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Uncertainty of measuring the simple Pitch Diameter of a Thread Gauge - MAC Comments 2008
This is a perennial issue. Attached is the section of the thread standard that names "Pitch Diameter" and "Simple Pitch Diameter". Also is the uncertainty budget from the EA that uses the same vocabulary. "Simple Pitch Diameter" is in wide use, and is generally the calibration performed. I don't personally think much of the idea, but it is in the standards system and we are stuck with it.
FYI gentlemen, ladies. The current guide replacing EA-10/10 is CG-10/v.01. It is attached for everyone's reference.
I have read this information. Following are my opinions: 1. Half angle uncertainty should NOT be considered in the uncertainty budget for the standard pitch diameter measurement. a. The method of measuring pitch diameter is the "measurement over wires". This is placing two calibrated wires of a given wire size on one side of a threaded items (usually a plug gage of some type) and one wire on the opposing side. A "constant" is associated with these wires. A measurement is made over these wires using a specific pressure. The constant is subtracted from the resultant measurement to yield the pitch diameter size. b. I believe the relevant uncertainties are the temperature, measurement wire diameters, parallelism of the measurement anvils, pressure, read-out, and the gage blocks if they are used to set the measurement equipment.

I am not aware of the uncertainty of half angle as a component in the uncertainty of budget the pitch diameter measurement ever being included in the past. I would like to point out that Ralph Veale did the first A2LA accreditation assessment on my thread calibration laboratory and he did not suggest we include the uncertainty of half angle in out uncertainty budget for the pitch diameter measurement process.

2. If you recall when I was on the Board of A2LA I encouraged A2LA to provide a guide for what the components of uncertainty budgets for all standard measurement processes. That was rejected then, but this is exactly the types of disputes between accredited laboratories and assessors. The measurement of pitch diameter is done by the same process all over the world. I see no reason why A2LA should not take industry input and agree on what the components for the uncertainty budget for this and all other measurement processes should be.

3. This kind of issue over consistency in the calibration of thread gages is why I asked you and your staff earlier this year to consider using the IFI-301 Thread Gage Calibration Requirements and Procedures as a guide for A2LA in determining if thread gage calibration laboratories are using recognized and proper techniques. This document does not address uncertainty budgets, but it does cover the measurement procedures.

I am sending a copy of this to Al Barrows, ASME B1 Chairman, to ask him to also send you his opinions regarding this issue.

I agree with Joe and offer theses additional comments.

Per ASME B1.7-2006- screw thread: nomenclature, definitions, and letter symbols

- simple pitch diameter: (ISO term) see pitch diameter, thread groove diameter

-pitch diameter is just that, the definition is for only the diameter and has no reference to it including the effects of any other thread elements.B10

Thread Groove Diameter: When calibrating a gage we are measuring and reporting individual thread elements i.e.; pitch diameter, lead and flank angels, and not computing and reporting the functional pitch diameter.

I reviewed the ASME B1 report on measurement uncertainty and I see the uncertainty values for pitch diameter, lead and angel listed separately. I could not find anything that says that pitch diameter includes values for lead and flank angle or anything about functional size.

Jeff did a thorough research/analysis of the issue in question and I agree with his conclusions. I have attached a copy of my response to Pam – I didn't copy all MAC members because after waiting about a month, I too had not seen any other responses and did not want to be the sole respondent in a broad distribution (as others may have also felt). I support the stand taken by the assessor. Although it is difficult (without knowing all the circumstances) to say with confidence whether the Tri-State budget is or is not appropriate, I can certainly relate to the issue of underrated uncertainties for pitch diameter measurements using the three-wire method.

A few years before I retired from McDonnell Douglas/Boeing my calibration lab participated in a pitch diameter round-robin with several other top laboratories (mostly aerospace) in the industry, including a couple of gage makers, a U.S. Navy Standards lab and NIST. It was remarkable what a spread in results there was in spite of our effort to all measure at the same location on each gage. All participants were experienced in thread gage calibration and reported uncertainties of 0.00005 in. or less, but as I recall, the range of measurements exceeded 0.00015 in.

The labs that I have assessed for pitch diameter have often shown best uncertainties that I thought were underestimated, but they claimed that it represented their capability for the measurement under nearly ideal conditions (i.e., when a gage has no significant deviation in flank angle, lead error and variation in gage uniformity is not taken into account). This might be acceptable but I did require them to demonstrate that they could assign an uncertainty for actual reported results that took into account all influences which would include the affect of angle deviation if not measured and compensated for. (The significance of this influence depends mostly on how far from "best size" the measuring wires are.) As did the assessor, I would question any uncertainty less than 0.0001 in. for routine measurements on working gages. This is especially the case where the lab measures their own thread measuring wires with a relatively large uncertainty in their diameter – pitch diameter uncertainty on 60° threads has a sensitivity coefficient (factor) of 3 times the uncertainty of the measuring wire diameter.

I have not seen any other assessor responses to this letter, so I am responding to all in hope that this will stir up some conversation on the subject. I have looked quite a bit for information on this matter, with not much luck. I will share what I do know about this particular parameter, and I would like to see other assessors do the same, as we could all benefit from this knowledge.
As I understand it, the laboratory and the assessor are in disagreement about the uncertainty associated with measuring the simple Pitch Diameter of a thread plug (ref-Lab letter page 1). The lab also seems to not believe the veracity of A2LA guidance document G103 pages 18-20. Since neither the letter nor the assessor response gave much specific detail about the actual quantity of uncertainty, I took a moment to look up the lab's scope and it appears that the lab can measure pitch diameter up to 4 inches with a BMC of 81 microinches.

The laboratory believes the assessor to be in error by making them include the uncertainty of the error in the 1/2 flank angle of the gage, and goes on to state his case. Much of his argument includes "practice in the U.S.A" with no references other than ASME B1.2 itself.
I have to say that Appendix B of ASME B1.2 is somewhat vague. It speaks very generally about significance of measurements, but does not provide a great deal of information about quantative numbers. The first paragraph of section B4, does give some very specific guidance "In order to measure the pitch diameter of a screw thread gage to an accuracy of 0.0001 in." Since the lab is claming uncertainty less than this value, their use of section B7, the simplified formula for pitch diameter (as referred to in their letter) may not be valid. Section B6 provides the general formula for measurement of pitch diameter. In order to fully understand the uncertainty of this measurement, a close examination of all variables of this formula need to be addressed. The lab states that when they recalibrate thread gages, they perform a measurement over best size wires. The general formula also includes

I would like to introduce two new documents into the discussion. The first is the ASME Technical Report on Measurement Uncertainty for 60 deg Screw Thread Gage Element Measurement (Available for purchase through ASME). Most of the work of this document pre-dates the GUM, but it does well to attempt to address uncertainty for this measurement situation. Unfortunately, the document is very brief, but what it does provide is tables with estimates of measurement uncertainty. Their tables report that the estimate of pitch diameter uncertainty for external thread gages is 0.0001 inch from .19 to 1.5 inches, 0.00015 inches from 1.5 to 6 inches, and 0.0002 from 6 to 12 inches. It does state that the uncertainty includes values for lead and flank angle.

The next document to introduce is EA-10/10 EA Guidelines on the determination of Pitch Diameter of Parallel Thread Gages by Mechanical Probing (Free for download from EURAMET). It is a very good document, and it defines several terms, including Pitch Diameter, Simple Pitch diameter, and Virtual Pitch Diameter. Basically, Simple Pitch Diameter is the definition that we all know and use. Virtual Pitch Diameter is the pitch diameter of an imaginary thread with absolutely perfect pitch and angle, lead, taper, roundness etc.
In this document, it states that the uncertainty analysis of simple pitch diameter (as noted in the customer's letter) must consider the uncertainty of the thread angle, and while not measured, it is assumed to be within tolerance limits. The virtual pitch diameter does not need to consider this uncertainty as it is assumed to be perfect.

Example 7.4 of this document describes measurement of the pitch diameter of an external thread gage using three calibrated wires (the method used by the laboratory according to their letter). The example provides an uncertainty budget that is the most thorough one I have seen to date. In this budget, the dominate source of uncertainty is associated with P, the standard uncertainty associated with the Pitch measurement, which brings us back to our knowledge (or lack thereof) of Thread Angle.
Both of these documents agree with A2LA Guidance document G103 for this particular example.
Based upon information contained in these two documents, I believe the example in G103 to be valid and correct. I do have to add some editorial opinion here as well. From what I can gather in the acknowledgements of G103, most of this work was done by Ralph Veale, who worked at NIST for many years in the dimensional metrology section and has a great deal of knowledge on this subject. With all due respect to the laboratory who has generated this complaint, they are not a national level laboratory by any means.

I am asking for further input into this discussion by other MAC members more knowledgeable than myself on this matter, of which I am sure there are many. If there is concurrence with the validity of G103 and the other documents that I provided, I would strongly encourage A2LA to go back the laboratory and make them include the "Error Caused by Assuming the Half Angle and Pitch are Normal" from G103 page 19 into their uncertainty budgets and to revise their scope as necessary. I would also recommend that EA-10/10 be considered to be added as an additional guidance document for use by A2LA. Lastly, I would also encourage the MAC to adopt the position that laboratories can not provide a measurement of the Virtual Pitch diameter as it deals with perfect situations, and is not representative of the thread gages being measured for customers of A2LA accredited laboratories.

Here is my two cents: We are required to identify in the budget either as part of the calculation or in the notes the contributions to the uncertainty, significant or not. We include the flank angle uncertainties in our calculations and they are small in comparison to the largest uncertainty by almost an order of magnitude. If the thread were perfect, flank angle would not be an issue and could be neglected, but then so would major and pitch diameters.

I am in agreement with the assessor. A2LA shold be taking an approach that will be consistent across the average laboratory. Of couse, high level organizations could deviate from that perspective.

The issues raised by both the laboratory and assessor related to the uncertainty of thread measurements are in my opinion valid, but not as “clear cut”. There are a number of attributes that could affect, in varying degrees, the measurement of pitch diameter of a thread plug/gage. Quantifying the contribution of each of them would be a difficult task in routine calibrations and a tenuous task in an experimental/scientific exercise. Accordingly, we have little choice but to rely, to a degree, on our own experience and on available guidance provided by norms or related documents (for example: ANSI, the A2LA guide for estimating uncertainty in dimensional measurements, etc.).

Though there is validity to both sides of the argument I feel that based on available guidance I would lean for the argument to include a predictable 29 µin uncertainty to the calculations. Mr. Ralph Veale, to the best of my knowledge instrumental on the development of the A2LA guide, provides a credible base for the argument that this uncertainty be considered. By the same token, one could also argue that other thread characteristics can also add a degree of uncertainty to the measurements; for example the helical path of the thread (not mentioned), surface finish (not mentioned), etc. I do believe that the more important point is that we (assessors for one) need to apply the norms equally across assessed laboratories.

On the practical side I would take a different position. In the case of a class W thread plug gage is typically used to set an adjustable thread ring gage or in practice used to check the condition of a fixed thread ring gage. As with a standard thread plug gages these are applications prone to significant variability due to operator influence/bias; Accept/Reject criterion for fixed threads can be also biased. The bias is more significant when the thread plug gage member is used to "set" an adjustable thread ring gage since the female thread member is set with the thread plug mainly by "feel" rather than by a physical measurement (other than for the number of threads engagement). Because of this, a debate on the significance of adding the additional 29 µin uncertainty to the calculations could be considered more of a scholastic argument. What is most important is that the practice be applied equally for to all accredited labs based on existing guidance.

In the interest of standardization I vote to include the uncertainty contribution due to half angle and pitch errors as indicated in the A2LA guide for estimating uncertainty in dimensional measurements. My suggestion is that this point be emphasized to all assessors as something that needs to be explicitly evaluated on future assessments to ensure the guidance is applied equally with all laboratories. I for one intent to be more cognizant and alert to this fact in the future.

The explanation by the laboratory was long and alittle overwhelming, but I got the point.

I have to agree with the assessor that uncertainties should not be the same or lower than a national laboratory. While I have seen that a lab could have the same equipment and capability as a national laboratory, the GUM would suggest that any secondary lab that is traceable would have some uncertainty piggy-backed over the national laboratory, thus have a higher uncertainty not lower.

It would be a bad idea to have A2LA underwrite scopes better or equal to those listed by the BIPM which use key comparison data from the national laboratories. It would seem contrary to everything we believe to be true in measurement.

I am not an expert in threads, but the logic of the assessor seems correct.

After reading both sides I would have to side with the assessor. First, based on the practical situations where the smaller uncertainties result in failed PT's, (which implies elements of uncertainty are missing). Also, not to side with the assessor would be in conflict with the A2LA Guide to Measurement Uncertainty of Cal, G103, which was produced by Ralph who I would consider one of the top experts. It would also be in direct contradiction to EA-10/10 which I have personally heard Ted D refer to as the perfect reference to this type of uncertainty calculations.
Having reviewed the correspondence, my support rests with the Assessor.
Anyway, to be brief, I agree with the assessor who has correctly pointed to the A2LA requirements in this area. I also agree that this lab is most likely not performing these calibrations to the level NIST would therefore making their argument, as the assessor correctly points out, null and void. The lab demonstrates very good technical knowledge of the issue but I doubt that there is practical application.
We at Tektronix have no experience in thread measurements, but I have a comment on the document submitted by Tri-State. Tri-State repeatedly refers to 'how the US' does the measurement. If the reasoning for accreditation is international equivalence and acceptance, the 'US way' may not be the best method to describe the scope of accreditation. If Tri-State's customers specifically require this method, this should be done on a case be case basis and well documented by Tri-State. Otherwise, the requirement should be as the assessor states, using methods for development of uncertainty that would be acceptable internationally.
I read the lab's response when you first sent it out, but had nothing learned to say at the time, so did not respond. Now that I read the assessor's response (from Henrik), I can look at this from a practical point also. I agree with the assessor in that labs often place unrealistically low best measurement uncertainties on scopes. I found the same thing when I did a review of reported best measurement uncertainty for torque wrench calibration. Most labs did not fail the PT because of poor calibration technique. Torque wrench calibration has poor repeatability and a large tolerance. The problem was, quite a few labs way under estimated their best uncertainties and failed for that reason. There were best uncertainties that were practically unattainable. I have the highest respect for Henrik's opinion.

Best measurement uncertainty is not a theoretical value. It must be attainable by the lab. Roxanne and I differ on whether it is based on everyday work (Roxanne) or ideal but attainable work (me). So Henrik says it is unlikely a client asks for such a level. That is not an issue to me. It would be to Roxanne. You may want to get her to clarify A2LA's policy. If the best uncertainty has to be based on routine work, I say Henrik wins. If the best uncertainty can be based on ideal conditions, although not theoretically perfect conditions, the lab has a chance.

Regardless, the lab must be able to demonstrate the ability to perform calibrations at the level of uncertainty it claims. Has the lab participated in a round of thread gage PT? Has the lab passed? Did the lab use its best uncertainty when participating?   If so, you can't argue with success. Otherwise, I suggest trial by fire. After all, Henrik does not dispute the technical merits of the lab's argument. He disputes its ability to perform at this level.

I did assess the laboratory and the letter was an amicable solution the laboratory and I came up with to address the matter without writing a deficiency and running it through that process with its associated deadlines.

I suppose a very sophisticated customer could want a measurement of a very specific point on a thread plug and use ongoing measurements of that point to monitor wear of the plug. My first problem is that I think such customers are very few and far between. I believe the vast majority of users of thread plugs do not consider that the pitch diameter varies from one point to the next and that it would take a lot of measurements to characterize the plug. Therefore I think it would be misleading in the vast majority of the cases to apply what the laboratory suggests. I also think there are practical problems in identifying the exact spot with sufficient accuracy.

Another issue which I think is very important in accreditation is equivalence of measurements. One of the proficiency tests I offer is a thread plug test. My experience with that test is that competent laboratories that claim uncertainties on the order of 100 µin pass the test. Laboratories that claim substantially less than 100 µin tend to fail the test. The thread plugs used in the test are unused, so it is not due to wear on the plugs that laboratories fail, it is because the uncertainty inherent in measuring thread plug pitch diameter competently is on that order of magnitude. So if the approach proposed by the laboratory is allowed, you will see disagreements amongst accredited laboratories when measuring the same thread plugs that exceed the stated uncertainties by a factor of 2 or more. That would bring accreditation in disrepute and I do not think that is in A2LA's interest.

The 100 µin uncertainty level substantially corresponds to the value one would get to by following the example given in the A2LA Guide to Dimensional Uncertainty. The example was put together by Ralph Veale, who used to be involved in thread calibrations at NIST. According to the BIPM KCDB, NIST can do pitch diameter measurements to 50 µin. Tristate essentially suggests that their calibrations (and those of anybody else who choose to follow their approach) are at the same level as NIST.

So that is my reasoning for essentially enforcing that thread plug pitch diameter uncertainty budgets shall consider the contributors in the example in the A2LA guide. As always, I think it would be a good idea if such an issue is subject to a written policy in the interest of leveling the playing field, as about half the scopes had uncertainties for this parameter that were unrealistically low in my opinion when I did a survey of the scopes in 2005. About 25% even claimed lower uncertainty than NIST.

I waited to reply hoping to get the opinion of others in the group. Since I have seen none, this is my opinion.

I agree with the folks at Tri-State and I commend their time and effort to support their position.

We have been accredited for about a decade: you were our LSO a few years back. I have not had this issue come up during one of our assessments and we have had some pretty good assessors.

I hope my position helps support the folks at Tri-State.

I have been reading Jeff & Dave's reply's regarding the pitch diameter measurement of thread plug gages- As a working group member of the ASME B89.1.17 standard on MEASUREMENT OF THREAD MEASURING WIRES and also many years of working in Quality within the trenches of manufacturing here in New England- My understanding would be to define what Pitch Diameter is per the current ASME B1.7-2006 standard, and let's all agree what the labs will be required to do in the future. In short, pitch diameter measurement seems to be made up of not just one but four different m easurements- Lead, Flank Angle, M.O.W. (measurement over wires) and Major Diameter. (and yes, the measurement uncertainties can get uncomfortably large)

During laboratory assessments that I perform, if the lab states "Pitch Diameter Measurement" on its scope and I find during the proficiency segment or procedure review that they are only performing "measurement over wires" I will have them change their scope to read M.O.W. instead of Pitch Diameter and if they are measuring t he Major Diameter they can put that on too. After a simple explanation, no labs have ever argued with me on this- The scope should state what the lab does, not what they think they are doing. If the laboratory performs Pitch Diameter Measurement as is stated in the ASME documents, then Pitch Diameter Measurement can be put on their scope. I don't know if it can actually be this simple but I think it's the direction we need to head in. Besides, the true fact is that M.O.W. (minus the constant) in three positions, is what 90% of the labs give their customers for data on working/used thread plug gages- and the customers aren't complaining.