

Quality Management Final Report

To see a world in a nut



Statistics Group 2

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CHAPTER 1 Introduction

1.1 Paper Industry Background in Taiwan

Nut industry is mainly small and medium enterprises in Taiwan, most less than 20 employees. Domestic manufacturers are mainly located in Tainan and Kaohsiung counties, about 44%. Domestic nut industry from 60 years to the development so far, with the development of peripheral industries mature, stable supply of raw materials and automated production efficiency, has gradually become a complete system of export-oriented production and marketing of metal products industry. Domestic nut industries covered a wide range of other industries, the main type bicycle parts, machinery, construction industry, electronic components, etc. Therefore, the nut industry, essential for development of the domestic industry .

In addition to high-speed railway built in 2004 for the case of the nut imports rise. Gradually decreased the proportion of imported nuts after 1996. In 2007, the proportion of imports to a minimum, about 3.2%, indicating that self-sufficiency rate of the nut and added value are higher.

Domestic nut exports hit a new high in 2007. More than ten years of rapid development and transformation, nut industry in Taiwan, creating a highly sophisticated technology and quality. Export unit price reflects the level and quality in product, shows the success of Taiwan avoid the low-cost strategy form China and Southeast Asian countries. Gradually escape from the Red Ocean strategy, restructuring the production of high value-added products.

1.2 Background

In 1776 , after the steam engine has been invented by Watt, Industrial Revolution era is coming. And then machinery industry has become an integral part of daily life. Until today machinery place every day exist in our lives, such as cars, refrigerators and other item . All mechanical equipment is composed of many parts, and one of the most important parts is nut.

Because of industrial machinery should be precision, often required to achieve zero error. Therefore, each part as necessary conditions for the precise, and the nut is the necessary parts, so the precision of the nut will usually affect the quality of mechanical. In the other way, nut is used to fix screw, and the error occurs when the nut with the screw will affect. So nut quality control is very important.

1.3 Research Purposes

Nuts used in many machines, so in fact the nut in our lives is often appear, such as: cars, street lamps, etc. And the major role in nut is fixed. Because the screws is fixed by nuts, when the inner diameter of the nut is inconsistent or when there is a gap, will cause the screw cannot be fixed.

In addition to measuring the inner diameter of the nut, the study also measured the weight of the nut. The results from the different composition ratio will cause weight and strength in difference. When the weight of the nut is inconsistent, the error may be caused by the proportion of components, it will cause insufficient strength. Therefore, this study measured the weight of the nut in order to understanding weathered the strength are the same.

Through the measurement of this experiment, our group hopes to know whether the nut inner diameter and weight are consistent, and error is small enough. We also want to learn how to operate the tool, and recorded data.

CHAPTER 2 Research Method

Quality control relies on a lot of measurements data analysis. Therefore, capability of measurement system has important effect for quality control and process improvement activities. Some of the variability will be inherent in items that are being measured. But in this study, to be discussed is the variability will result from the measurement system that is used.

According to Douglas C. and Montgomery(2009) the purpose of capability of measurement system is:

1. Determine how much of the total observed variability is due to the gauge or instrument.
2. Isolate the components of variability in the measurement system.
3. Assess whether the instrument or gauge is capable.

Usually want to measurements data should have accuracy and precision, where accuracy is variability in size. In this study we focus on accuracy, and the major reasons effect accuracy is:

1. Gauge error: One operator used same tool repeat measure. The error caused by tool, also called Repeatability Error.
2. Operator Error: Different operators measured same product, also mean reproducibility problem.

In this study used Classical GR&R and ANOVA analysis.

2.1 Classical GR&R

Classical GR&R used concept about range from x-bar –R chart to estimate variance. When all observations in R-bar chart are under statistical control, it means discriminative. The purpose is to reduce measurement variation, and let the measurement variation closer to real variation.

First, we should estimate repeatability variation.

$$\hat{\sigma}^2_{repeatability} = \frac{\overline{R}}{d_2}$$

Second, we should estimate reproducibility variation.

$$R_y = \overline{y}_{\max} - \overline{y}_{\min}$$

$$\hat{\sigma}^2_{repeatability} = \frac{R_y}{d_2}$$

Third, we estimate tools total variation.

$$\hat{\sigma}^2_{gauge} = \hat{\sigma}^2_{repeatability} + \hat{\sigma}^2_{reproducibility}$$

2.2 P/T ratio

Measurement total variance and specification tolerances ratio(P/T)usually used to assess whether this measure can accurately measure the quality characteristics of products.

$$P/T = \frac{6\hat{\sigma}_{Gauge}}{USL - LSL}$$

This measurement capability be appropriate when the ratio less than 0.1, and inappropriate when the ratio larger than 0.3.

2.3 ANOVA analysis

We want to understand the variation between factors, also estimate reproducibility and repeatability. Therefore, we use ANOVA analysis.

Because of the same measurement conditions, we use two factors randomization experiments. One of factor is parts, and the other factor is operators. These two factors are random effect, and the model as follows:

$$y_{ijk} = \mu + P_i + O_j + (PO)_{ij} + \varepsilon_{ijk}$$

$$i = 1, 2, \dots, p$$

$$j = 1, 2, \dots, o$$

$$k = 1, 2, \dots, n$$

y_{ijk} : Measured by the j th operator for k th times and i th products.

μ : Measured values average.

P_i : Parts effect

O_j : Operators effect

$(PO)_{ij}$: Products and operators interaction effect

ε_{ijk} : Error

The model's basic assumptions are:

1. Measured samples were obtained random, and independently of each other,
2. P_i 、 O_j 、 $(PO)_{ij}$ 、 ε_{ijk} are independent and identically distribution from normal distribution with mean=0, variance are σ_p^2 、 σ_o^2 、 σ^2

ANOVA analysis table as follow show:

Table.2.3.1 ANOVA analysis

Source	Sum square	Degree of freedom	Mean square	Expected Mean Square
Parts	SS _P	p-1	MS _P	$\sigma^2 + n\sigma_{po}^2 + pn\sigma_p^2$
Operator	SS _O	o-1	MS _O	$\sigma^2 + n\sigma_{po}^2 + on\sigma_o^2$
Parts*operators	SS _{PO}	(p-1)(o-1)	MS _{PO}	$\sigma^2 + n\sigma_{po}^2$
Error	SS _E	po(n-1)	MS _E	σ^2
total	SS _T	pon-1		

The relationship between sum of squares as follow:

$$SS_{Total} = SS_{Parts} + SS_{Operator} + SS_{PO} + SS_{Error}$$

And the mean of squares are as follow:

$$MS_P = \frac{SS_{Parts}}{p - 1}$$

$$MS_O = \frac{SS_{Operator}}{o - 1}$$

$$MS_{PO} = \frac{SS_{PO}}{(p - 1)(o - 1)}$$

$$MS_E = \frac{SS_{Error}}{po(n - 1)}$$

The variations estimate on analysis is

$$\hat{\sigma}^2 = MS_E$$

$$\hat{\sigma}^2_{p^*o} = \frac{MS_{p^*o} - MS_E}{n}$$

$$\hat{\sigma}^2_o = \frac{MS_o - MS_{p^*o}}{pn}$$

$$\hat{\sigma}^2_p = \frac{MS_p - MS_{p^*o}}{on}$$

Repeatability and reproducibility variations estimate are:

$$\hat{\sigma}^2_{repeatability} = \hat{\sigma}^2$$

$$\hat{\sigma}^2_{reproducibility} = \hat{\sigma}^2_o + \hat{\sigma}^2_{po}$$

$$\hat{\sigma}^2_{gauge} = \hat{\sigma}^2_{repeatability} + \hat{\sigma}^2_{reproducibility}$$

CHAPTER 3 Data Collection

3.1 The procedure of data collection

Our samples are thirty nuts and the measuring instrument are vernier caliper and electronic scale. vernier Caliper is use to measure the inner diameter of nuts.

Electronic scale is use to measure the weight of nuts. In our research, the measure instruments is vernier Caliper and Electronic scale, which is provide on Industrial Statistics and Quality Control Laboratory .The Measuring time at 2:00 to 5:00 pm on May 29, 2011. The research planning is 3 x 30 full factorial experiment and each operators measured twice.

The steps are as following:

- (1) Number these thirty nuts. (figure 3.1)
- (2) Using Minitab to randomize measuring order. Because each operators measure twice, we enter number one to sixty into Minitab. So that number one to thirty means the first measurement, number thirty one to sixty means the second measurement.
- (3) Using the same method to measure the weight of nuts.
- (4) Each operators measure twice.
- (5) Recording the value.
- (6) Complete the measuring work.

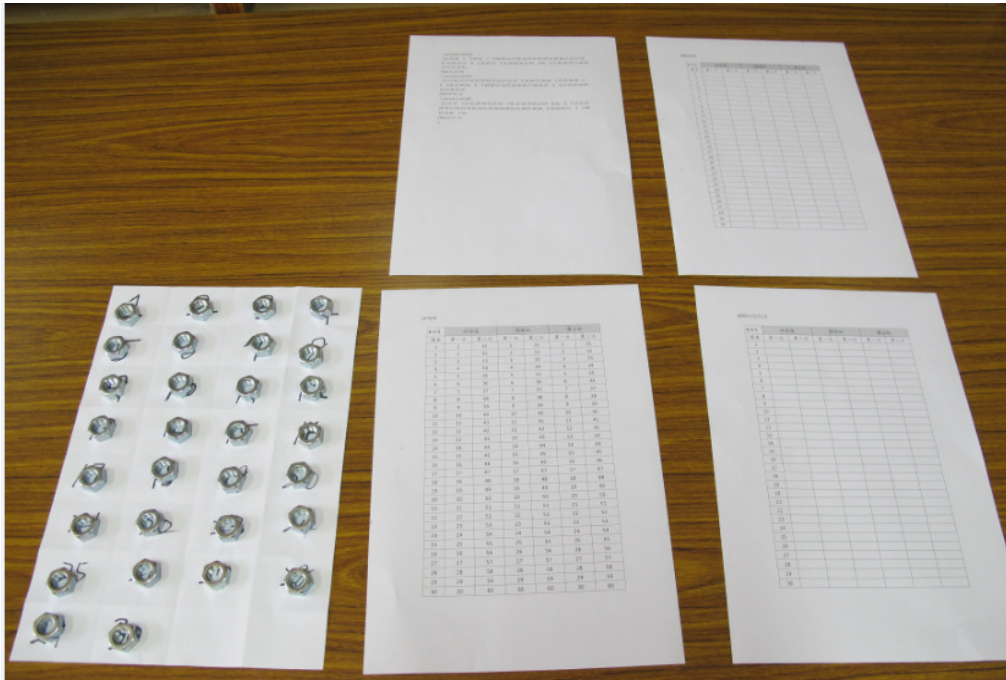


Figure 3.1 The procejure of data collection

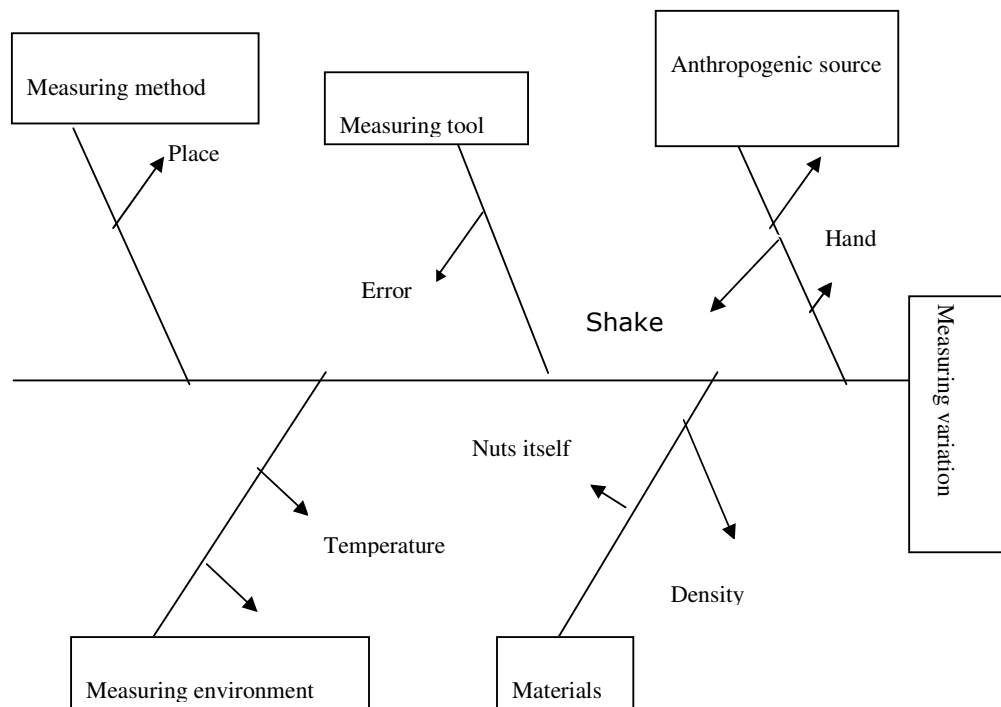


Figure 3.2 vernier caliper



Figure 3.3 measuring situation

3.2 Cause & Effect Diagram



CHAPTER 4 Data Analysis

4.1 Inner Diameter of Nuts

4.1.1 Descriptive statistics and Normality

Firstly, we calculate the descriptive statistics of inner diameter of nuts. We have the upper and lower bond of inner diameter of nuts by table 4.1 and equation(4.1).

$$\hat{\mu} \pm 4\hat{\sigma}_p \quad (4.1)$$

where $\hat{\mu}$ is sample mean

$\hat{\sigma}_p$ is sample standard deviation

The upper and lower bond of inner diameter of nuts is (9.3473 , 9.5105) °

Table 4.1 Descriptive Statistics of Inner Diameter of Nuts

Operators	N	Mean	StDev	Min	Max
Qwoop	60	9.4340	0.0214	9.3800	9.4900
Wendy	60	9.4220	0.0196	9.3700	9.4700
Tony	60	9.4307	0.0187	9.3900	9.4700
Total	Mean	StDev	Operators	Parts	Replication
180	9.4289	0.0204	3	30	2

Before conducting gauge R&R, we should check the normality of inner diameter of nuts. We construct a normal probability plot to check the inner diameter of nuts.

A normal probability plot is a graphical method for comparing two probability distributions by plotting their quantiles against each other. The points plotted in a normal probability plot are always non-decreasing when viewed from left to right. If

the two distributions being compared are identical, the normal probability plot follows the 45° line $y = x$. A normal probability plot of the inner diameter of nuts is shown in Figure 4.1. Residuals of the data by different operators do not come from normal distribution. By conducting the Shapiro-Wilk test, all the P-value are smaller than 0.05. Therefore, it is significant that the data (inner diameter of nuts) do not come from normal distribution.

Because the data do not come from normal distribution, we would use classical gauge R&R to analyze the data later.

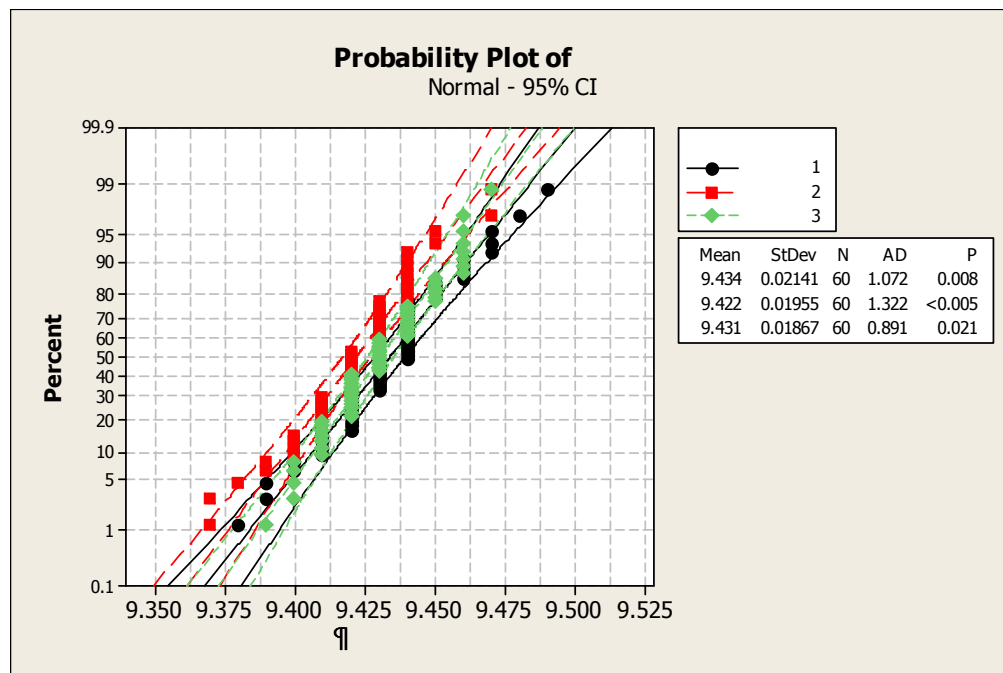


Figure 4.1 The normal probability plot of operators

4.1.2 R - chart for inner diameter of nuts

Before conducting classical gauge R&R, we plot R-chart to examine whether the data out of control or not. The R chart represents the discrepancy between measurements

made on the same unit, using the same instrument. Figure 4.2, 4.3 and 4.4 show that the R chart is in control indicating that all the operators do not have a problem with using the instrument and making consistent measurements.

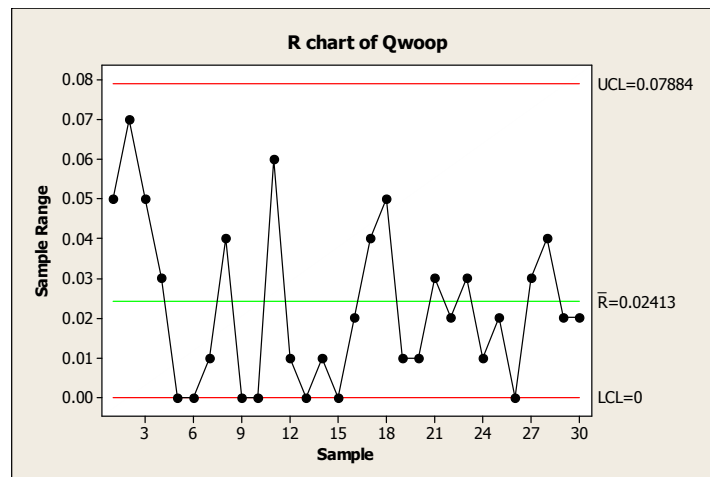


Figure 4.2 R Chart of operator 1 - Qwoop

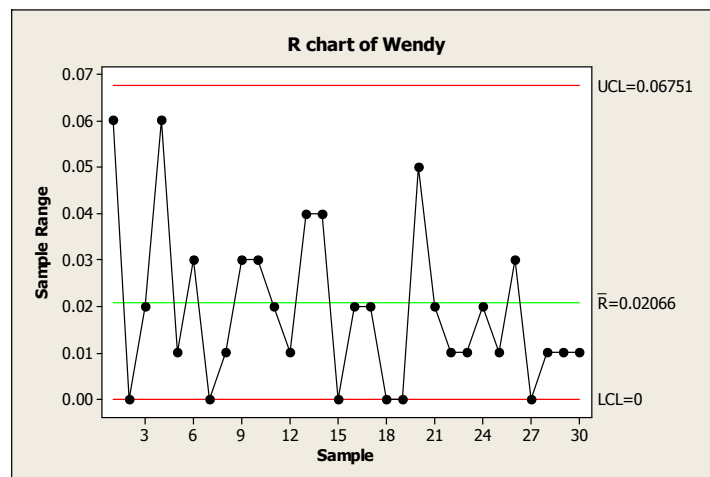


Figure 4.3 R Chart of operator 2 – Wendy

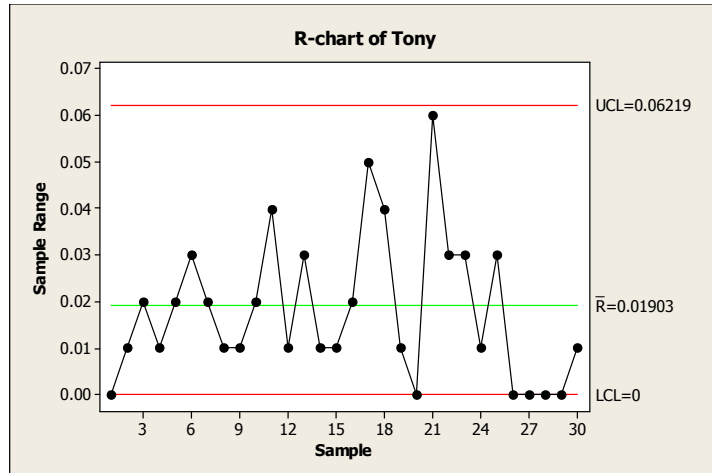


Figure 4.4 R Chart of operator 3 - Tony

4.1.3 Gauge Repeatability and Reproducibility

Table.4.2 Gauge R&R Study—inner diameter of nuts

Source	VarComp	%Contribution	StdDev (SD)	(6 * SD)	(%SV)
Total Gage R&R	0.0002899	56.00	0.0170255	0.102153	74.83
Repeatability	0.0002546	49.19	0.0159574	0.095745	70.14
Reproducibility	0.0000352	6.81	0.0059354	0.035612	26.09
Part-To-Part	0.0002278	44.00	0.0150922	0.090553	66.33
Total Variation	0.0005176	100.00	0.0227518	0.136511	100.00
Number of Distinct Categories = 8					

Though these variations were still quite small, with the variance of gauge repeatability being 0.0002546, and the variance of gauge reproducibility being 0.0000352. And part-to-part variation was 0.0002278, with then the total gauge variation making up 56% of the total variation. Figure 4.5 is gauge R&R study of

inner diameter of nuts. The variance of total GRR and the variance of total part to part are closed by components of variation. It also shows that the experiment of measurement is not very precise.

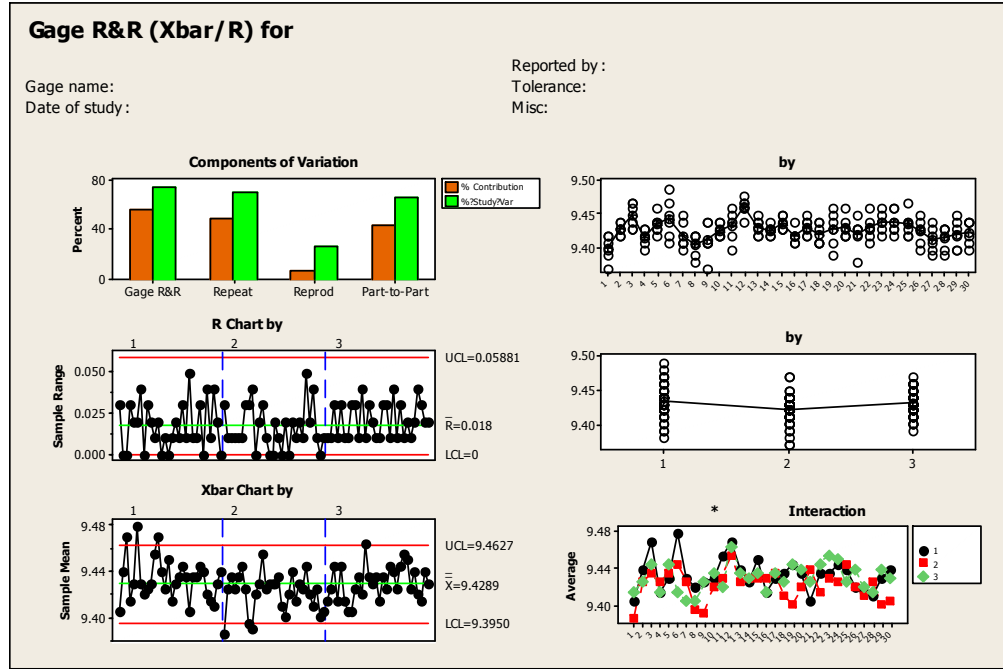


Figure 4.5 Gauge R&R Study—inner diameter of nuts

Because we do not have the USL and LSL of inner diameter of nuts, so we assume $C_p=1.33$ to get the upper and lower bond is (9.3473 , 9.5105). And P/T ratio is

$$P/T \text{ ratio} = \frac{6\hat{\sigma}_{\text{gauge}}}{USL - LSL} = \frac{0.102153}{0.1632} = 0.625937$$

P/T ratio is larger than 0.3, which is a very high value. But the number of distinct categories is more than 5. So the measurement system is acceptable.

Table.4.3 ANOVA method of Gauge R&R Study—inner diameter of nuts

Source	DF	SS	MS	F	P
Part	29	0.0282111	0.0009728	2.82645	0.000
Operator	2	0.0046044	0.0023022	6.68908	0.002
Part*Operator	58	0.0199622	0.0003442	1.40799	0.072
Repeatability	90	0.0220000	0.0002444		
Total	179	0.0747778			

Using the variance components given by table 4.3, the GRR components were computed as follows:

$$\sigma^2 = MS_E = 0.0002444$$

$$\sigma_O^2 = \frac{MS_O - MS_{PO}}{pn} = \frac{0.0023022 - 0.0003442}{(30)2} = 3.2632 \times 10^{15}$$

$$\sigma_P^2 = \frac{MS_P - MS_{OP}}{on} = \frac{0.0009728 - 0.0003442}{(3)2} = 1.048 \times 10^{14}$$

$$\sigma_{OP}^2 = \frac{MS_{OP} - MS_E}{n} = \frac{0.0003442 - 0.0002444}{2} = 4.99 \times 10^{15}$$

$$\sigma_{Gauge}^2 = \sigma^2 + \sigma_O^2 + \sigma_{OP}^2 = 0.00018$$

The P/T ratio was once again computed:

P/T ratio is larger than 0.3, which is a very high value, indicates that the measurement system has an inadequate capability.

4.2 Weight of Nuts

4.2.1 Descriptive statistics, Normality and R-chart

We firstly calculate the descriptive statistics of inner diameter of nuts. We have the upper and lower bond of inner diameter of nuts by table 4.4 and equation(4.1).

The upper and lower bond of inner diameter of nuts is (9.68 , 10.736) °

Table 4.4 Descriptive Statistics of Inner Diameter of Nuts

Operators	N	Mean	StDev	Min	Max
Qwoop	60	10.208	0.133	10.062	10.682
Wendy	60	10.208	0.133	10.061	10.682
Tony	60	10.208	0.133	10.062	10.682
Total	Mean	StDev	Operators	Parts	Replication
180	10.208	0.132	3	30	2

A normal probability plot of the inner diameter of nuts is shown in Figure 4.5. Residuals of the data by different operators do not come from normal distribution. By conducting the Shapiro-Wilk test, all the P-value are smaller than 0.05. Therefore, it is significant that the data (inner diameter of nuts) do not come from normal distribution. Because the data do not come from normal distribution, we would use classical gauge R&R to analyze the data later.

Figure 4.6,4.7 and 4.8 show that the R chart in control indicating that all the operators do not have a problem with using the instrument and making consistent measurements.

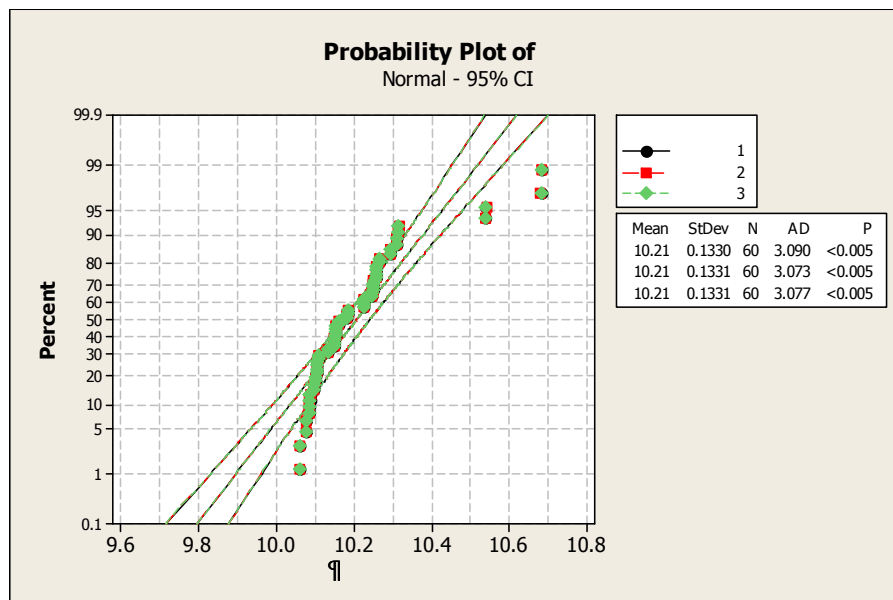


Figure 4.5 Gauge R&R Study—inner diameter of nuts

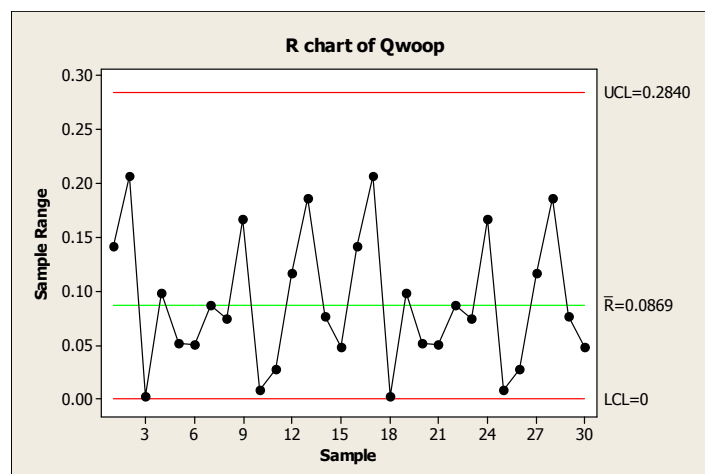


Figure 4.6 R Chart of operator 1 - Qwoop

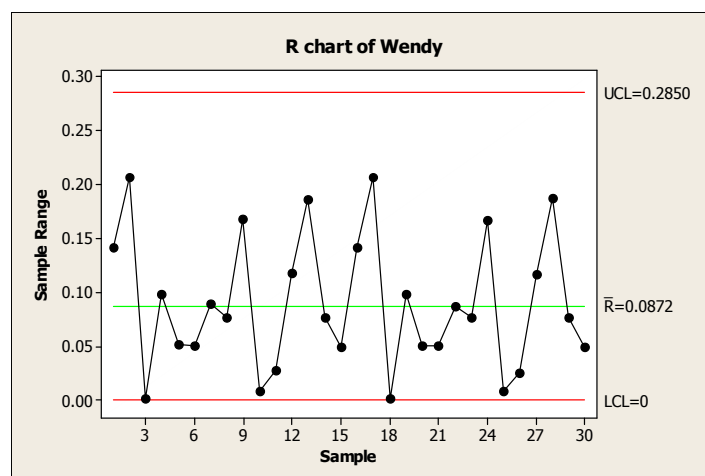


Figure 4.7 R Chart of operator 2 - Wendy

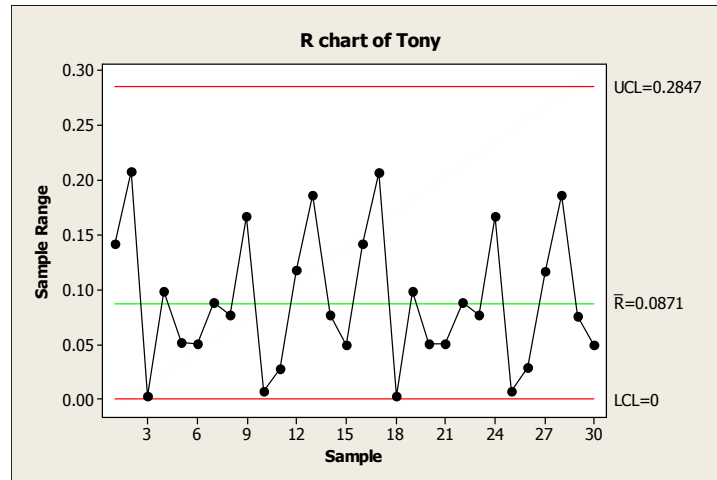


Figure 4.8 R Chart of operator 3 - Tony

4.2.2 Gauge Repeatability and Reproducibility

Table.4.5 Gauge R&R Study—weight of nuts

Source	VarComp	%Contribution	StdDev (SD)	(6 * SD)	(%SV)
Total Gage R&R	0.0000001	0.00	0.000281	0.001684	0.19
Repeatability	0.0000001	0.00	0.000266	0.001596	0.18
Reproducibility	0.0000000	0.00	0.000090	0.000538	0.06
Part-To-Part	0.0230119	100.00	0.151697	0.910181	100.00
Total Variation	0.0230120	100.00	0.151697	0.910183	100.00
Number of Distinct Categories = 762					

Though these variations were still quite small, with the variance of gauge repeatability being 0.0000001, and the variance of gauge reproducibility is around 0. And part-to-part variation was 0.0230119, with then the total gauge variation making

up about 100% of the total variation. Figure 4.9 is gauge R&R study of weight of nuts. The chart shows that the part-to-part component contributes for 100 percent of the total variation. This indicates that the weight variation that was measured was largely caused by the variation of the nuts itself.

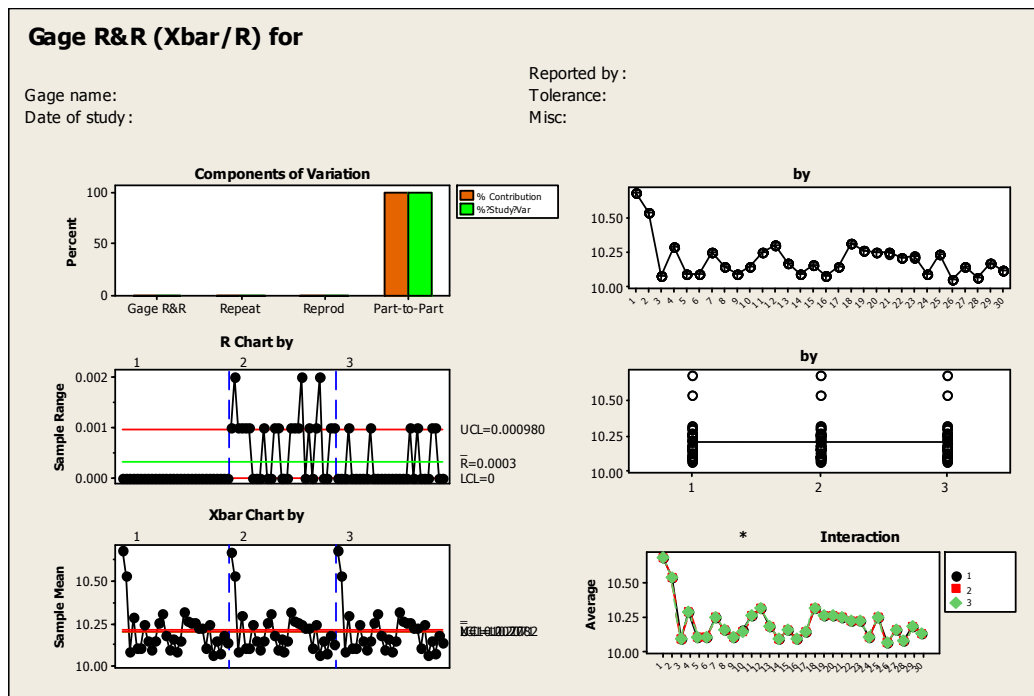


Figure 4.9 Gauge R&R Study—weight of nuts

Because we do not have the USL and LSL of inner diameter of nuts, so we assume

$C_p = 1.33$ to get the upper and lower bond is (9.68 , 10.736). And P/T ratio is

$$P/T \text{ ratio} = \frac{6\hat{\sigma}_{\text{gauge}}}{USL - LSL} = \frac{0.001684}{1.956} = 0.0008609$$

P/T ratio is less than 0.1, which is a very small value, indicates that the measurement system has an adequate capability.

Table.4.6 ANOVA method of Gauge R&R Study—weight

Source	DF	SS	MS	F	P
Part	29	3.133275	0.108044	403715	0.000
Operator	2	0.000001	0.000001	2	0.127
Part*Operator	58	0.000016	0.000000	1	0.053
Repeatability	90	0.000017	0.000000		
Total	179	179	3.133308		

Using the variance components given by table 4.6, the GRR components were computed as follows:

$$\sigma^2 = MS_E = 0$$

$$\sigma_O^2 = \frac{MS_O - MS_{PO}}{pn} = \frac{0.000001 - 0.00016}{(30)2} = 0$$

$$\sigma_P^2 = \frac{MS_P - MS_{OP}}{pn} = \frac{0.108044 - 0}{(3)2} = 0.018$$

$$\sigma_{OP}^2 = \frac{MS_{OP} - MS_E}{n} = \frac{0}{2} = 0$$

$$\sigma_{Gauge}^2 = \sigma^2 + \sigma_O^2 + \sigma_{OP}^2 = 0.018$$

The P/T ratio was once again computed:

P/T ratio is larger than 0.1, indicating that the measurement system has an inadequate capability. And the results is identical as before.

CHAPTER 5 Conclusions

5.1 Conclusion

In the experiment, the P/T ratio of inner diameter of nuts are larger than 0.1, which indicates that the caliper we used to experiment cause large variation. We can see that in ANOVA table, the factor of operators are significant. Due to the inner of nuts are not a plane, we do not have an effort force. And Palm strength for everyone are different, which is one of the major causes of large P/T ratio. Relatively speaking, the P/T ratio of weight of nuts are very small. One of the reasons is that the measuring instrument is very precise. It cause the Measured value almost the same in each nuts by different operators.

5.2 Suggestion

In order to improve the outcome, we can give the following suggestions.

- (1) If we still want to measure the inner diameter of nuts, the most important thing is to stipulate the measuring rule. Something like we can put the nuts on the desk rather than take it in the hand.
- (2) we can choose the measuring items which is a plane to make it measured more easily, like outer diameter.