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Thank you for the overwhelming response to the first edition of Metrology Insight. I received quite a lot of very positive E-mail. I appreciate it very much.

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.

In this issue the first article discusses a new standard, ISO 14253-1, which deals with how uncertainty is to be taken into account when we are proving conformance or non-conformance of parts to a specification. I am sure this standard will have a profound impact on how business is conducted and cause great debate.

The other article looks at some of the steps involved in the proper calibration of a roundness instrument.

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.

S Henrik Nielsen

See the Winter/Spring Uncertainty Training Schedule on Page 4

ISO 14253-1: Decision rules for proving conformance or non-conformance with specifications

Actually, that is only part of the title of this new standard. The full title is: *Geometrical Product Specifications (GPS) - Inspection by measurement of workpieces and measuring equipment - Part 1: Decision rules for proving conformance or non-conformance with specifications.*

We all know the legal phrase "prove beyond a reasonable doubt." What ISO 14253-1 does is to lay down a framework for how this principle can be introduced in commercial transactions where workpieces or measuring equipment are evaluated against a specification.

In a drawing specification, it is usually clear what the limits of the tolerance are. It may be a maximum acceptable Ra value for the surface finish or a +/- tolerance on a diameter.

However, when we measure a workpiece to confirm that it is in (or out of) tolerance, our measurement has some level of uncertainty and things are not so clear cut, see figure 1.

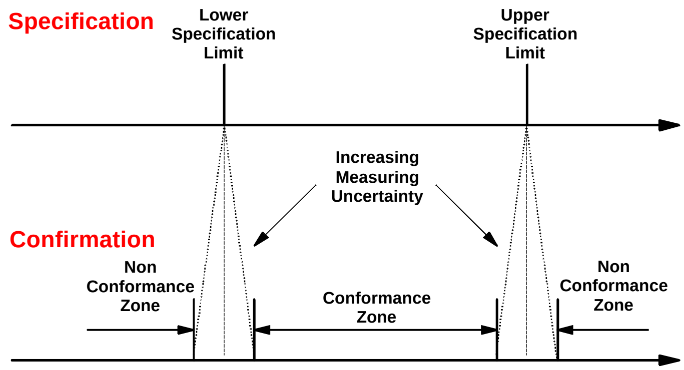

Figure 1: *The specification (top) has two clear limits. Uncertainty makes the question of conformance (bottom) more complex.*

If we have a workpiece that is exactly on the limit of the tolerance and we measured it several times, we would find it to be within the tolerance 50% of the time and out of tolerance the other 50% of the time.

If the true value of the workpiece moves inside the tolerance, the probability of measuring it to be outside the tolerance gets smaller and if the true value of the workpiece moves outside the tolerance, the probability of finding it to be inside the tolerance gets smaller.

But as long as we are no further away from the tolerance limit than our measuring uncertainty, there is a chance that we may misclassify the workpiece. In a commercial transaction this is primarily a problem if the manufacturer of a workpiece measures it to be inside the tolerance and the user of the workpiece subsequently measures it to be outside the tolerance.

The purpose of ISO 14253-1 is to avoid these costly disputes all together. Therefore the standard defines 3 types of zones, see figure 2.

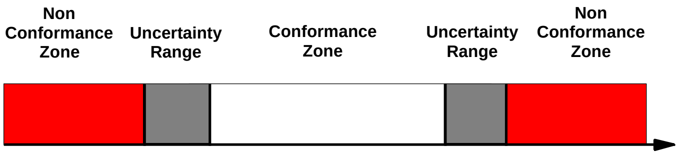

Figure 2: The Conformance Zone (white) is the tolerance reduced by the measurement uncertainty at each end. The Non Conformance Zones (red) are the areas outside the tolerance by more than the measurement uncertainty. The Uncertainty Ranges (gray) are the areas where conformance or non-conformance cannot be determined.

ISO 14253-1 states that in order to prove that a workpiece or measuring equipment is conforming to a tolerance, the manufacturer has to measure it to be within that tolerance by more than *his* measuring uncertainty.

On the other hand for the user to prove that a workpiece or measuring equipment is not conforming to a tolerance, he has to measure it to be outside that tolerance by more than *his* measuring uncertainty.

The standard provides several advantages when applied correctly. First it provides the logic behind the need to understand the measuring uncertainty when determining conformance or non-conformance. This can be a great help when working with a counterpart who has difficulty understanding this need.

The second advantage is that tolerances can be expanded when the standard is used. In order to gain this advantage, it is important to stipulate in contracts referring to the standard, that the manufacturer has to prove conformance of all workpieces shipped.

The tolerances can be expanded in most industries since there is normally an allowance for a certain amount of uncertainty built into the tolerances and specifications. Especially in older designs, this allowance may be larger than what is required with newer measuring equipment. Applying ISO 14253-1 will allow the new zone of conformance to be larger than the original tolerance. This means we can save money by expanding the tolerances while still producing functioning parts.

The third advantage is that ISO 14253-1 reduces workpiece conformance disputes dramatically, when applied correctly.

These disputes are very costly, because they may cause a production line to shut down from part shortage; they may cause significant amounts to be spent on airfreight to keep production lines going; they may cause significant cost for re-measurement, maybe even by third parties, and they may require significant meeting time for a large team of engineers and executives to resolve.

With the promise of cost savings from relaxed tolerances and fewer workpiece conformance disputes, the rigorous, correct application of ISO 14253-1 is a great opportunity for all branches of industry.

HN Metrology Consulting offers the seminar *Managing Measurement Uncertainty*, see page 4, where the participants learn how to estimate measurement uncertainty, according to ISO/TR 14253-2 "*Guide to the estimation of uncertainty in GPS measurement, in calibration of measuring equipment and in product verification*", which is a simplification of the ISO Guide to the Expression of Uncertainty in Measurement (GUM), and a complement to ISO 14523-1.

Calibration of Roundness Instruments

What does it really take to be sure that you get good data from your roundness instrument? First of all you have to understand all the transformations of the signal from when the surface is traced until the final result is displayed or printed. Once you understand these transformations, you can calibrate the instrument along the path of the signal. This will ensure that the input signal at each step is good. With this information you can properly evaluate, if the transformation at this particular step is correct.

The Spindle

The spindle is the reference element of the roundness instrument. We start the calibration by ensuring that the spindle works properly and has a sufficiently small error.

We check the spindle error with a glass sphere or hemisphere. The reason for using a spherical element is that you can cut it with a plane in any direction and the intersection will always be a circle. If we used a precision cylinder instead, we would have to align it very accurately to avoid it appearing to be elliptical.

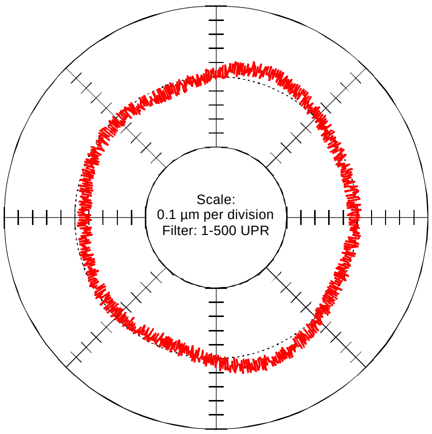

Figure 3*: Trace of glass hemisphere used to check the scale error. The 1-500 UPR filter setting used here generally gives the highest noise level, represented by the “width” of the trace.*

The spindle check tells us the lowest roundness value we can measure. The result we see is made up of the error of the spindle itself, the vibration of the instrument and the noise in the instrument. We normally test the spindle at all the filter settings we intend to use. We should expect to see higher values when we increase the undulations per revolution (UPR) setting of the filter.

The Probe

The probe is the element that contacts the surface and converts the undulations in the surface into an electrical signal. There are several attributes of the probe that we must check. First we have to make sure that we use the right probe tip radius. As discussed in Metrology Insight Vol. 1 No. 1, a difference in tip radius will result in a difference in measured value. The correct tip radius depends on the diameter of the feature we are measuring and the UPR range we are looking at. Generally we can calibrate our roundness instrument with the smallest tip radius we intend to use and assume that it will work just as well with larger tip radii for larger feature diameters.

The second probe issue is the static magnification. On simpler instruments, the static magnification is normally adjusted using three gage blocks wrung onto an optical flat.

The Filter and Dynamic Response

Once the static magnification is known, it is possible to look into the dynamic response of the instrument. Unfortunately, it is difficult to separate the dynamic response from the filter function of the instrument, but it is still possible to get a good idea how well the instrument responds.

For this test we need an artifact that has been calibrated at several different UPR filter settings. A good artifact for this test is a so-called Flick standard. It has a cylindrical surface with a small flat ground into it. Figure 4 shows a trace of a Flick standard. The depth of the flat below the cylindrical surface is the calibrated value of the standard. This value will vary with different filter settings.

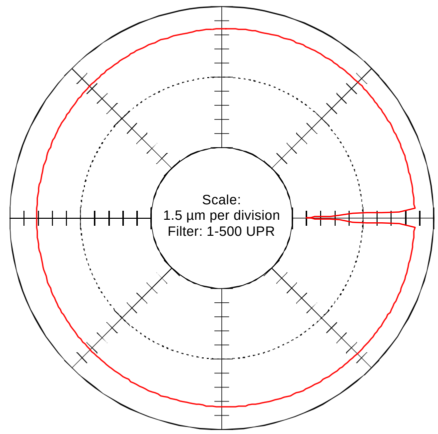

Figure 4*: Trace of a Flick standard. Using the 1-500 UPR setting gives the least distorted trace of the standard.*

Figure 5 shows two typical deviation patterns. The black curve is from an instrument with an inadequate dynamic response. Such an instrument will tend to read too low for high filter settings. Of course, if the instrument has been adjusted using a Flick standard and a high filter setting the whole curve will be shifted up.

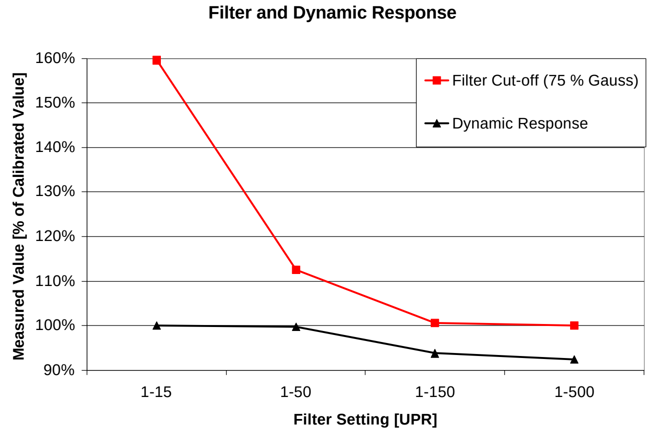

Figure 5: *Typical deviation patterns for a non-standard filter and a limited dynamic response.*

The red curve shows typical deviations for an instrument that uses a Gauss filter with 75% transmission at the cutoff point versus the 50% Gauss filter called out in emerging ISO and ANSI/ASME roundness standards. Knowing these typical patterns can help troubleshoot the deviations in a roundness instrument and identify the settings where the instrument deviations are within acceptable limits.

Some Final Thoughts...

While this article is not intended to be a comprehensive guide to the calibration of roundness instruments, I hope it has given some food for thought.

I strongly recommend the practice of establishing a baseline for your instrument's performance. Then design a short test that you can run on a weekly basis to ensure that the performance does not change. This way, you will know very quickly if anything has changed.

For example, a new production machine may have been installed next door, creating an increased vibration level. Or that new welding station may send spikes through the power supply that shows up in your traces.

Whatever you find, it is always better to be able to detect deviations up front, than it is to be surprised by them.

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