

Gage R&R Repeatability and Reproducibility Analysis on Wafer Chocolatos Length Measurement

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Abstract – This study aims to evaluate the reliability of a measurement system using the Gage Repeatability and Reproducibility (Gage R&R) method on Chocolatos wafer length measurements. The experiment involved three appraisers, each measuring five wafers with three repeated trials. The collected data were processed through several steps to determine repeatability (EV), reproducibility (AV), and overall measurement system capability (%R&R). The results showed that the %R&R value was 95%, indicating that the gage system is not satisfactory. Furthermore, the repeatability value was higher than the reproducibility value, which suggests that the main source of measurement variation comes from the measuring instrument. Therefore, the gage requires maintenance and possibly redesign. This research highlights the importance of proper calibration and system evaluation to ensure measurement accuracy and reliability.

Abstrak – Penelitian ini bertujuan untuk mengevaluasi keterandalan suatu sistem pengukuran menggunakan metode Gage Repeatability and Reproducibility (Gage R&R) pada pengukuran panjang wafer Chocolatos. Eksperimen dilakukan oleh tiga appraiser, masing-masing mengukur lima wafer dengan tiga kali pengulangan. Data yang dikumpulkan kemudian diolah melalui beberapa langkah untuk menentukan nilai repeatability (EV), reproducibility (AV), dan kapabilitas keseluruhan sistem pengukuran (%R&R). Hasil menunjukkan bahwa nilai %R&R sebesar 95%, yang mengindikasikan bahwa sistem pengukuran tidak memadai. Selain itu, nilai repeatability lebih tinggi dibandingkan reproducibility, yang berarti sumber utama variasi pengukuran berasal dari alat ukur. Oleh karena itu, alat ukur memerlukan pemeliharaan dan kemungkinan perlu dirancang ulang. Penelitian ini menekankan pentingnya kalibrasi dan evaluasi sistem untuk menjamin akurasi dan keandalan pengukuran.

Keywords – *gage r&r, measurement system analysis, validity and reliability*

INTRODUCTION

Better quality not only enables superior products but also enhances productivity and customer satisfaction. Essentially, improving productivity and customer satisfaction must be consistent to ultimately reduce the cost of achieving higher quality. One of the tools used to analyze variation in production processes is the control chart. Control charts typically consist of lines representing the Upper Control Limit (UCL), the Center Line (CL), and the Lower Control Limit (LCL). These control

limits help monitor and maintain process consistency.

To ensure that a product is both accurate and precise, the Gage R&R (Gage Repeatability and Reproducibility) method can be applied. If the measurement system meets these criteria, the repeatability and reproducibility variation values can then be calculated. The purpose of this research is to assess the reliability of a measurement system by identifying measurement variation in Chocolatos wafer using the Gage R&R method. Gage R&R is an estimate of the combined effects of repeatability and

reproducibility, which can be analyzed through datasheets and measurement report forms [1].

Gage, Repeatability, and Reproducibility (GRR) is one of the most commonly used measurement system analysis (MSA) methods, as it allows evaluation of both repeatability and reproducibility. The proposed method is sufficient to model the variance-covariance structure among several quality characteristics [2]. Repeatability refers to the analytical variability of results obtained under the same experimental conditions over a short period of time [3]. GRR analysis is a widely used measurement system analysis technique because it allows the evaluation of both repeatability and reproducibility [4].

Validity is a test used to measure the effectiveness of a measurement tool or medium in obtaining accurate data [5]. Validity is an index that indicates whether a measurement tool truly measures what it is intended to measure. The higher the instrument's validity, the more accurate it is in capturing data [6]. Content validity specifically measures how accurately a research instrument captures the variables intended to be measured [7]. Reliability, on the other hand, is an index that reflects the extent to which a measurement tool can be trusted or relied upon [8]. A measuring instrument is considered acceptable if it meets the standards of having passed both validity and reliability testing [9]. Measurement is defined as the assignment of a numerical value to a material that indicates its relationship to a specific characteristic [10].

The objective of this study is to evaluate the reliability of a measurement system using the Gage R&R method to determine the extent of variation in the measurement process of Chocolatos wafer, ensuring that the system produces consistent and accurate data.

METHOD

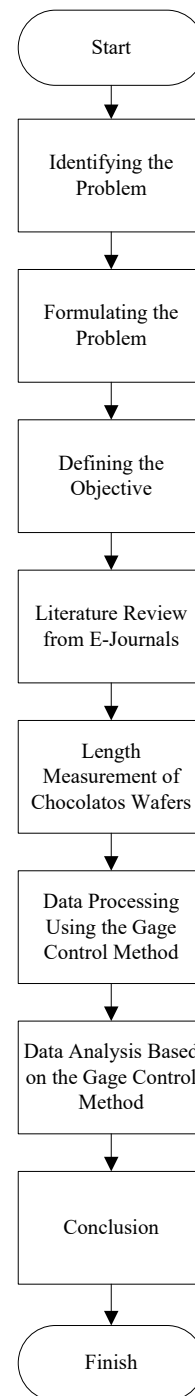


Figure 1. Research Flowchart

RESULTS AND DISCUSSION

In this study, the respondents conducted an experiment by measuring the length of 15 Chocolatos wafers, divided among three respondents. Each respondent measured five wafers, with three trials for each wafer. After the measurements were taken, each respondent collected the measurement data of the Chocolatos wafer lengths.



Figure 2. Chocolatos Wafer Product

Figure 2 shows the wafer product that will be used for data collection.



Figure 3. Measurement of Chocolatos Wafer Length by Respondent 1



Figure 4. Measurement of Chocolatos Wafer Length by Respondent 2



Figure 5. Measurement of Chocolatos Wafer Length by Respondent 3

Figures 3, 4, and 5 show Respondent 1, Respondent 2, and Respondent 3, respectively, measuring the length of the wafer product to be used for data collection.

Table 1. Chocolatos Wafer Data Collected by Appraiser 1

Appraiser I	1	2	3	4	5
Trial 1	21,5	21,5	21,7	21,9	21,7
Trial 2	21,9	21,6	21,6	21,8	21,8
Trial 3	21,8	21,9	21,8	21,9	21,8
X bar	$\frac{21,7}{3}$	21,67	21,70	21,87	21,77
R	0,4	0,4	0,2	0,1	0,1

Table 1 above shows the data collection table of Chocolatos wafer length measurements conducted by Appraiser 1.

Table 2. Chocolatos Wafer Data Collected by Appraiser 2

Appraiser II	1	2	3	4	5
Trial 1	21,7	21,8	21,7	21,7	21,7
Trial 2	21,8	21,9	21,8	21,7	21,7
Trial 3	21,7	21,8	21,8	21,8	21,7
X bar	$\frac{21,7}{3}$	21,83	21,77	21,73	21,70
R	0,1	0,1	0,1	0,1	0

Table 2 above shows the data collection table of Chocolatos wafer length measurements conducted by Appraiser 2.

Table 3. Chocolatos Wafer Data Collected by Appraiser 3

Appraiser III	1	2	3	4	5
Trial 1	21,3	21,4	21,6	21,7	21,6
Trial 2	21,4	21,9	21,8	21,6	21,7
Trial 3	21,8	21,6	21,8	21,6	21,7
X bar	$\frac{21,5}{0}$	21,63	21,73	21,63	21,67
R	0,5	0,5	0,2	0,1	0,1

Table 3 above shows the data collection table of Chocolatos wafer length measurements conducted by Appraiser 3.

After the data collection was completed, the data was processed using the Gage Control method based on the measurement results obtained. In the first step, the average value (\bar{X}) and range (R) were

calculated for each appraiser. Once the average (\bar{X}) and range (R) values for each appraiser were obtained, the following are the results of the calculations in the first step.

Table 4. Data Processing Table Step 1

Step 1	
Xa	21,75
Ra	0,24
Xb	21,75
Rb	0,08
Xc	21,63
Rc	0,28
Rbar3	0,20
Xd	0,12

Table 4 above shows the data processing table for Step 1. The calculated results show that Xa is 21.75 and Ra is 0.24. Next, Xb is 21.75 and Rb is 0.08. Then, Xc is 21.63 and Rc is 0.28. The values Xa through Xc represent the average of the \bar{X} values obtained by each appraiser, and likewise, the values Ra through Rc are the averages of the R values for each appraiser. The value \bar{R}_2 is 0.20 and is obtained from the average of Ra, Rb, and Rc. Lastly, the value Xd is 0.12, which is calculated by subtracting the minimum value among Xa, Xb, and Xc from the maximum value among them.

Table 5. Data Processing Table Step 2

Step 2	
UCL	0,5148
LCL	0

Table 5 above shows the data processing table for Step 2. Based on the data processing results, the Upper Control Limit (UCL) for R was found to be 0.5148, and the Lower Control Limit (LCL) for R was 0. The UCL for R is calculated by multiplying the D4 value of 2.574 (as listed in the table) by the \bar{R}_2 value. Meanwhile, the LCL for R is obtained by multiplying the predetermined D3 value of 0 by the \bar{R}_2 value.

Table 6. Data Processing Table Step 3

Step 3	
Xbar1	21,66
Xbar2	21,71
Xbar3	21,73
Xbar4	21,74

Step 3	
Xbar5	21,71
Rp	0,09

Table 6 above shows the data processing table for Step 3. In this step, the following \bar{X} values were obtained: $\bar{X}1$ is 21.66, $\bar{X}2$ is 21.71, $\bar{X}3$ is 21.73, $\bar{X}4$ is 21.74, and $\bar{X}5$ is 21.71. These \bar{X} values represent the average measurements collected for each wafer by the appraisers. The value of Rp is 0.09, which is calculated by subtracting the minimum value from the maximum value among $\bar{X}1$ to $\bar{X}5$.

Table 7. Data Processing Table Step 4

Step 4	
EV	0,61

Table 7 above shows the data processing table for Step 4, which contains the EV (Equipment Variation) value. The EV value is 0.61. This value is obtained by multiplying r (the number of trials) by \bar{R}_2 , where r is 3.05 because there were three trials conducted.

Table 8. Data Processing Table Step 5

Step 5	
AV	0,28

Table 8 above shows the data processing table for Step 5, which contains the AV (Appraiser Variation) value. The AV value is 0.28. This value is obtained from the following calculation:

$$Av = \sqrt{(k \cdot \bar{x}d)2 - \frac{EV^2}{nr}} \dots \dots \dots (1)$$

The value of k is 2.70 because there are 3 appraisers. The value of n is obtained from the number of parts, which is 5, as 5 wafers were used. The value of r is derived from the number of trials, which is 3, as each measurement was conducted 3 times.

Table 9. Data Processing Table Step 6

Step 6	
R&R	0,69

Table 9 above shows the data processing table for Step 6, which contains the R&R (Repeatability and Reproducibility) value. The R&R value is 0.69. This value is obtained from the following calculation:

$$R\&R = \sqrt{EV^2 + AV^2} \dots \dots \dots (2)$$

The value of EV^2 is obtained by squaring the EV value from Step 4. Then, the AV^2 value is obtained by squaring the AV value from Step 5.

Table 10. Data Processing Table Step 7

Step 7	
PV	0,18

Table 10 above shows the data processing table for Step 7, which contains the PV (Part Variation) value. The PV value is 0.18.

$$PV = j \times RpA = \pi r^2 \dots \dots \dots (3)$$

The value of j is obtained from the number of parts, which is 5, and j is valued at 2.08. The value of Rp can be found in Step 3.

Table 11. Data Processing Table Step 8

Step 8	
TV	0,72

Table 11 above shows the data processing table for Step 8, which contains the TV (Total Variation) value. The TV value is obtained from the following calculation:

$$TV = \sqrt{R\&R + PV^2} \dots \dots \dots (4)$$

The R&R value is taken from Step 6 and then squared. The PV value is taken from Step 7 and also squared. The next step is to calculate the gage control percentage based on the previously obtained values of EV, AV, R&R, PV, and TV. This involves the calculation of gage control.

Table 12. Data Processing Table Step 9

Step 9	
Ket Percentage	
%EV	84%
%AV	39%
%R&R	95%
%PV	26%

Table 12 above shows the data processing table for Step 9. The %EV value is 84%, the %AV value is 39%, the %R&R value is 95%, and the %PV value is 26%. These percentages are obtained by dividing the values of EV, AV, R&R, and PV by the value of TV. Therefore, it

can be stated that if the %R&R value is 95%,

Table 13. Data Processing Table Step 10

<i>Step 10</i>
%R&R = 95%
<i>Gage system is not satisfactory</i>

This indicates that The Gage System is Not Satisfactory; the work cannot be accepted because the gage control value exceeds the limit of >30%.

Table 14. Data Processing Table Step 11

<i>Step 11</i>
%EV = 84%, %AV = 39%, (EV>AV)
<i>The gage needs maintenance</i>
<i>The gage should be redesign</i>

It is obtained from the comparison between %EV and %AV that the repeatability value is greater than the reproducibility value. When repeatability is higher, it indicates that “the gage needs maintenance, the gage should be redesigned,” meaning there is an issue with the measuring instrument used during the experiment it may not have been calibrated, or the measuring tool should be tested first to ensure it meets the required standards.

CONCLUSION

Based on the analysis conducted in this study, it can be concluded that the measurement system (gage system) used to measure the length of Chocolatos wafers is not reliable and does not meet acceptable standards of accuracy and consistency. This is evidenced by the %R&R value of 95%, which exceeds the acceptable threshold of 30%, indicating that the gage system is not satisfactory and the resulting data cannot be accepted for decision-making in the production process.

Furthermore, the comparison between %EV and %AV reveals that the repeatability value is higher than the reproducibility value, indicating that the main source of variation comes from the measuring equipment itself rather than from operator differences. Therefore, it can be

concluded that the measuring instrument requires maintenance and possibly a redesign to align with proper measurement standards.

As a recommendation, it is advisable to recalibrate the measuring equipment before it is used for data collection. Regular validation and reliability testing of the instruments should also be implemented. Future research could involve a larger sample size and a wider range of product types to provide a more comprehensive understanding of the performance and consistency of the measurement system used.

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