution of data is too uphill or not with the criterion test rejected $H_{02}$ if $z_2 \geq z_{a/2}$.

2.3. Multivariate average equality test

The multivariate average equality tests performed in this section include: one-way manova and expansion of Kruskal Wallis test for multivariate data.

- One-way manova

This admission can be done if the assumption of homogeneity of variance and multivariate normal distribution is met, where the homogeneity test of variance can be done by M-box test, but if both assumptions are not met then non-parametric statistics can be performed. The test statistic used is Wilks Lamda according to the equation:

$$\Lambda^* = \frac{\left|\sum_{i=1}^{m} \sum_{j=1}^{n} (\bar{x}_i - \bar{x}_j) (\bar{x}_i - \bar{x}_j)^T \right|}{\left|\sum_{i=1}^{m} \sum_{j=1}^{n} (x_{ij} - \bar{x}_i) (x_{ij} - \bar{x}_j)^T \right|}$$

(6)

where $x_{ij}$ = observation method of reading the paper specifications to-$l$ variable characteristics of paper to-$j$; $\bar{x}_t$ = average vector paper reading method for paper specification to-$l$; and $\bar{x}$ = the average vector of both paper reading method specifications [2].

Test criteria reject the null hypothesis if $(n - 1 - \frac{p+q}{2}) \ln(\Lambda^*) \geq x^2_{p(g-1)}$

- Expansion of Kruskal Wallis test for multivariate data

This test is performed if the assumption of normal distribution cannot be met. This test is conducted to find whether there is a difference of distribution between QCS and QC Lab. The steps to perform this test are as follows [3].

Develop a statistical hypothesis $H_0 : \text{med } (X)_a = \text{med } (X)_b$ and $H_1 : \text{med } (X)_a \neq \text{med } (X)_b$; $a \neq b$. Where $a$ = method of reading lab paper QC specifications, and $b$ = QCS paper specification reading method. Calculate the value of the test statistic $KW$ with the following formula:

$$KW = \sum_{k=1}^{n} n_k (\bar{R}^{(k)})' \hat{\Sigma}_m^{-1} \bar{R}^{(k)}$$

(7)

$$\bar{R}^{(k)} = \frac{1}{n_k} \sum_{i \in K_k} R_k (x^{(i)})$$

(8)

$$R_k (x^{(i)}) = \frac{1}{n_k} \sum_{j=1}^{n_k} \text{sign} (x^{(i)} - x^{(j)})$$

(9)

where

$$\text{sign} (x^{(i)} - x^{(j)}) = \begin{cases} -1 & \text{if } a_k (x^{(i)} - x^{(j)}) < 0 \\ 0 & \text{if } a_k (x^{(i)} - x^{(j)}) = 0 \\ 1 & \text{if } a_k (x^{(i)} - x^{(j)}) > 0 \\ \end{cases}$$

$$\hat{\Sigma} = \frac{1}{n_k} \sum_{k=1, i \in K_k} R_k (x^{(i)}) R_k (x^{(i)})'$$

(10)
where $N_k$ many observations on the reading method to-$k$; $n_k$ many observations of each variable on the reading method to-$k$; $k$ paper specification reading method (QC Lab, QCS); and $R_k(x(i))$ vector size scale ranking method of reading paper specification to-$k$.

Test criteria for the calculation, reject the null hypothesis if $KW \geq \chi^2_{a,k-1}$. Level of significance $\alpha$ used is 5% or 0.05.

2.4. Multivariate control chart $T^2$ Hotelling free distribution

From the checking assumption of multivariate normality, if the normal multivariate assumption is not met, then the control chart formed is a control chart $T^2$ Hotelling free distribution. This diagram can be formed according to the steps below [1; 14].

$$T^2_i = n(\bar{x} - \bar{x})'S^{-1}(\bar{x} - \bar{x})$$  \hspace{1cm} (11)

$$UCL = \overline{T^2} + ks^2$$  \hspace{1cm} (12)

Create a control chart by creating a plot between values $T^2_i (i = 1,2,3,…,n)$ with UCL.

$$\bar{x}_{jk} = \frac{1}{n} \sum_{i=1}^{n} x_{ijk} \{ j = 1,2,\ldots,p \}, \{ k = 1,2,\ldots,m \}$$  \hspace{1cm} (13)

If the value $T^2_i$ is outside the control limit (UCL) then the observations are declared uncontrollable.

2.5. Process capability analysis

Good capability analysis is used for normally distributed data but when data not normally distributed we use the following equation:

$$C_{pc} = \frac{UCL - LSL}{6 \sqrt{E[X-T]}}$$  \hspace{1cm} (14)

where $E[X - T]$ obtained through $E[X - T] = \frac{1}{n} \sum_{i=1}^{n} |x_i - T|$; $x_i$ = process row to-$i$; and $T$ = target company [13; 15].

The capability value of Equation (14) can be used to predict the process performance but can only be used if the process is declared in control. It is necessary to obtain the in control process by making a revision control chart without any uncontrolled observation (out of control).

Capability calculations are performed for each characteristic variable of paper in QCS and QC Lab. Then the capability value obtained is compared through hypothesis testing, whether the capability value given from QCS is the same as compared to QC Lab.

2.6. Capability comparison

Steps in performing capability comparison are as follows: Compiled the statistical hypothesis of capability comparison with comparator 1.33, and Finding critical value $C$. The $C$ critical value obtained with the following formula [15]:

$$C = \frac{C}{C_{p \text{ low}}} \times C_{p \text{ low}}$$  \hspace{1cm} (15)

where the value $\frac{C}{C_{p \text{ low}}}$ obtained from table of sample size and critical value of determination based on the value of $A$ with $\alpha=5\%$. A value is obtained by using the formula:

$$A = \frac{C_{p \text{ high}}}{C_{p \text{ low}}}$$  \hspace{1cm} (16)

where $C_{p \text{ high}}$ = process capability to be received with opportunities 1-α; $C_{p \text{ low}}$ = process capability to be rejected with opportunities 1-β; $C_{p \text{ high}} = \max(1.33, C_{pc}(QCS))$ or $\max(1.33, C_{pc}(QC \text{ Lab}))$; and $C_{p \text{ low}} = \min(1.33, C_{pc}(QCS))$ or $\min(1.33, C_{pc}(QC \text{ Lab}))$. 


The test criterion is $\hat{C}_p$ compared to Critical C, with the criterion of the starting test $H_0$ when $\hat{C}_p >$ critical value $C$ ($\alpha = \beta = 0.05$). Where $\hat{C}_p$ is the process capability shown by QCS and QC Lab.

$$C = \frac{c}{C_{p\text{ low}}} \times C_{p\text{ low}}$$ (17)

where the value $\frac{c}{C_{p\text{ low}}}$ obtained from table of sample size and critical value of determination based on the value of A with $\alpha=5\%$. The value of A is obtained by using the formula:

$$A = \frac{C_{p\text{ high}}}{C_{p\text{ low}}}$$ (18)

$\hat{C}_p$ compared to Critical value of $C$, with the criterion of the starting test $H_0$ when $\hat{C}_p >$ critical value $C$ ($\alpha = \beta = 0.05$). Where $\hat{C}_p$ is the process capability shown by QCS and QC Lab [14; 15].

3. Results and discussion

Based on the analysis steps and problems that have been described in the previous chapter, in this chapter will be discussed about the analysis of the problems. This analysis is assisted by Microsoft Office Excel software and R software.

3.1. Correlation Testing

Before the analysis begins, the first test is to test the correlation assumption between the Grade A paper measurement variables, if there is a correlation between the corresponding variants then the multivariate test is feasible to use. There are 5 variables that will be tested each from QCS reading method and QC Lab reading method that is variable of paper weight, axis, CaCo3 content, transparency, and paper strength. It is said that these variables are correlated if they do not form an identity matrix. So the null hypothesis is $H_0: R = I$ (the correlation matrix is the same as the identity matrix, meaning the paper quality specification variable has no correlation). While the one hypothesis is $H_1: R \neq I$ (the correlation matrix is not the same as the identity matrix, meaning the paper quality specification variables correlate each other). Thus, using the formula (1) can be calculated as follows:

$$\chi^2_{QCLab} = -68 - 1 - \frac{2(5)+5}{6} \ln |0.642806| = 28.50332$$

$$\chi^2_{QCS} = -68 - 1 - \frac{2(5)+5}{6} \ln |0.457049| = 50.50116$$

Based on the results of these calculations can be concluded that both have a value greater than $\chi^2_{0.05; (5-)\times(5-1)} = 18.30704$, then the null hypothesis is rejected which means the correlation matrix is not the same as the identity matrix or the paper quality specification variables correlate each other, then a multivariate analysis is feasible to use.

3.2. Testing of multivariate normality assumption

Testing the assumption of normality is necessary, because it will determine the method of analysis used in accordance with previously described. At this stage will be examined the form of quality data distribution paper produced in PT BMJ whether the distribution is normal or not. The data used is the average data of Grade A paper samples per subgroup. There are as many as 68 subgroups of 5 variables which will be seen from two paper specification reading methods (QCLab and QCS). Testing the assumption of multitask normality is aided by software R using the equations (2) to (5) each used to test skewness and kurtosis.
From the subgroups of 68 and two different populations, namely QCS and QC Labs with each corresponding 5 interrelated variables, the following outputs are obtained in Table 2.

### Table 2. Statistical Calculation of the Mardia Test

| Description     | QC Lab  | QCS     |
|-----------------|---------|---------|
| $z_1$           | 69.07942| 91.26461|
| $z_2$           | 0.2436779| 3.120264|

Based on visual testing and using test statistic it is known that the data is not multinormal distributed.

Based on the above results, it can be concluded that Grade A paper quality data obtained by QCS paper specification method and QC Lab paper specification reading method are not multivariate normal distribution, this is because the production of PT BMJ is unstable from subgroup to subgroup. Where, subgroups are sampled data taken every production reaches the length of paper along the 30,000 meters.

#### 3.3. Kruskal Wallis multivariate nonparametric test

Because the assumption of normality is not met, parametric procedures will not be done, because it will make it difficult to draw conclusions. Therefore, the test is followed by a nonparametric procedure where the data is converted to ordinal scale by making it in rank. The method to be used is Kruskal Wallis for multivariate data with hypothesis as follows: hyphotesis $H_0 : \text{med}(\mathcal{X})_{QCS} = \text{med}(\mathcal{X})_{QC\_LAB}$, meaning that the median of both paper-reading methods does not give the difference in paper specification values. While the hyphotesis $H_1 : \text{med}(\mathcal{X})_{QCS} \neq \text{med}(\mathcal{X})_{QC\_LAB}$, meaning that the median of both paper-reading methods gives different paper value specifications.

From equation (7) obtained value $KW = 8.7064 \times 10^{-29} < \chi^2_{0.05,5-1} = 3.841458821$ which means by the same sample size, the output produced by both methods of reading paper specifications on Grade A is the same based on the median.

#### 3.4. Making the $T^2$ Hotelling control charts free distribution

Making this control diagram is intended to get a controlled process, where out-of-control observation will be eliminated, so that later process capability can be calculated through controlled observation. The calculation of the value of equation (11) uses the mean of equation (12), and the average matrix of covariance variance uses excel. Then the calculation of the statistical value of $T^2$ Hotelling on equation (11) and the control limit of equation (13) is calculated using the R software.
Then the statistical value of $T^2$ Hotelling is compared with the control limit in equation (13) with $p=5$ then the value $\alpha' = 1 - (1 - 0.05)^5 = 0.2262$, thus obtained value $k = \sqrt{\frac{1}{1 - 0.05}} = 2.102497$, which means the control limit is at interval 2.102497 standard snail $T^2_i$ of the average $T^2_i$. Constants $k$ this will be used for UCL formation in both paper specification reading methods. Value $T^2_i$ and UCL are then formed into a control chart for each QC Lab and QCS and the results are as follows:

![Control chart of revision 6](image1)

![Control chart of revision 4](image2)

Figure 3. Control chart of revision 6

Figure 4. Control chart of revision 4

Uncontrolled uncontrolled data will be used for capability calculation. Capability calculation results are shown in Table 3 and Table 4.

### Table 3. Calculation of Variable Capability Values Characteristics of QC Lab Paper

| Variable | Target Value | Upper | Lower | Difference | $E|X-Target|$ | $C_{pc}$ |
|----------|--------------|-------|-------|------------|----------------|-----------|
| Contents CaCo3 | 18 | 18.5 | 17.5 | 1 | 0.185347 | 0.717324 |
| Paper Weight | 25 | 26.5 | 23.5 | 3 | 0.518056 | 0.769921 |
| Paper Strength | 5 | 6.5 | 3.5 | 3 | 1.157986 | 0.344445 |
| Opacity | 74 | 100 | 70 | 30 | 1.004167 | 3.97207 |
| Porosity | 20 | 23.2 | 16.8 | 6.4 | 0.585417 | 1.453504 |

### Table 4. Calculation of Variable Capability Values Characteristics of QCS Paper

| Variable | Target Value | Upper | Lower | Difference | $E|X-Target|$ | $C_{pc}$ |
|----------|--------------|-------|-------|------------|----------------|-----------|
| Contents CaCo3 | 18 | 18.5 | 17.5 | 1 | 1.66549 | 0.079829 |
| Paper Weight | 25 | 26.5 | 23.5 | 3 | 0.74119 | 0.538135 |
| Paper Strength | 5 | 6.5 | 3.5 | 3 | 1.32088 | 0.301966 |
| Opacity | 74 | 100 | 70 | 30 | 0.44264 | 9.010913 |
| Porosity | 20 | 23.2 | 16.8 | 6.4 | 1.45606 | 0.584387 |
3.5. Comparative analysis of process capability

This process capability calculation is performed for each characteristic variable of Grade A paper produced by PT BMJ for both QCS data and Lab QC data. The calculation data is a calculation data with a controlled process. The calculation of this capability value will be presented in table form as follows.

According to Ferrer [5], a process can be said to be capable if it exceeds the value of 1.33. To see if the process of each variable is capable in both methods, then the hypothesis is formulated as follows:

\[ H_0^i : \hat{C}_p^i(a) = 1.33, \text{ paper process capability Grade A the } i^{th} \text{ variable in the reading method } a \text{ is not capable} \]

\[ H_1^i : \hat{C}_p^i(b) > 1.33, \text{ paper process capability Grade A the } i^{th} \text{ variable on a capable reading method}. \]

Where, \( a=QC \text{ Lab, QCS} \).

Table 5. Results of Process Capability Testing between QC Lab and Value 1.33

| Variable  | \( C_p \) High | \( C_p \) Low | \( \frac{A = C_p \text{ High}}{C_p \text{ Low}} \) | Distance \( A \times d \) | \( C \) / \( C_p \text{ Low} \) | \( \hat{C}_p \) (QC Lab) | Critical Value C | Description |
|-----------|----------------|--------------|---------------------------------|-------------------|-----------------|----------------|----------------|-------------|
| Contents  | 1.33           | 0.72         | 1.85                            | 0.21              | 0.026           | 1.286          | 0.717324      | 0.92        | No          |
| CaCo3     |                |              |                                 |                   |                 |                |                |             |
| QC Lab    | 1.33           | 0.77         | 1.73                            | -                 | -               | 1.210          | 0.769921      | 0.93        | No          |
| Paper Weight | 1.33   | 0.34         | 3.86                            | 0.21              | 0.332           | 1.702          | 0.344445      | 0.59        | No          |
| Paper Strength | 1.33  | 1.33         | 2.99                            | 0.21              | 0.151           | 1.521          | 3.97207       | 2.02        | Capable     |
| Opacity   | 3.97           | 1.33         | 2.99                            | 0.21              | 0.151           | 1.521          | 3.97207       | 2.02        | Capable     |
| Porosity  | 1.45           | 1.33         | 1.09                            | 0.50              | 0.084           | 1.026          | 1.453504      | 1.37        | Capable     |

Table 6. Results of Process Capability Testing between QCS and Value 1.33

| Variable  | \( C_p \) High | \( C_p \) Low | \( \frac{A = C_p \text{ High}}{C_p \text{ Low}} \) | Distance \( A \times d \) | \( C \) / \( C_p \text{ Low} \) | \( \hat{C}_p \) (QCS) | Critical Value C | Description |
|-----------|----------------|--------------|---------------------------------|-------------------|-----------------|----------------|----------------|-------------|
| Contents  | 1.33           | 0.08         | 16.66                           | 0.21              | 2.989           | 4.36           | 0.08           | 0.35        | No          |
| CaCo3     |                |              |                                 |                   |                 |                |                |             |
| QCS       | 1.33           | 0.54         | 2.47                            | 0.21              | 0.044           | 1.41           | 0.54           | 0.76        | No          |
| Paper Weight | 1.33  | 0.30         | 4.40                            | 0.21              | 0.445           | 1.82           | 0.30           | 0.55        | No          |
| Paper Strength | 1.33  | 1.33         | 6.78                            | 0.21              | 0.937           | 2.31           | 9.01           | 3.07        | Capable     |
| Opacity   | 9.01           | 1.33         | 6.78                            | 0.21              | 0.937           | 2.31           | 9.01           | 3.07        | Capable     |
| Porosity  | 1.33           | 0.58         | 2.28                            | 0.21              | 0.003           | 1.37           | 0.58           | 0.80        | No          |

3.6. Discussion

The critical value of C is obtained by interpolating the value of the table C/C_{p \text{ Low}} and the value of table A, then the critical value of C obtained compared with the value \( \hat{C}_p \) (QCS) and \( \hat{C}_p \) (QC Lab), where the
value $\hat{C}_p$ (QCS) and $\hat{C}_p$ (QC Lab) each representing the value of process capability provided by QCS and QC Lab. The null hypothesis is rejected if $\hat{C}_p > C(\alpha = \beta = 0.05)$.

Table 5, shows the result of testing the process capability between the QC Lab and the value of 1.33 on each variable. Apparently on the paper Grade A Porosity and Opacity variables are said to be capable, because it meets the value of 1.33. However, paper weight, paper strength and opacity on Grade A paper have not fulfilled the value, meaning that the production process running on PT BMJ has not been able to produce Grade A paper products that are in accordance with the specification or production process has not yet had the ability to produce a Grade A paper product accurate.

Table 6, shows the result of testing the process capability between QCS and the value of 1.33 on each variable. It turns out that only the Opacity variable can be said capable, this happens because the reading of Porosity of Grade A paper on QCS is still not accurate so that the resulting product is said not to meet the specifications even though the Grade A paper has met the customers' specifications. This is a dangerous thing for PT BMJ because it will be very detrimental to the company where later Grade A paper that is ready to sell will be declared as reject goods.

Thus, it can be said that QCS has not been capable in reading the specifications of Grade A paper products. PT BMJ will incur losses when using QCS as a paper reading method believed in this condition. Manual process control cannot yet be replaced with online process control.

4. Conclusion

Based on the Kruskal Wallis test, the results of Grade A paper quality measurements on QC Lab and QCS have no differences in median. Simultaneously, they have the same median QCS and QC Lab are from the same population, meaning that different paper-reading methods do not give a difference to the quality measurements of Grade A paper produced. But testing using Kruskal Wallis only represents the size of the central symptoms. Therefore, an in-depth analysis of the testing of variations based on the specification is done by testing the hypothesis of capability comparison. The results of the capability comparison test for Grade A paper show that QCS still cannot replace the QC Lab, because: (i) QCS has a difference with QC Lab in representing the capability value that can be seen from CaCo3 Content variable. In QC Lab, Porosity is significantly expressed capable with capability of 1.453504, whereas in QCS Porosity variable is not capable, where the value of capability given only 0.58; and (ii) QC Labs are more capable than QCS. This can be seen from the amount of capability shown by both paper reading method specifications. The value of capability shown by QC Lab is larger when compared to QCS.

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