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How to perform a gauge (instrument) repeatability and reproducibility study (measurement/range type)

Scope

A summary of a procedure to identify types of measurement error and to determine the total measurement error of a system which then allows the confident use of statistical process control in the corrugated box industry.

Safety precautions

Safety precautions do not apply.

Content

The authors wrote this Technical Information Paper (TIP) on the technique to perform a gauge repeatability and reproducibility study. Statistical process control (SPC) is one technique to improve product quality in the corrugated box industry. The collection of statistical data can determine variations within a manufacturing process. Using this data, one can make control decisions. The underlying assumption, however, is that there is confidence in the measurement system used to gather that data.

As with any process, the measurement system has variation requiring definition. Various techniques to evaluate measurement systems help determine the degree of confidence in data gathered for SPC use. Some corrugated industry customers, particularly those aligned with ISO 9000 or other formal Quality Management Systems, require knowledge of measurement error. This TIP provides a procedure to identify types of measurement error and to determine the total measurement error of the system.

Gauge repeatability (gauge variation) and gauge reproducibility fundamentally differ from TAPPI repeatability and reproducibility as discussed in TAPPI T 1200 (as Standard Practice) and published as a part of TAPPI's Test Methods. TAPPI T 1200 deals with the expected variation in overall results when successive testing is done within a laboratory with the same material, operator, apparatus, and environmental conditions and when testing is done at two different laboratories on the same material but where the operator, apparatus and perhaps environmental conditions could be different. TIP 0304-71 deals with individual observations and identifies the portion of variation that is attributable to measurement devices. Other differences between TIP 0304-71 and T 1200 include the following:

- The procedure in TIP 0304-71 cannot be applied to destructive tests (assuming the lack of homogenous samples)
- Gauge R & R (TIP 0304-71) refers to different operators, not different laboratories (as does T 1200).
- It is possible that gauge repeatability may be larger than gauge reproducibility as a result of a gauge R & R study. This reversal of normal variation magnitudes would be highly unlikely in an "overall results" study per T 1200.

Terminology

Following are the definitions of terms used in this TIP:

1. Gauge: Any instrument or other device used to obtain measurements
2. Measurement system: The collection of operators, procedures, environment, gauges, and other equipment used to assign a number to a characteristic under measurement
3. Accuracy: The difference between the average of the number of measurements and the accepted reference
4. Repeatability: The variation in measurements obtained with one gauge used several times by one operator while measuring the same sample
5. Reproducibility: The variation in the average of the measurements made by different operators using the same gauge when measuring the same sample
6. Gauge R & R: The combination of gauge repeatability and reproducibility expressed as the summation of gauge and operator variability to determine total measurement system variation also known as Total Measurement Error (TME)
7. TPV: The Total Product Variation (TPV) range that is acceptable. $TPV = [\text{upper product specification limit} - \text{lower product specification limit}]$
8. % TME: The percentage of the TPV associated with TME for the measurement system used

Procedure

The assessment of a measurement system involves examining the variation of the measurement system and determining the factors that influence the variation. A prerequisite is having a well-defined measurement process and operating procedure. Flow charting can do this as can a cause and effect diagram to identify critical variables that can cause variation. One can determine gauge R & R by performing the following steps:

1. Select a measurement system that is essential to determining quality.
2. Calibrate the measurement device.
3. Develop a written operating procedure for the measurement system, if not already available.
4. Train the operator(s) to perform the measurement test, if necessary.
5. Select five samples for testing.
6. Select two trained operators.
7. Have the first operator measure the five samples in random order.
8. Have the second operator measure the five samples in the same order as the first operator without seeing the results of the first operator.
9. Repeat step 7 using a different random order of the samples.
10. Repeat step 8.
11. Complete a form such as the example in Table 2 showing the measured values.
12. Calculate the R & R by using the summary data and a calculation form.

Gauge R & R calculation

Statistical analysis provides an effective, easy to use method for performing the gauge R & R calculation. Statistical analysis can quantify the gauge, operator, and total measurement system error.

Repeatability of the measurement system defines gauge variability. Sources of repeatability error include, but are not limited to, variation due to the gauge itself and the actual location on or within the sample where the measurement is made. Standard deviation for repeatability provides an estimate for gauge variation: