Mitutoyo America Corporation

Q&A with Dr. Salsbury

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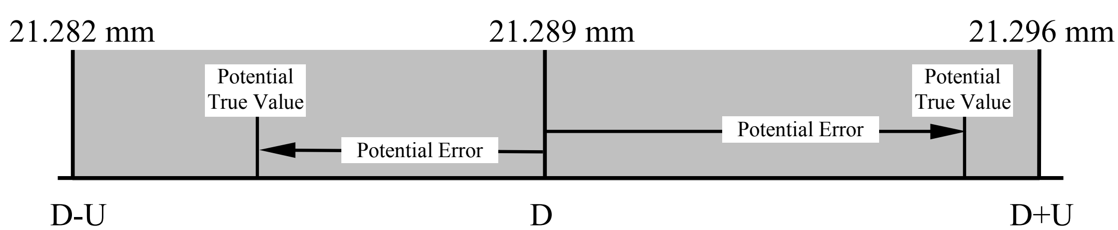
On Measurement Uncertainty

The concept of measurement uncertainty is continuing to create confusion in the dimensional metrology community. As a supplier of measuring instruments and tools, Mitutoyo America receives many questions from customers about measurement uncertainty. I hope the answers to the questions below, along with the included example, will help reduce some confusion. -JGS

What is measurement uncertainty?
Measurement uncertainty is the estimation of potential errors in a measurement process. When determining uncertainty, you must consider all factors that impact the variation in your measurement results. Error in the measuring instrument, tool, or gage is just one source of uncertainty. Another contributor is the environment, particularly temperature for dimensional measurements. Other common factors to consider are calibration limits, operators, repeatability, and the geometry and condition of the measured workpiece.

How is uncertainty expressed?
Say you use an external micrometer to measure the diameter of a shaft and your measurement result is D=21.289 mm. If you had determined the uncertainty was U=0.007 mm, then you would say the measurement result is 21.289 ± 0.007 mm. Uncertainty is normally expressed as a 95% confidence interval, which corresponds to about plus or minus two standard deviations ($\pm 2\sigma$). Therefore, since uncertainty is the estimation of potential error, what you are really saying is that you believe the true value, i.e. the correct value, has a 95% chance of being somewhere between 21.282 and 21.296 mm. Graphically it would look like this:



Can Mitutoyo tell me my measurement uncertainty for all my Mitutoyo products?
We really wish we could just tell you your uncertainty when using our measuring instruments and tools, but unfortunately uncertainty is not that simple. The only meaningful uncertainty is the uncertainty of the entire measuring process, not just the instrument. Since uncertainty varies with factors such as environment, operator, calibration, and workpiece, your uncertainty will likely differ from someone else using the same instrument but for a different measurement. As the instrument supplier, our job is to make sure you know the instrument specifications and the best methods of operation. We can also help you understand significant sources of uncertainty.

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How do I calculate measurement uncertainty?
This question is best answered in a training class. However, we thought an example would be useful to see typical sources of uncertainty and how they add up. The table below represents an uncertainty estimate (or budget) for the measurement of a diameter using a 0-25 mm external micrometer. The values are for a specific measurement process and should <u>not</u> be generally applied to other measurements. This table is based on an example found in the international standard, *ISO/TS 14253-2:1999*. Note how the instrument, operator, environment, and measured workpiece all contribute significantly, and somewhat equally, to the total uncertainty. The uncertainty due to the micrometer is only a portion of the total measurement process uncertainty.

<table>
<tr><th colspan="2">Uncertainty Component</th><th>Uncertainty Value (μm) *</th><th>Contribution to Total (%)</th></tr>
<tr><td rowspan="4">Equipment:
The micrometer and its calibration</td><td>Error of indication</td><td>0.9</td><td rowspan="4">19.4</td></tr>
<tr><td>Anvil flatness</td><td>0.5</td></tr>
<tr><td>Spindle flatness</td><td>0.5</td></tr>
<tr><td>Spindle to anvil parallelism</td><td>1.0</td></tr>
<tr><td rowspan="2">Operator and usage of the micrometer</td><td>Repeatability</td><td>1.2</td><td rowspan="2">20.5</td></tr>
<tr><td>Zero point repeatability</td><td>1.0</td></tr>
<tr><td rowspan="2">Environment</td><td>Temperature difference between workpiece and micrometer</td><td>2.0</td><td rowspan="2">32.9</td></tr>
<tr><td>Temperature variation from standard 20°C</td><td>0.3</td></tr>
<tr><td>Workpiece</td><td>Workpiece form error</td><td>1.8</td><td>27.2</td></tr>
<tr><td colspan="4">Uncertainty, U = 6.9 μm
(this U is officially the expanded uncertainty, which is sometimes called total uncertainty)</td></tr>
</table>

* These values, called *standard uncertainties*, are estimated for this specific measurement example. Do not apply them generally. They must be determined on a case by case basis.

What is the difference between measurement uncertainty and gage R&R?
The concepts found in the *AIAG Measurement Systems Analysis* are familiar to many people, particular those in the automotive industry. Measurement uncertainty can be considered a single number that represents a combination of the concepts of gage R&R, bias, linearity, and stability.

Where can I get more information on uncertainty?
The ultimate authority in the U.S. is the standard *ANSI/NCSL Z540-2-1997 (the GUM)*, but it can be tough to read. NIST offers a free publication, *NIST Technical Note 1297*, which is a bit easier. The international standard, *ISO/TS 14253-2:1999* is a useful practical guide and includes some industrial examples. A number of companies offer training in uncertainty, including Mitutoyo America. We offer a one day educational course that is taught about twice a month at various locations around the country. A good training class is recommended for those new to uncertainty.

Dr. James G. Salsbury is the Corporate Metrologist for Mitutoyo America Corporation. He provides technical support for various metrology issues and is active in a number of national and international metrology standards organizations. He can be reached at 630-820-9666 (ext. 6570) or by email at Jim.Salsbury@mitutoyo.com.