19 MEASUREMENT SYSTEMS ANALYSIS

Description

A Measurement System Analysis (MSA) determines the variation of the measurement system in proportion to the variation of the process and/or the allowable tolerance. It is the process by which a measurement system is analyzed to assess whether the quality of that system is fit for use.

Purpose

A Measurement Systems Analysis is done to indicate whether the measurement system is capable of measuring changes and improvements in process variation and/or whether it is suitable to determine process capability with respect to the tolerance band. It can be used to detect what may be causing measurement variation. Sources of variation may be people, parts, or the measurement system.

Benefits

- A successful MSA promotes confidence in the measurement system and equipment being used.
- A well-done MSA readily highlights deficiencies and areas causing deficiencies, which can be resolved to improve the measurement system.
- Systems introducing an unacceptable amount of variation can be identified, improved, or replaced, thus improving the quality of the data. Higher quality data provide a truer picture and, ultimately, a better understanding of the process.

Implementation

The AIAG *Measurement System Analysis Reference Manual* should be consulted before starting an MSA. The *Manual* has valuable information on the technical approach and terminology associated with the MSA.

Selecting the proper Repeatability and Reproducibility (R&R) experimental design is crucial to a successful MSA. R&R is an important component of an MSA. It involves using different operators and different samples. It measures ratio of the variation of the measurement system to the variation in the process. An R&R value less than 10percent is considered to be an acceptable measurement system. Values between 10percent and 30percent may be acceptable based upon the importance of the application, cost of the measurement device, cost of repair, etc. A value greater than 30percent indicates an unacceptable measurement system. Every effort should be made to improve the measurement system for this case since the goal in all cases is to accurately measure changes in process variation.

Precision to Tolerance Ratio is another valuable output of a MSA. It measures the ratio of the variation of the measurement system to the allowable tolerance. The ranges of acceptance and rejection are the same as defined above. The goal is to measure process capability.

Properties required in all measurements systems:

The process or system being measured must be in statistical control. Otherwise, the concept of measurement system analysis is meaningless. Variation in the measurement system must be due to common causes only and not due to special causes.

The variability of the measurement system must be small compared with the manufacturing process variability if the intention is to accurately measure process variability.

The variability of the measurement system must be small compared with the specification limits if the intention is to measure process capability.

The increments of measure must be small relative to the smaller of either the process variability or the specification limits, depending on what the intention is.

The common rule of thumb is for the increments of measure to be no greater than 1/10th of the smaller of either the process variability or the specification limits depending on whether the process variability or capability is being measured, respectively.

The statistical properties of the measurement system may change as the items being measured vary. If so, then the largest variation of the measurement system must be small relative to the smaller of the process variation or the specification limits, depending on the intention.

- Analysis Types
  - Continuous
  - Range Method
  - Variance Estimate
  - Percent Tolerance
  - Average and Range Method
  - Analysis of Variance (ANOVA)
  - Analysis of Variance (ANOVA) Percent Tolerance
- Attribute
  - Crosstab Method
  - Signal Detection Approach

Process Flow

1. Define the process to be measured.
2. Develop the Cause and Effect Matrix.
3. Define the measurement.
4. Define the measurement system.
5. Choose the specific parts.
6. Select the appraisers.
6. Determine the test matrix.
7. Collect data according to the test matrix.
8. Perform statistical analysis of the data, determining repeatability and reproducibility and precision- to-tolerance ratio.
9. Take corrective action as required.

Example

A certain piece of equipment in an engineering lab was studied to assess fitness for use. The tolerance on the feature that is to be measured is 0.00 to .900. A Six Sigma level is to be used to assess gage capability as a percent of total tolerance or precision to tolerance ratio. The analysis included three operators, three parts, and two trials. Measurements were taken and the following was observed using the ANOVA method, percent tolerance.

The measurement matrix and measurements taken are shown below:

Table 19.1. Test Design and Results

	Operator	Part	Trials	Measure
	Summary of Design for R & R Study Operators: 3 Parts: 3 Trials: 2			
1	1	1	1	0.12
2	1	2	1	0.14
3	1	3	1	0.13
4	1	1	2	0.14
5	1	2	2	0.12
6	1	3	2	0.15
7	2	1	1	0.12
8	2	2	1	0.11
9	2	3	1	0.16
10	2	1	2	0.13
11	2	2	2	0.12
12	2	3	2	0.14
13	3	1	1	0.12
14	3	2	1	0.14
15	3	3	1	0.15
16	3	1	2	0.11
17	3	2	2	0.14
18	3	3	2	0.15

The results are :

Table 19.2. Measurement System Analysis

Source (Expected MS)	Measrmnt Units	.90 Lowr Conf.Lim	.90 Uppr Conf.Lim	% Proc. Variatn	% Total Contrib.	% of Tolernce
	Percent Tolerance Analysis:Measure Sigma intervals:6. Mean=.132778 Std.Dv=.149E-1 Operators: 3 Parts: 3 Trials: 2					
Repeatability (Equipment Var).	0.061644	0.044960	0.101417	61.3382	37.6238	6.8493
Operator (Appraiser Var.)	0.000000	0.000000	0.055746	0.0000	0.0000	0.0000
Interaction (Operator x Part)	0.047434	0.000000	0.151641	47.1988	22.2772	5.2705
Part Variation	0.063640	0.000000	0.321233	63.3238	40.0990	7.0711
Combined R & R	0.077782	0.068881	0.095998	77.3957	59.9010	8.6424
Total Process Variation	0.100499			100.0000	100.0000	11.1665
Tolerance	0.900000					100.0000

Combined precision to tolerance was measured to be of 8.64 percent of the tolerance band. (Less than 10 percent implies that the measurement system is good.) Part variation accounts for 7.07 percent of part tolerance. Equipment variation accounts for 6.85 percent of part tolerance, and operator-Part interaction accounts for 5.27 percent of part tolerance.

While the measurement system can determine part acceptability to the tolerance, it cannot be used to assess improvements in the process itself as measurement variation is a significant portion of the part variation.

The Box Plot and Operator by part plots are shown below. They are just some of the plots that can be used to graphically assess sources of variation.

Conclusion: Based on the results of this MSA, the equipment and operators are deemed more than capable enough of measuring the required part feature. Therefore, we have a satisfactory measurement system.

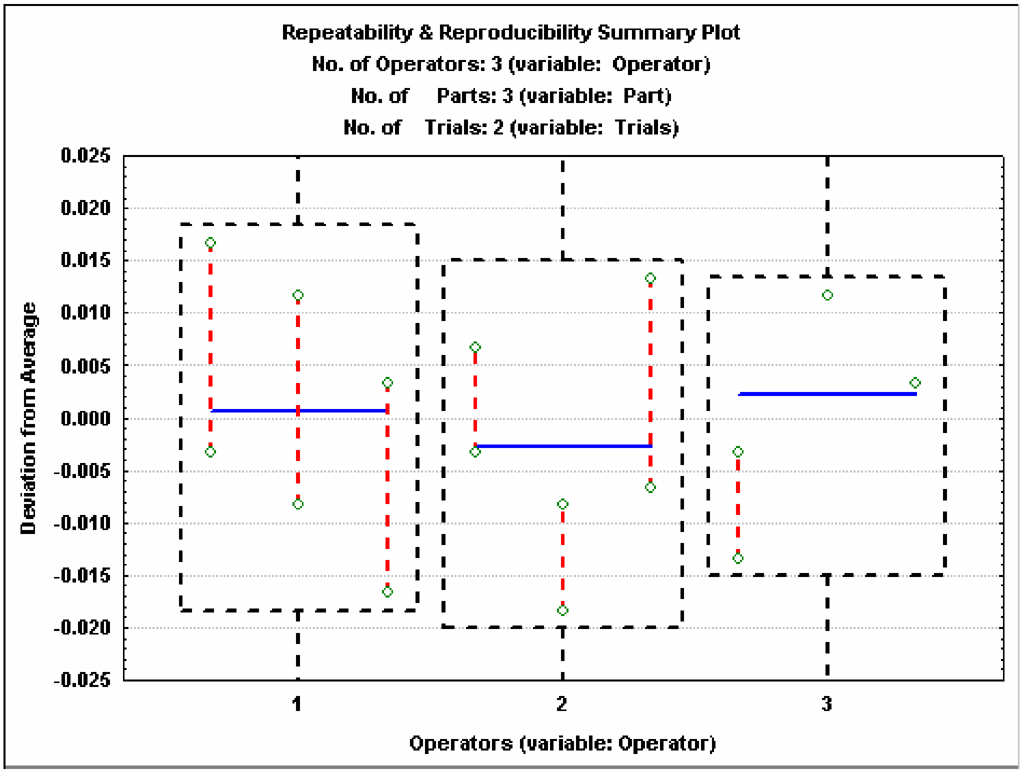

Figure 19.1. Box Plot

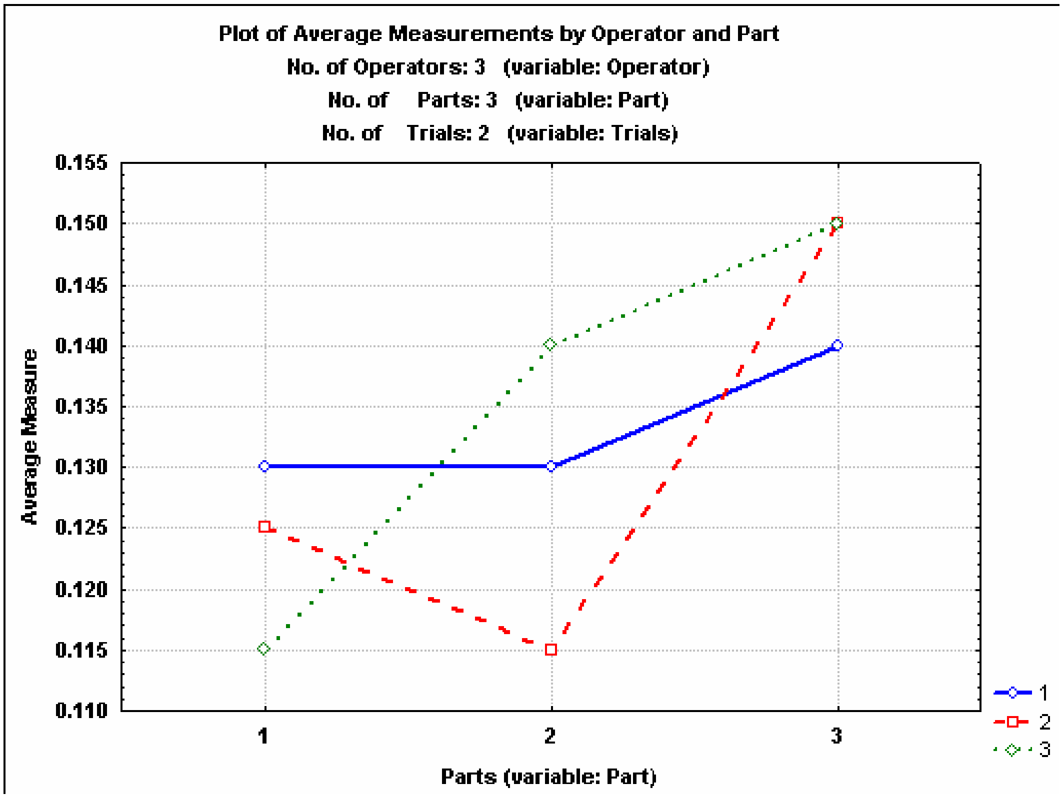

Figure 19.2. Operator Response Plots

General Comments

A good MSA is absolutely necessary to Phase 4 and 5 activities as the product and process are developed and produced. The quality of the evaluation and improvement process is defined by the quality of the measuring equipment. For confirming the integrity of product features measured as part of a control plan requirement or by management directive, the MSA is crucial for validating the measurement system used. All product development and processing measurement equipment must have a well-documented MSA performed.

References

AIAG. *Measurement Systems Analysis (MSA) Reference Manual*, 3rd Edition.March 2002.