Metrology Consulting, Inc.

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I am still amazed by the feedback I get from Metrology Insight. When I hand people my business card at conferences and they see the logo, I often get the response: “Oh yeah, you are the one with the newsletter.” I always like positive feedback, but I have also received some from people who disagree with me. I also like those, because they force me to re-evaluate what I have written and I learn from that, so thank you very much for *all* the feedback.

Metrology Insight is published by HN Metrology Consulting. The purpose of Metrology Insight is to heighten awareness of the details that go into making good metrology and, of course, HN Metrology Consulting as a source of information about these details.

There is only one article in this issue of Metrology Insight. It covers new terminology proposed in a new ISO technical specification, ISO/TS 17450-2.

I hope you find Metrology Insight useful and educational. If you have a suggestion for a topic or any other comment or suggestion, please do not hesitate to contact me.

\- Henrik Nielsen

HN Metrology Consulting will be offering an ISO Guide 25 compatible quality manual, see page 4

Expanding the concept of uncertainty.

In transactions involving measurement, it is often critical that the supplier and the customer agree on what is to be measured, how good the measurement has to be and what the result of the measurement means. If there is a disagreement over any of these issues, there is a potential conflict and a costly correlation issue may be the result.

What is to be measured?

This question is not as trivial as it seems, at least not in the dimensional metrology area. If, for example, we are asked to measure a diameter, is it then the minimum circumscribed diameter, the maximum inscribed diameter, or a two-point diameter? All of these will give different results, unless the part we are measuring is perfectly round. But if we know how round the part is and we know which diameter is called for, it is still quite acceptable to measure another diameter, if we account for the difference in our uncertainty budget and find it sufficiently small compared to the tolerance we are measuring.

How good must the measurement be?

The “goodness” of a measurement is quantified in the uncertainty of the measurement. It is important that we calculate the uncertainty back to what we were asked to measure, as described above.

What does the measuring result mean?

We use the measurement result to draw a conclusion. We may accept or reject a part or a batch of parts based on our measurement, or we may adjust our manufacturing process. To get the maximum benefit out of our measurement, we need to have a clear set of rules for how we decide what to do based on our measuring result. In Metrology Insight Vol. 2 No. 1 I discussed the decision rules in ISO 14523-1, which is one example of such a set of rules.

New ISO work on terminology

To provide a framework and a language, ISO TC 213 “Geometrical Product Specification and Verification” has started work on terminology that covers these concepts. The terminology covers function, specification and verification/measurement and expresses the differences between them in terms of uncertainty.

Function

The function of a part can be anything from a simple: Will the pin fit in the hole? To the more complex: Will the engine run for 100,000 miles before requiring a tune-up?

Some functions, such as the pin-in-hole scenario are very easy to express in terms of geometry, whereas others, such as the engine scenario are very complex and almost impossible to express purely in terms of geometry without having to be overly restrictive, i.e. reject a significant percentage of the parts that might have worked.

The difference between the functional requirements (what it takes to make the engine run for 100,000 miles) and what is in the specification can be viewed as an uncertainty.

We may not know or truly understand these functional requirements, just like we generally do not know the true value of what we are measuring, but we can still calculate an uncertainty relative to it, just as we calculate the uncertainty relative to a true value.

Specification

The specification is what is put down in a product documentation. It often is based on international or national standards or internal company standards. Sometimes these standards are clear and unambiguous, but sometimes the language of a standard is open to interpretation or gives equal value to choices that are not equivalent. In those cases there may be an ambiguity built into the specification. This ambiguity can also be interpreted as an uncertainty.

If you can reasonably interpret a specification in different ways and reach different results, then all of these results are correct per the definition in the specification and the span between them is the uncertainty built into the specification.

Verification/Measurement

The basis for our measurement may be something else than what the specification called for. An example is measuring a two-point diameter, when the minimum circumscribed diameter is called for. Another aspect of the measuring uncertainty arises from the imperfections in our measuring equipment and our measuring process. This is often the only aspect that is taken into account when calculating measurement uncertainty, but while it is the most tangible one, it may still end up being the smallest of them all.

Terminology

The ISO/TS 17450-2 draft provides a terminology for the uncertainty components quantifying the difference between the function and the measurement result. Figure 1 gives an overview of all the components and their relationship.

Method Uncertainty

The method uncertainty accounts for the difference between what the specification calls for and what is implemented in the measuring process, disregarding the physical imperfections of the measuring equipment and inaccuracies in the measuring process.

Even with perfect measuring equipment and strict adherence to the measuring procedure, it is impossible to reduce the measuring uncertainty below the method uncertainty. For example, measuring a two-point diameter when the specification calls for a minimum circumscribed diameter, results in method uncertainty if the part is not round.

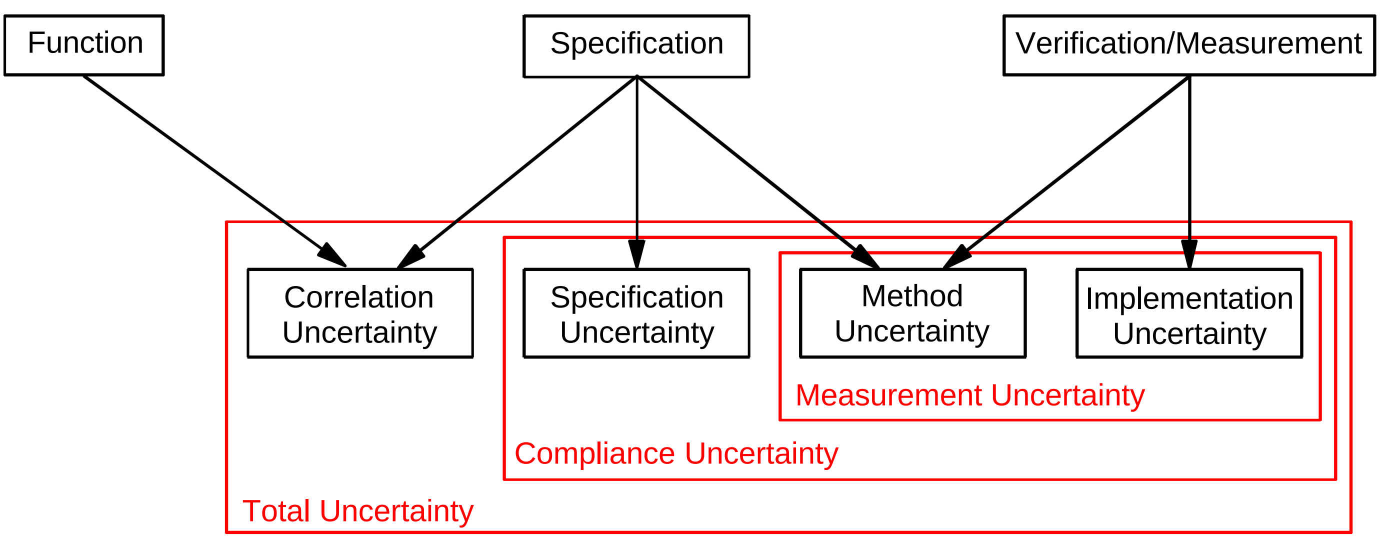

Figure 1: *Relationship between function, specification, verification/measurement and various uncertainties.*

Implementation Uncertainty

The implementation uncertainty covers the uncertainty arising from the physical imperfections of the measuring equipment and deviations from the measuring procedure. The purpose of calibration is to control the metrological characteristics of the measuring equipment in order to reduce, control or eliminate the implementation uncertainty. Other effects, such as environmental effects, that are not directly related to the measuring equipment may also contribute to the implementation uncertainty.

Examples of implementation uncertainty contributors are: scale error, zero-point error and linearity of the gage.

Measurement Uncertainty

The *Guide to the Expression of Uncertainty in Measurement* (GUM) defines measurement uncertainty as a "parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand ."

For the purposes of this discussion, measurement uncertainty can be considered as the sum (in the sense of the GUM) of the method and implementation uncertainty.

Specification Uncertainty

The specification uncertainty is the uncertainty inherent in a specification when it is applied to a real part. Most specifications are defined such that they are unambiguous, if the part has perfect form and no roughness. However, as the part imperfections increase, the specification may be less well defined. An example is "diameter". If a part is perfectly round, no qualifiers are needed to define the diameter, but if the part has form error, then various methods of measuring diameter will lead to different results.

For example, if the tolerance for a pin's diameter is 1 inch +/- 0.001 inch and the call-out does not specify what diameter, e.g. minimum circumscribed or two-point diameter is covered by the tolerance, then the difference between results obtained with all acceptable methods using perfect measuring equipment is specification uncertainty.

The magnitude of the specification uncertainty depends on the particular specification and the geometrical deviations of the actual part.

Compliance Uncertainty

The compliance uncertainty quantifies the uncertainty with which it can be determined that a workpiece complies with all possible interpretations of a specification. It is the sum (in the sense of the GUM) of the specification uncertainty, the method uncertainty and the implementation uncertainty.

The compliance uncertainty, rather than just the measuring uncertainty, is what has to be taken into account, when suppliers and customers try to solve a dispute over product compliance.

Correlation Uncertainty

The correlation uncertainty arises from a less than perfect correlation between a specification and the intended function of the workpiece, expressed in the terms and units of the specification. Correlation uncertainty is usually not related to a single specification item. Usually it takes a number of specification items to simulate a function (e.g. size, form and surface texture of the part).

The correlation uncertainty quantifies our ability to predict whether a part will work or fail, based on its compliance with a given specification.

In the case of the pin, this is fairly straightforward, but in the case of the engine, there are a lot of gray zones, where we do not know whether the engine will run for 100,000 miles before requiring a tune-up. To accommodate this uncertainty, we tighten the tolerances, so we reject all the engines we are not sure about, but which *might* run for 100,000 miles. A lower correlation uncertainty would obviously allow us to reject fewer potentially good engines.

Total Uncertainty

The total uncertainty is the sum (in the sense of the GUM) of the correlation uncertainty, the specification uncertainty, the method uncertainty and the implementation uncertainty.

The total uncertainty quantifies our ability to predict whether a part will work or fail, based on the result of a measurement of the specified characteristic(s).

The next steps

Standing alone, this terminology will not solve any problems. But the awareness that it raises and the implementation of these concepts in future standards from ISO TC 213, may give us a better understanding of what uncertainty contributors we need to take into account when we try to solve disputes and discrepancies between measurement results and functional performance of parts and products.

Coming soon from HN Metrology Consulting: An ISO Guide 25 compatible model quality manual.

For most laboratories considering accreditation, there are two major issues to work through. One is to develop uncertainty budgets for all the tests and calibrations the laboratory plans to offer, the other is to develop the necessary quality documentation to live up to the requirements of ISO Guide 25.

In their search for help with these issues many laboratories turn to the ISO/QS 9000 community. However, the requirements of Guide 25 are significantly different from the ISO/QS 9000 requirements and the level of documentation needed is surprising even to seasoned ISO/QS 9000 experts. The result is often an adapted ISO/QS 9000 quality system that does not really fit the requirements, is difficult to work with and leaves the laboratory vulnerable at assessments.

Having gained an understanding of the magnitude of these challenges through my work as an accreditation assessor, I am developing an ISO Guide 25 compatible model quality manual with all the related operating procedures.

Contact HN Metrology Consulting for more information on this project and how the model quality manual can be adapted to cover your specific needs.

Training from HN Metrology Consulting:

HN Metrology Consulting offers in-house training seminars on metrology, measurement uncertainty and quality assurance for calibration laboratories.

The following 2 day seminars are available at short notice and can be tailored to your specific needs:

- Managing Measurement Uncertainty
- Quality Assurance to ISO Guide 25

Contact HN Metrology Consulting for more information on these seminars and to request the brochure.

Training offered through MTI/Mitutoyo:

These are very intense 1 day seminars. They cover a lot of material in a very short time.

Advanced Metrology:
Surface Roughness and Roundness
September 30 in Cincinnati, OH
October 21 in Springfield, MA
October 26 in Indianapolis, IN

Estimating Measuring Uncertainty
October 1 in Cincinnati, OH
October 22 in Springfield, MA
October 27 in Indianapolis, IN

These seminars are offered nationwide. New seminars are scheduled every month. Call MTI/Mitutoyo Education at (630) 978 6469 for more information, to sign up for a seminar or to check availability in your area.

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