APPLICATION OF MEASUREMENT SYSTEM ANALYSIS

R. Ashokanand  
Research Scholar  
Anna University Coimbatore  
Coimbatore – 641 041

Dr. S. Balasubramanian  
Research Supervisor  
Anna University Coimbatore  
Coimbatore – 641 041

ABSTRACT

Measurement System Analysis is a collection of Measurement devices or system used to capture the data. Any Measured data has variation which is inevitable. Taking measurements can be considered as a process, similar to a manufacturing process.

1.0 MEASUREMENT DATA

a. Professional Management calls for taking decisions based on facts, as expressed in terms of data.
b. The decision to adjust a process or not, is based on the measured values of the output characteristic.
c. Benefits of using data based procedures largely depend on the Quality of the measurement data (GIGO).
d. The Quality of the measurement data is related to the Statistical properties of multiple measurements from a measurement system.
e. Quality of the data is low, if measurements are away from the master value.
f. When all the measurements are close to a master value, the Quality of data is said to be high.

2.0 MEASUREMENT SYSTEM

A Measurement System consists of

a. Measuring instrument(s)
b. Accessories
c. Inspector
d. Environmental conditions
e. Measured part

2.1 STATISTICAL PROPERTIES OF MEASUREMENT SYSTEM
a. An ideal measurement system will produce measurements that will 'always' agree with a master value, when repeat measurements are taken.
b. Such a measurement system will have ZERO variance and ZERO bias.
c. Measurement systems with such properties seldom exist.
d. Measurement systems have variations.
e. They do not necessarily provide the same numbers even if repeat measurements on the same part are taken.
f. It is necessary to recognize this variation and to provide systems in such a way that this variation is within the required capability of the measurement system.

2.2 MEASUREMENT SYSTEM REQUIREMENTS
a. Measurement system must be in a state of Statistical Control.
b. The variation in the measurement system should be due to common causes only.
c. No special causes of variations should be present in a measurement system.
d. Variability of the measurement system must be small compared to manufacturing process variability.
e. Measurement system variability must be small compared to the specification tolerance.
f. The increments of measurement must be small relative to the smaller of either the process variability or the specification limits.
g. A common rule of thumb is for the increments to be no greater than one-tenth of the smaller of either the process variability or the specification limits.
h. Statistical properties of the measurement system may change as the items being measured vary.
i. The largest variation of the measurement system must be small relative to the smaller of either the process variability or the specification limits.
3.0 WISDOM OF CROWD

- It is a technique used to find the better value than the prejudged value.
- This refers to the fact that the collective wisdom is better than the individual wisdom.
- The main benefit of this technique is to reduce the assumption that obtained because of the individual wisdom.

3.1 AN EXERCISE ON WISDOM OF CROWD

The activity is to determine the age of a particular person in a group.

Let us consider a group containing 20 people.

Let us pick one person say A, from the group and asked to write down his/her original age in a piece of paper and to be kept undisclosed till the exercise is over.

Now each and every person need to guess the age of A. (Person A should not participate in this game as he/she is the observer).

Now we have 19 different readings from the group that need to be noted down.

Average of all the 19 readings need to be taken.

Now the person A has to reveal his/her true value.

The true value and the average value from the group will be considered.

There exists some variation while comparing the reading however the average value tends very closely towards the true value.

The objective of this exercise is to understand that the collective wisdom is better than the individual wisdom. In this exercise the true value is 30 years. Even though there exists many number of varied observation the average value tends closer to the true value.

True Value = 30 yrs.

Average value = 29.63 yrs closer to 30 years.

4.0 ROLE OF VARIANCE IN THE MEASUREMENT SYSTEM ANALYSIS

A Measurement System is said to be acceptable if variance of Measurement System is lesser that variance of manufacturing process.
4.1 RELATIONSHIP AMONG VARIATION OF MEASUREMENT SYSTEM AND MANUFACTURING PROCESS

V - Variance
MS - Measurement System
MP - Manufacturing Process

4.2 LEAST COUNT
The least count (LC) is the smallest count which is a multiple of measurement system.
LC <= One tenth of Tolerance
LC <= (1/10) * Tolerance

4.3 TOLERANCE
Tolerance is the difference between the Upper Specification limit (USL) and Lower specification limit (LSL).
Tolerance = USL - LSL

4.4 CONDITION FOR USING A MEASUREMENT SYSTEM
A Measurement system is said to be acceptable only if it satisfy the following condition.
LC <= [(1/10) * (USL - LSL)]
The recent version says that,
LC <= (1/10) Min (Tolerance, 6s)
Where 6s is the process spread or process enticement.

5.0 THE MEASUREMENT SYSTEM ERRORS
   a. Bias (In Accuracy)
   b. Repeatability
   c. Reproducibility
   d. Stability
   e. Linearity

5.1 BIAS
Bias can be defined as the True value and the Average of the repeated reading.

Illustration:
Let us consider the following illustration.
   a. Let us keep the Device constant
b. Let us keep the Part constant
c. Let us keep the CTQ constant
d. Let us keep the Operator constant
Take the repeated readings.

The Expected value is '0' and the true value can take any one of the following.
Bias > 0
Bias = 0
Bias < 0
The process of rectifying the bias is called as the Calibration.

True value can be achieved by using the Master Gauge. Or use the wisdom of crowd for the individual values that will give the nearer value.

5.2 REPEATABILITY

Illustration:
Let us consider the following illustration.
  a. Let us keep the Device constant
  b. Let us keep the Part constant
  c. Let us keep the CTQ constant
  d. Let us keep the Operator constant
Take the repeated readings.
Hence the repeatability can be defined as the variation in the output of the Measurement system due to the devices.

5.3 REPRODUCIBILITY

Reproducibility can be defined as the difference between the maximum average values of a particular operator to the minimum average value of a particular operator.

Illustration:
Let us consider the following illustration.

a. Let us keep the Device constant
b. Let us keep the Part constant
c. Let us keep the CTQ constant
d. Let us keep the Operator constant

Take the repeated readings.
5.4 STABILITY

Stability can be defined as the difference between the average performances of the device over a period of time. Analyzing the influence of time is dealt with the stability in the Measurement System.

The average performance is referred to as "µ"

Assumption Made:

Standard Deviation remains Constant.

5.5 LINEARITY

Linearity is highly influenced in the Electrical Devices.

Some facts on Linearity:

a. When Bias is constant throughout the entire operations, then there exists no linearity.
   - Let us consider an example of determining the true weight of a weighing scale.
   - Consider the standard weights say 1 kg, 2kg, 3kg etc.
   - Now compare the weight to be tested with that of the standard weights.
- Say when compared with 1kg 25 gms were shown as error. This 25 grams will remain the same whatever the standard weighing measures.

b. If the bias has influence over the operating range of the device then the Linearity is said to exists.

c. Bias of 1 Kg is same as that of any standard weights.

d. Linearity deals with the Average.

5.6 RELATIONSHIP BETWEEN MEASUREMENT SYSTEM ERRORS AND AVERAGE

a. Bias - Mean as average is used
b. Repeatability - Variance is used
c. Reproducibility - Mean is used
d. Stability - Mean is used
e. Linearity - Mean is used

Out of five Measurement System Properties,
a. Bias can be corrected easily.
b. Linearity can be done with very extra efforts but is done once in a life time.
c. Stability can be achieved generously.

And hence only the repeatability and reproducibility need to be considered. However before considering repeatability and reproducibility it is very mandatory to ensure that Bias, Linearity and Stability are taken care. Repeatability and Reproducibility which is called as R&R is a subject of Measurement System Analysis.

5.7 PARTS SELECTION

Selection of parts for consideration:
a. Very good part
b. Good part
c. Better part
d. Bad part
e. Very bad part.

This is done by selective manner and not by random so as to have all type of parts.

5.8 ASSUMPTION MADE DURING THE STUDY

a. Linearity is taken care.
b. Bias is taken care.
c. Stability is taken care.

5.9 RELATIONSHIP AMONG MEASUREMENT SYSTEM ERRORS

5.9.1 Repeatability

Let us consider the R - Chart.

Relationship between 'R' and 's' is given as below.

\[ \sigma = \frac{R}{d^2} \]

\[ \bar{R} = \frac{\sum_{i=1}^{n} R_i}{n} \]

\[ S_e = \frac{\bar{R}}{d_2} \]

\( d_2 \) – depends on the number of sub group. \( m=3 \) refers to number of samples and \( g=10 \)

Reproducibility is given as follows:

Repeatability = 6* \( S_e \)

5.9.2 Reproducibility

\[ R_0 = \text{Max (Operator 1 Average, Operator 2 Average, \ldots \ldots Operator K Average)} - \text{Min (Operator 1 Average, Operator 2 Average, \ldots \ldots Operator K Average)} \]

Where \( m=2 \) refers to sub group size and \( g = 1 \) refers to Number of samples.

Reproducibility is given as follows:

\[ S_0 = \frac{R_0}{d_2} \]

Reproducibility = 6* \( S_0 \)

\[ \text{Adjusted Reproducibility } S_{\theta \, \text{Adj}} = \sqrt{\left(\frac{6 \times R_0}{d_2}\right)^2 - \left(\frac{6 \times S_e}{n r}\right)^2} \]

\[ \text{Gage R \\& R} = \sqrt{S_e^2 + S_{\theta \, \text{Adj}}^2} \]
5.9.3 PROCESS VARIABILITY BY PART TO PART VARIATION

Since the variation is due to operator and also from other factors we need to go for Adjusted So. We need to look into the part to part variation in order to check whether the So adj is considered correctly.

\[ Rp = \text{Max}[\text{Part 1 Average, Part 2 Average, \ldots \ldots \ldots \ldots Part K Average}] - \text{Min}[\text{Part 1 Average, Part 2 Average, \ldots \ldots \ldots \ldots Part K Average}] \]

Standard Deviation of Parts \( Sp = \frac{Rp}{d^*_2}, \text{ where } m=k, g=1 \)

Hence part to part variation = \( 6 \times Sp \)

5.9.4 Relationship between So, Se and Sp

\[
\text{Gage R & R} = \sqrt{S_e^2 + S_{o \text{ Adj}}^2}
\]

The measurement system will be found satisfied only when the equation is

\[
\sqrt{S_e^2 + S_{o \text{ Adj}}^2} \leq 6 \times S_p
\]

In Practice the measurement system will be governed by the equation

\[
\sqrt{S_e^2 + S_{o \text{ Adj}}^2} \leq 0.3 \times 6 \times S_p
\]

6.0 TYPES OF GAGE STUDIES

a. Attribute Gage study
b. Variable Gage study

Variable Gage studies

a. Control chart method
b. Gage R & R study
c. ANOVA method

6.1 INITIAL CONSIDERATIONS ON REPEATABILITY & REPRODUCIBILITY STUDY (GAGE R&R STUDY)

a. Use the engineering judgment to assess the variation factors.
b. Critical dimensions require more parts and/or trials (repeat measurements).
c. Bulky/heavy parts may dictate fewer samples and more trials.
d. Appraisers should be selected from those who normally operate the instrument.
e. Sample parts must be selected from the process and they should represent its entire operating range.
f. Instrument must have discrimination (resolution) that allows at least one-tenth of the expected process variation of the characteristic.
g. The measurement method is well defined.
h. Measurements should be made in a random order.

6.2 CONDUCTING THE R&R STUDY

a. Select ten parts from the process at random, preferably one part from every day's production.
b. Identify them with a serial number, than cannot be observed by the appraisers.
c. Select two or three appraisers, who normally operate the measuring system.
d. Measure the parts randomly so that all the parts are measured by all the appraisers for two or three times (trials).
e. Record the observations.
f. Calculate the variations due to different factors, according to the formulae given.
g. A measurement system with a R&R% of 10% or less is considered good.
h. A measurement system with R&R% more than 30% requires review and is considered not acceptable.
i. A measurement system with R&R% between 10% to 30% may have to be evaluated for acceptance, considering the criticality of the part.

6.3 APPLICATIONS OF GR&R STUDIES.

a. Provides a criterion to accept new measuring device.
b. Provides a comparison of one measuring device against another.
c. Provides a basis for evaluating a gage suspected of being deficient.
d. Provides a comparison for measuring equipment before and after repair.
7.0 CONCLUSION

Decisions based on facts, as expressed in terms of data.

The decision to adjust a process or not, is based on the measured values of the output characteristic. Any measured data has variation which is inevitable. Measurement systems have variations. They do not necessarily provide the same numbers even if repeat measurements on the same part are taken. It is necessary to recognize this variation and to provide systems in such a way that this variation is within the required capability of the measurement system.

The quality of the measurement data is related to the statistical properties of multiple measurements from a measurement system.

8.0 REFERENCES

3. Indian Statistical Institute, Chennai, Presentation Material, 2009