Approach of Measuring System Analyses for Automotive Part Manufacturing

S. Homrossukon, S. Sansureerungsigun

***Abstract*—**This work aims to introduce an efficient and to standardize the measuring system analyses for automotive industrial. The study started by literature reviewing about the management and analyses measurement system. The approach of measuring system management, then, was constructed. Such approach was validated by collecting the current measuring system data using the equipments of interest including vernier caliper and micrometer. Their accuracy and precision of measurements were analyzed. Finally, the measuring system was improved and evaluated. The study showed that vernier did not meet its measuring characteristics based on the linearity whereas all equipments were lacking of the measuring precision characteristics. Consequently, the causes of measuring variation via the equipments of interest were declared. After the improvement, it was found that their measuring performance could be accepted as the standard required. Finally, the standardized approach for analyzing the measuring system of automotive was concluded.

***Keywords*—**Automotive part manufacturing measurement, measuring accuracy, measuring precision, measurement system analyses.

I. Introduction

MEASUREMENT is one of the important controlling mechanisms of quality management especially for a very high competition manufacturing industrials. The quality of product could be displayed through the measurement of product characteristics that customer required, which may be an attributed and/or a variable value. In manufacturing, it is possible to accept non-conforming products and/or to reject good ones depending on the result of the measurement. Both cases build the damage to the enterprise. The first one would effect to the perspective of the company if such product is sent to the buyer whereas the manufacturing cost would be unnecessarily increased for the latter. In this case, the measurement system should be very important. The damage could be vigorously raised if such product has highly effect to the life such as in automotive part manufacturing. Therefore, an automotive industrial gives an importance to the measurement as the automotive part manufacturer is required to perform the measurement system analyses according to QS-9000 and TS 16949 [1], [2].

The measurement means to the collection of instruments or gages, standards, operations, methods, fixtures, software, personnel, environment and being measured; the complete process used to obtain measurements [3]. It will assign the numbers to material things to represent the relations existing among them with respect to particular properties [4]. In the point of quality management view, the manufacturer should have the ability to design and to provide the tools, showing that the quality level demanded by customer is achieved. Such achievement could be really done if the tool used to measure such quality has an accepted variation [5]-[7]. The variation is always found in the measurement. Measurement could be considered as one work. Therefore, its input consists of at least 4Ms' including man, machine, material, and method. These inputs could have the individual and/or interaction variation affecting to the measured value. The variation of measured value mainly comes from the product variation and the measurement system variation [5]. In this case, this work emphasis on the measurement variation as the measurement is the activity used to demonstrate the quality value. The case of interest will illustrate that the large variation of measurement could be found even in the simple tools. The flow of measurement system analyses to inspect and to improve the ability of measuring equipments of interest is raised to demonstrate how to manage the measurement system.

II. Basic Background and Measurement System Analyses Approaches

A. Measurement Variation

The measurement variations exist from two main factors including the failure of device in repeating itself and the failure of measurer in reproducing the measurement method [7]. It could be classified as location variation and width variation. Location variation or accuracy is the difference between a measured value and the real value of the sample of interest. It can be determined via the bias, stability, or linearity of the measurement system. The width variation or precision is the measurement variation or the difference when measuring the same sample with the same equipment. It can be detected by the determination of the repeatability or the reproducibility of the measurement system [5].

To diminish the measurement variation, it is necessary to make sure that the measurement system is effective or it is easily managed and improved whenever it is ineffective. To achieve such goal, the measurement must be assessed by performing measurement system analyses (MSA). It is a systematic procedure to identify the variation in accuracy and precision measuring of the instruments [7]. It aims to determine the variation from an instrument, to identify the variation from measuring system, and to assess the capability

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of measuring instrument [8].

B. Measurement System Analyses Approach

The measurement is the assignment of numbers to material things to represent the relations existing among them with respect to particular properties [4]. In order to achieve an excellent quality of material things or product, the system of measurement should be capable to provide the measured value with least error or least variation. But the measured value is also dependent on the characteristic of product which made by the production process. To clearly display the effect of measurement system, the production process must be in the stage of statistical control [3], [8], [9]. If it is not, it means that there is some assignable variation which will affect to the value measured by the tool of interest, consequently. Therefore, it is necessary to determine the cause of existed variation and try to get rid of it, firstly.

The measuring tool is run by mechanic and/or electronic. Some of its component is time decayed or worn away. Therefore, it must be periodically calibrated to confirm that the tool is ready to be used to measure the characteristic of interest. The selected tool could effectively provide the measured value satisfying the customer specification when it is under the rule of thumb which requires at least 10 times finer authority of the scale needed [1], [3]. For example, if the customer required 2 decimal points value, such tool should be able to provide 3 decimal points value. With the right and suitable condition of tool, then the measurement should be effectively performed.

Measuring system consists of measurer, tool, method, and materials. Measurer uses a tool to perform the measurement. As the measurement variations exists from tool and measurer, the location and the width variation of the tool and the measurer of interest should be determined. For location variation, the bias and stability studies are preferred for all tools but linearity study is preferable if the range of measurement is required [3], [9]. Such tool will be able to give an accurate measured value when the location variation is acceptable. As the tool will be used by a measurer, in this case, the width variation should be determined via gage repeatability and reproducibility (GR&R) to confirm that the various measurers could perform the same measurement [8].

If the measurement using the tool of interest cannot provide either location or width variation, the measurement using such tool is not effective any more. In this case, such measuring system must be investigated and improved until it is effective then the measurement can be further performed. On the other hand, if such measuring tool and measurer can provide a suitable condition for measurement, it would be useful if the studied values are plotted. By doing this, the measuring performance or capability can be monitored and reviewed for continual monitoring and improvement [2], [5], consequently.

As described above, the approach of measuring system analyses and management could be constructed and written as in Fig. 1. The approach can be divided into 3 stages consisting of (I) preparation stage, (II) measurement performance or capability determination stage, and (III) improvement and control stage.

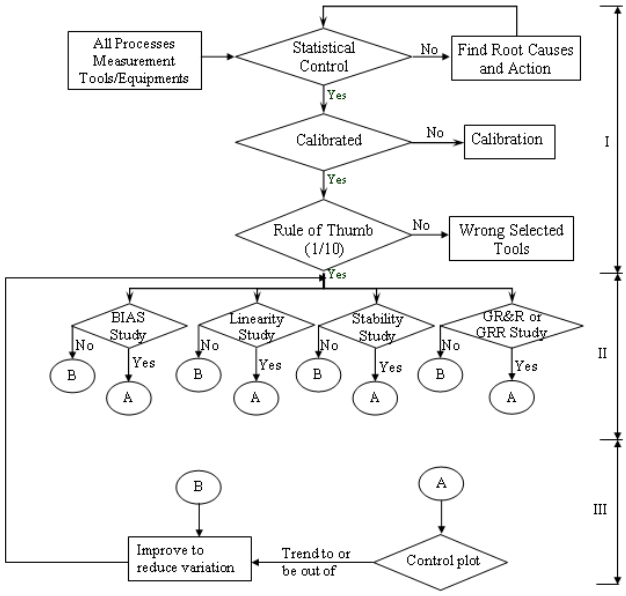

Fig. 1 Measurement system analyses and management

III. Preparation of Measuring System

This section presents stage I of measuring system analyses approach. Based on the approach described in the previous session, this work selected a measuring system in one automotive manufacturer. Based on the production data, the statistical controlled process is selected. The quality of the product of interest is its length and thickness. The customer specification required one decimal and two decimal points for length and thickness, respectively. Two simple measuring tools including vernier caliper and micrometer were focused as they are mainly used. They were also calibrated as scheduled. The measuring authority of vernire and micrometer are 0.01 mm. and 0.001 mm, respectively. Their measuring ranges are shown as in Table I. In this case, stage I or measuring system preparation was already accomplished. Then, stage II or determination of measuring system capability can be performed.

TABLE I
Measuring Range Reference of Tools of Interest

Tool	Referring tool	Measuring Range Reference (mm)		
		A	B	C
Vernier caliper	Profile projector	7.975	37.664	63.975
Micrometer	Scale Calibrator	0.4997	1.0008	2.9255

IV. Determination of Measuring System Capability and Results

This section presents the determination of measuring system capability of the case of interest. From Fig. 1, the bias, stability, linearity and GR&R of each tool were determined in this stage. Their studies and result were also presented and discussed.

A. Bias Determination

Bias is the difference between the average measured value and the reference value. The interpretation of bias values (Table II) will be based on its percentage value as calculated from [1], [3];

$$\%\text{bias} = \left(\frac{|\text{bias}|}{\text{reference}}\right) \text{x } 100 \quad (1)$$

where; bias is the deviation of average measured value from the measuring reference.

TABLE II
BIAS VALUES INTERPRETATION [1]

Bias	Description
<5	Acceptable
5≤ bias <10	Possibly acceptable with some adjustment
≥10	Completely unacceptable

The reference is the value measured by higher authority instrument on the precise standard master piece. The reference may be the range of specification if such bias is determined based on the range of specification.

Bias of each tool was determined and the results were shown in Table III. It was found that the measuring performance of each tool based on the bias was completely acceptable at some range of measurement represented by A, B, and C. The same meaning as shown in Table II, some of them are possibly acceptable but overall they can provide an acceptable measuring performance. At B level, the uses of vernier might be more carefully as its bias value was closed to 10.

TABLE III
BIAS DETERMINATION RESULTS

Tool	Bias (%) of each measuring range of reference		
	A	B	C
Vernier caliper	1.25	8.25	0.11
Micrometer	7	2.67	1.5

B. Stability Determination

Stability is the consistency of the average measured value or bias throughout the period of time. It can be determined via average and range chart [1]. The stability can be also determined by its percentage value as calculated from [3];

$$\%\text{ stability} = \left(\frac{\bar{\bar{X}}_2 - \bar{\bar{X}}_1}{\text{USL-LSL}}\right) \text{x } 100$$

Stability of each tool was determined and the results were shown in Table IV. The interpretation of stability is in the same manner as the bias as shown in Table II. It was found that the measuring capability of each tool based on stability was acceptable.

TABLE IV
STABILITY DETERMINATION RESULTS

Tool	Stability (%) of each measuring range of reference		
	A	B	C
Vernier caliper	5.5	5	6
Micrometer	0.5	0.3	0.7

C. Linearity Determination

Linearity is the change of the bias when the measuring range is changed. Linearity of each tool was determined throughout the range of measurement. The linearity is found when the average bias is not changed in the range of study. Their results were shown in Figs. 2 and 3. It was found that venier and micrometer had no linearity on the measuring as their average biases were significantly changed in the rage of study.

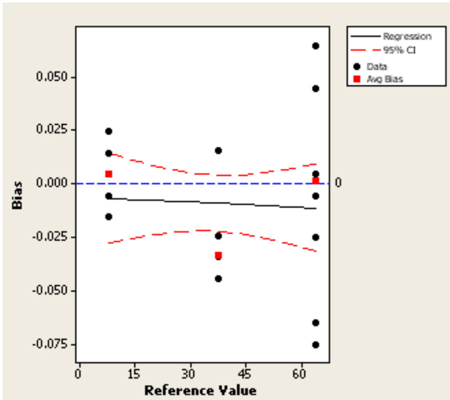

Fig. 2 Linearity determination of vernier caliper

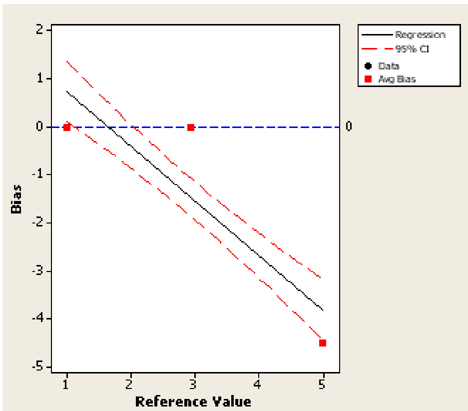

Fig. 3 Linearity determination of micrometer

D. GR&R Determination

As mention before, GR&R is used to determine the capability to repeat and reproduce a work or a measurement. In this case, it could reflect the effect of a measurer and/or measuring tool during the measurement. GR&R of each tool was determined and the results were shown in Table V. The interpretation can be conducted according to the value of %GR&R as shown in Table VI [3]. It was found that the measuring performance of each tool was unacceptable as its

R&R value was more than 30% [1].

TABLE V
GR&R DETERMINATION RESULTS

Tool	GR&R (%) of each tool		
	EV	AV	R&R
Vernier caliper	40.1	11.5	41.7
Micrometer	38.1	41.6	51.4

TABLE VI
R&R VALUES INTERPRETATION [1]

%GR&R	Description
<10	Acceptable
10≤ % <30	Possibly acceptable with some adjustment
≥30	Completely unacceptable

E. Location and Width Determination Conclusion

From A to D in this section, it was found that the overview performances of measuring tools of interest were unacceptable as their measurement capability based on linearity and R&R were unacceptable. In this case, it meant that there were a lot of variations in the measuring system. Therefore, the measurement using these tools needed to be investigated and improved according to stage 3 of the measuring analyses approach.

V. IMPROVEMENT STAGE AND RESULT

A. Improvement

Section II reveals that the measuring by verneir caliper and micrometer had no linearity. Furthermore, both tools also had a width variation as GR&R values were very high. On the other hand, it was be able to conclude that the measuring system of interest was unacceptable as there were a lot of variations. In this case, the cause of theses variation were investigate based on the measuring system of interest. The quality improvement techniques such brain storming cause and effect diagram were employed [9].

The possible causes of non linearity of vernier were investigated and found that there were 4 potential causes including calibration period, maintenance, master gage, and measuring position. The possible causes of width variation also were investigated and found that there were 5 potential causes including work piece, measuring method, operator, master gage, and measuring position. In this case, the new calibration period was reduced from 1 year to 0.5 year based on history data. New work instruction was also established as well as training and retraining was induced to reduce the variation among the operators. Fixture was used for setting up a part during the measurement to reduce the variation from measuring position. Then, the measurement system was analyzed again.

B. Results

Even though the biases of vernier and micrometer were acceptable but some of working system was changed during the improvement. Therefore, all measuring properties must be determined to ensure that those changes had no effect to any one of measuring capability of the system. Bias and stability of both tools after the improvement were shown in Table VII.

TABLE VII
MEASURING PERFORMANCE AFTER IMPROVEMENT

Tool	Bias (%)	Stability (%)
Vernier	0.17-0.25	0.5-1
micrometer	0-0.5	0.0-0.02

Each tool had its linearity in the range of measuring after the improvement as their bias did not significantly change in the range of measurement.

For width variation determination, it was found that the measuring performance of each tool based on bias was acceptable as R&R value was less than 30% as shown in Table VIII.

TABLE VIII
GR&R DETERMINATION RESULTS AFTER IMPROVEMENT

Tool	GR&R (%) of each tool		
	EV	AV	R&R
Vernier caliper	14.7	5.4	15.5
Micrometer	25.6	8.6	26.2

C. Measuring Monitoring

One important approach for measurement system either came from the improvement or the origin is that its measuring performance needed to be monitored. In this stage, control chart or run chart may be employed [8]. By doing this, the measuring system will be immediately detected its trends whenever unacceptable condition start reaching. By doing this, the system will be able to reduce the undesired variation before it affects to the measurement.

VI. DISCUSSION

After the improvement stage, all tools could provide an effective measurement. They had better measuring capability based on the bias, stability, and linearity. Even though the measuring capability based on GR&R of vernier and micrometer were acceptable (Table VIII) but further improvement should be required, especially for vernier. Once the system is improved, the measuring system must be reanalyzed. This is a cycling action proposed in stage II and III.

Following the approach of measuring system analyses allows the system being capable to provide an acceptable variation measurement. Such approach helps automotive part manufacturer easily manage its measurement system. Stage I and II are constructed from measuring data and system analyses theory [1], [3], [9]. Stage III was raised from the quality improvement theory [8].

As the measurement is very important for a precise dimension required product such as in automotive industry, a good plan of measurement system management is also required. The plan might follows the requirement of quality management ISO/TS 16949 based on measuring system analyses and system monitoring [2]. For the complicated measuring instruments, their usage will be more complicated than the tools of this study. In this case, the design of experiment should provide the most suitable condition in the improvement stage (III) but if it is time consuming such calibration period, the historical data should be more preferable. If the condition is affordable, design of experiment would provide a more precise measuring system condition [6].

ACKNOWLEDGMENT

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