Language and Terminology

Measurement system studies can go by many different names, depending on the industry and the application. Some of the most common names are listed here. Measurement system analysis (MSA), measurement capability analysis, gauge study, repeatability and reproducibility (Gage R&R) study, round robin study, and interlaboratory uniformity (ILU) study. In this lesson, we generally use the generic term measurement system study, or the term measurement system analysis, or MSA. For simplicity, we use the term gauge to refer to the measurement instrument or system, even though many measurement systems are quite complex. Note that the word "gauge" is sometimes spelled "gage". We also use the generic term part to refer to the individual units that are measured. There are five characteristics of a measurement system that can be studied in an MSA: repeatability, reproducibility, stability, bias, and linearity. Repeatability is the variability in repeated measurements of the given characteristic with the same operator, same gauge, same location, and same part.

For example, let's say you pick one part, and measure it multiple times with the same gauge. The standard deviation (or the variance) of these measurements is a measure of the repeatability variation. Reproducibility is the variability introduced by different operators using the same gauge to measure a given characteristic on the same part. Reproducibility variation can also include different gauges, different test sites, or different labs.

Repeatability and reproducibility together describe the precision of the measurement system relative to the specification limits. Most MSAs study repeatability and reproducibility variation, and that is the focus of this lesson. But bias, linearity, and stability are important characteristics that should also be studied.

Stability is the consistency of the measurement system over time.

For example, if you measure the same part or parts over time, a stable measurement system will not show special causes, like shifts or trends. The average and standard deviation of the measurement does not change over time. Bias is the difference between the measurement and the true (or reference) value. For example, if you weigh materials on a scale, and the measured weight is always 10 grams heavier than the true weight, the bias is 10 grams.

In order to measure bias, you must know the true value of the item being measured, ideally from a traceable standard. You see an example of a bias study later in this lesson. Linearity is the absence of bias across the operating range of the measurement system.

For example, let's say the operating range of a scale is 10 grams to 1000 grams. If the measurement system is linear, the difference between the measured weight and the true weight is constant across this operating range.

In a nonlinear measurement system, the bias changes as the measured value increases. The ideal measurement system is stable, is accurate, or unbiased, and is precise, or, has little variability relative to the spec limits. One way to think about the accuracy and precision of a measurement system is to use the analogy of a target for archery or darts.

If the points are tightly clustered around the target, the system is both accurate and precise.

If the points are not on target but they are tightly clustered, the system is biased but precise.

If the points are generally on target but are not tightly clustered, the system is accurate, but not precise.

And if the points are off target on average and are not tightly clustered, the system is both biased and not precise. The first scenario is the best. With an accurate and precise measurement system, the measured values are close to the true values. The worst scenario is a measurement system that is both biased and not precise. In this case, there is a lot of variability in the measured values from the measurement system, and the average measurements are far from the true values. The objective of a measurement system analysis is to understand and quantify the sources of measurement variation, in order to guide your improvement efforts.

In the next video, we see how to design a simple MSA to study repeatability and reproducibility variation.

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