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Introduction to Measurement System Analysis

Key Learning Points

1. Describe the importance of identifying measurement system error and how it affects operations.
2. Explain how to analyze measurement systems to determine their adequacy and capability for a given application.
3. Utilize Measurement System Analysis in an improvement project.

What is Measurement System Analysis?

It is important to demonstrate that a measurement system is stable and capable of measuring data with accuracy and precision. Data collected in any process will exhibit variability caused not just by process effects but also by variation in the measurement itself. Measurement System Analysis (MSA) is a methodology to quantify variation caused by the measurement process. Minimizing measurement variation is necessary for identifying and reducing process variation.

Identification

MSA identifies that portion of the variance in the observations which does NOT originate from the process output (product, parts) measured, but from the measurement system employed. Typically, the questions to be answered are: How large is the measurement variation (error) relative to (1) total observed process variation and (2) the specified product tolerance (what portion of the tolerance is "used up" by the measurement system variation)?

Implication

The term "system" implies that carrying out measurements is itself a process, which includes the measuring instrument (gauge), the observers (operators), as well as all procedures necessary for measuring. Also included in MSA are the provisions for checking the calibration, maintenance, and storage of measurement instruments. The worse the measurement system is, the higher its portion of the variation, which then distorts more actual variation in the process output (parts). In other words, a bad measurement system makes a process look worse. The mathematical formula for total observed variation: σ2Total = σ2 Product + σ2 Measurement.

Measurement System Capability

Measurement error is a statistical measure that quantifies the net effect of all sources of measurement variability that cause an observed value to deviate from the true value.

Why Study Measurement System Capability?

- To quantify the amount of observed process variation due to an error in the measurement system.
- To insure that acceptance policies can separate good quality work from unacceptable work. This includes areas in service, front offices, or hospitals where there is a quality audit of finished work.
- To evaluate new measurement devices before releasing them to operations.
- To compare different types of measurement devices.
- To evaluate a gage suspected of being deficient.
- To evaluate the impact of repairs.
- To assure measurement error will not lead to a false product acceptance and/or Statistical Process Control result.

MSA Definitions

- Accuracy: The overall agreement of the measured value with the true value (which may be an "expert" value). Bias plus precision.
- Attribute Data: Discrete qualitative data.
- Attribute Measurement System: Compare parts to a specific set of criteria and accepts the item if the criteria are satisfied.
- Bias: A systematic difference from the true value. Revealed in the differences in averages from the true value.
- Precision: Variation in the measurement process.
- R&R: Repeatability and Reproducibility.
- Repeatability: The variation observed when the same operator measures

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the same item repeatedly with the same device.

- Reproducibility: The variation observed when different operators measure the same parts using the same device, sometimes it can be the same operator using different devices.

Two Types of MSA Studies

There are two types of MSA studies based on the type of data being analyzed.

Attribute MSA Study

- Discrete qualitative data
- Go/no-go basis; or limited data categories
- Compares parts to specific criteria for accept/not accept or to be placed in category
- Must screen for effectiveness to discern good parts from bad
- At least two appraisers and two trials each
- If available, have Quality Master rate parts first

Continuous MSA Study

- To quantify the amount of observed process variation due to error in the measurement system
- To evaluate new measurement devices before releasing them to operations
- To compare different types of measurement devices
- To evaluate a gage suspected of being deficient
- To evaluate impact of repairs
- To assure measurement error will not lead to a false product acceptance and/or SPC results

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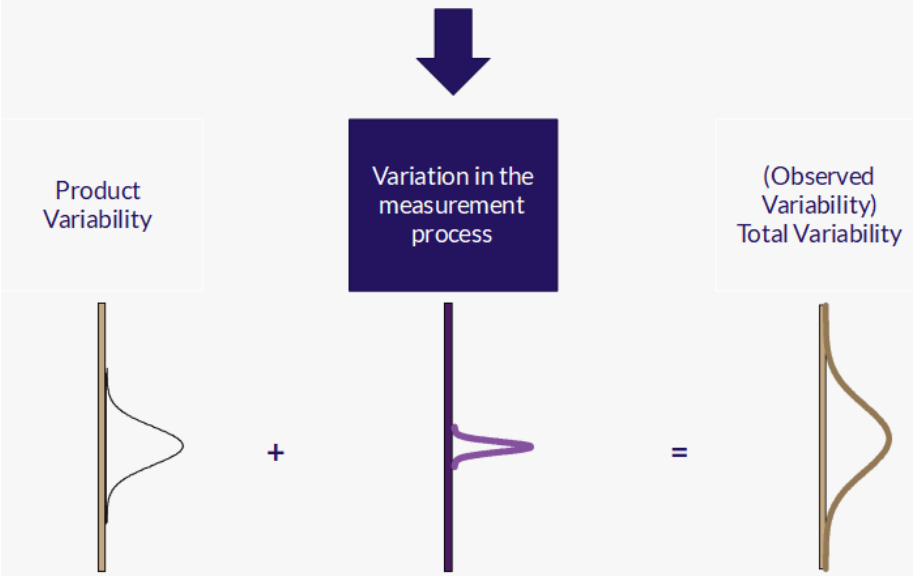
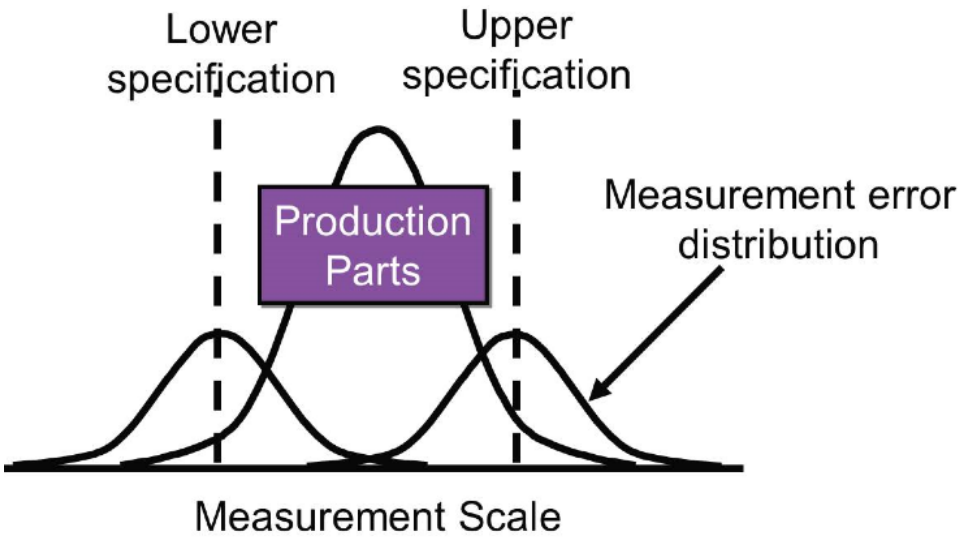
The Fundamental MSA Question

"Is the variation (spread) of the measurement system too large to study the current level of process variation?"



Interpretation of Measurement



Possible Sources of Variation

Observed process variation is not only the actual process variation. To reduce process variability, the variation due to the measurement system must first be identified and separated from that of the process.

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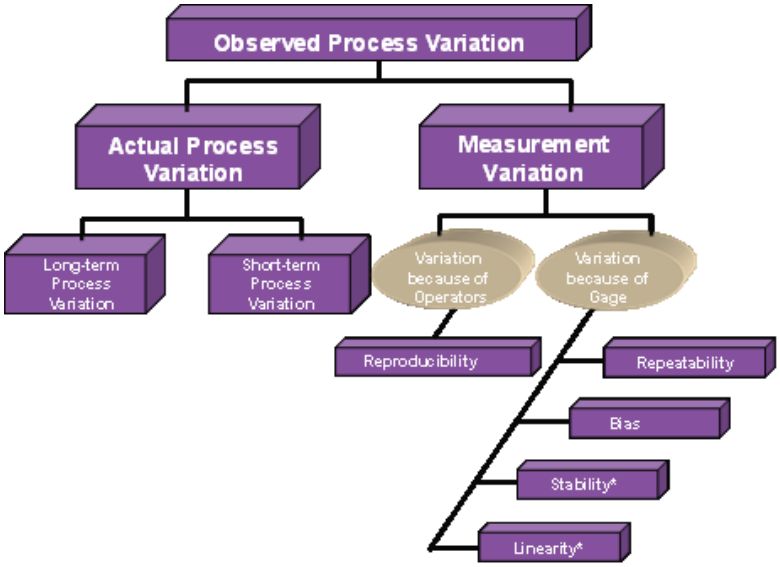


Analyzing a Measurement System

When looking at a measurement system there are three main aspects that need to be closely scrutinized.

The first aspect is location error for which there are three parts:

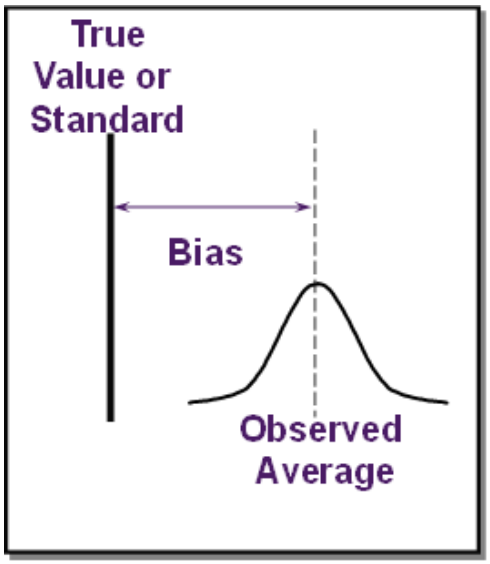
- Bias
- Linearity
- Stability

The second aspect is the width or spread of the measurements derived from a measurement system. The two components of width or spread are:

- Repeatability
- Reproducibility

The third aspect is measurement system discrimination, the ability of the measurement device to measure to a sufficient number of decimal places in order to accurately evaluate the required dimension.

Bias



Bias is the difference between the observed average of measurements and the true average. Validating accuracy is the process of quantifying the amount of bias in the measurement process. Experience has shown that bias and linearity are typically not major sources of measurement error for continuous data, but they can be.
In service and transaction applications, evaluating bias most often involves testing the judgment of people carrying out the measurements.

Possible Causes of Bias

- Sensor not properly calibrated
- Improper use of sensor
- Unclear procedures
- Human limitations

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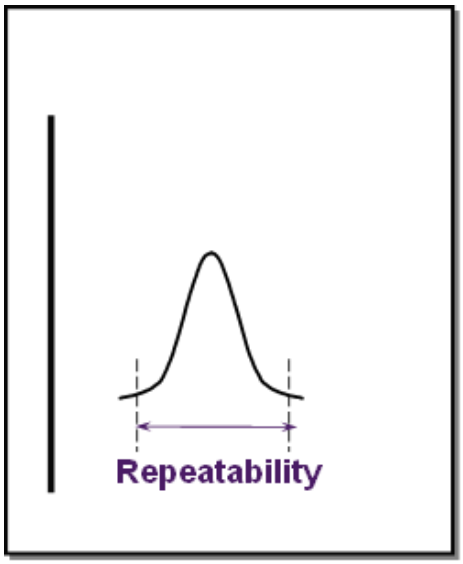
Repeatability



Gage repeatability is the variation in measurements obtained when one operator uses the same gage or measurement process for measuring the identical characteristics of the same parts or items.

Repeatability is determined by taking one person, or one measurement device, and measuring the same units or items repeatedly. Differences between the repeated measurements represent the ability of the person or measurement device to be consistent.

Possible Causes of Poor Repeatability

Equipment

- Gage instrument needs maintenance
- The gage needs to be more rigid

People

- Environmental conditions (lighting, noise)
- Physical conditions (eyesight)

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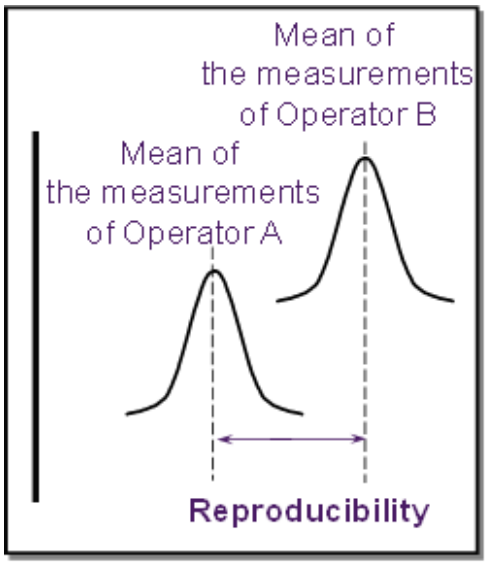
Reproducibility



Reproducibility is very similar to repeatability. The only difference is that instead of looking at the consistency of one person, you are looking at the consistency between people.

Reproducibility is the variation in the average of measurements made by different operators using the same gage or measurement process when measuring identical characteristics of the same parts or items.

Possible Causes of Poor Reproducibility

- Measurement procedure is not clear
- Operator is not properly trained in using and reading gage
- Operational definitions have not been established

How to Complete an MSA Study

1. Complete the MSA planning worksheet.
2. Select the appropriate analysis tool.
3. Collect the data.
4. Input the data and run the calculations.
5. Analyze the data.
6. Fix the measurement system (if necessary).

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MSA Planning Worksheet

Use this worksheet in your project to guide you in setting up your MSA.

1. Select the questions about potential source(s) of measurement variation that you need to have answered.
   _____ Is my measurement system repeatable, i.e., will you get the same results if you make the measurement more than once?
   _____ Is my measurement system reproducible, i.e., will someone else be able to complete the same measurement and get the same results?
   _____ Is my measurement system free from bias, i.e., will the average results from the study match the actual value or expert averages?

2. Planning Checklist.
   _____ Calibration needed?
   _____ How many operators?
   _____ How many samples (parts or items)?
   _____ Sample selection plan in place?
   _____ How many trials per operator?

3. Develop data-collection worksheet.

When Should MSA Be Used?

Measurement system analysis is necessary for any process measuring product quality. This is especially true for measuring processes with low process capability.

Discrete MSA should be used whenever judgment is required to discriminate good quality, especially when there can be differing opinions on acceptable conditions.

MSA is the perfect tool for evaluating gages, operators for accuracy and precision.

Pitfalls to Avoid

- Parts selected for MSA testing should reflect the entire range of production.
- Testing must be done in a blind and randomized fashion
- Evaluate your results with your requirements in mind

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