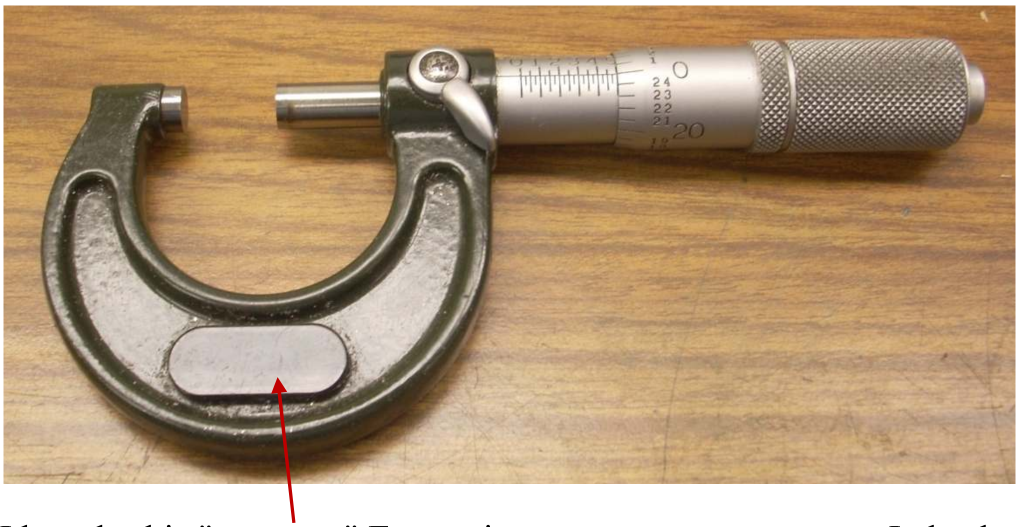
How Accurate is Your Micrometer?

Version 3.3

By R. G. Sparber



I bought this "no-name" Enco micrometer many years ago. I also have a few "big-name" used micrometers. I don't blindly trust any of them.

This is not to say that I don't use my mics often. I just have to be careful. If I need to make two parts of equal size, then repeatability is more important than accuracy. Repeatability is as much a function of my ability to achieve a consistent "touch" as it is the mechanical integrity of the mic. Here's an easy test – measure the same thing 10 times and see how much the readings vary. I routinely see variations of +/-0.0001" on a good day.

If I must get to an absolute size, I use my Spacer Blocks which are accurate to +/-0.0001" each. In the worst case, this means that the stack of Spacer Blocks needed to get to a given height has an accuracy of +/- (0.0001") x N where N is the number of blocks used. It should go without saying that all surfaces must be absolutely spotless. A bit of swarf can easily be 0.001" thick and throw off any hope of accuracy.

Let's say I want to achieve a thickness of 0.5000". I have a single spacer block of this thickness. It is good to +/-0.0001". Assume it is a good day and my repeatability is +/-0.0001". So if my mic was perfect, I should expect it to read 0.5000" +/- 0.0002" worst case[2]. Yet when I use my mic, I read 0.5003". The way I handle this situation is to trust my Spacer Blocks and correct my mic reading. In other words, when I read 0.5003" on my mic, I will assume I am measuring 0.5000" +/-0.0002". The Spacer Blocks give me my absolute accuracy while my mic simply transfers that thickness to my piece being measured. If I wanted to measure 0.4990", I would select a stack of Spacer Blocks to give me this value and tack on the appropriate error limits.

But What About the Mic?

The obvious question is – how much can I really trust my mic? To answer this question we have to think about how a mic works. There is a threaded rod that fits into a threaded sleeve. The engraved thimble with the numbers etched into it is attached to the threaded rod. By using a special tool, we can turn the thimble without turning the threaded rod. This feature is used during calibration.

[2] For more on this subject, see http://www.npl.co.uk/publications/uncertainty-guide/

Zero

After carefully cleaning of the anvil (the fixed part), and spindle (the movable part) of the mic, we gently turn the thimble until the anvil touches the spindle. The thimble should then read exactly 0. In my case it does. This is necessary but not sufficient.

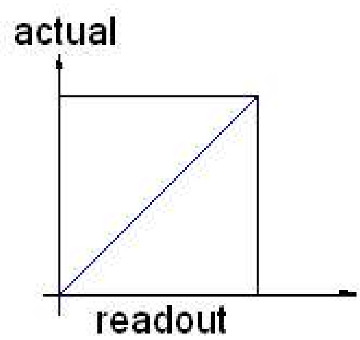
One Inch

This is a 1" mic so I next open it up and set in a 1.000" spacer block.

The thimble should then read exactly 1.000". In my case it does. This too is necessary but not sufficient.

What Do You Want From Me?

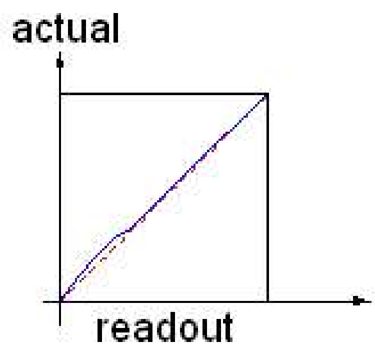
My mic reads zero when it should and 1" when it should, so why not be happy and move on to making chips?



We have demonstrated that 0" and 1" are correct but know nothing about the mic's behavior between these two points. Ideally we have a straight line but in reality, it is might not be straight.

Error Source #1

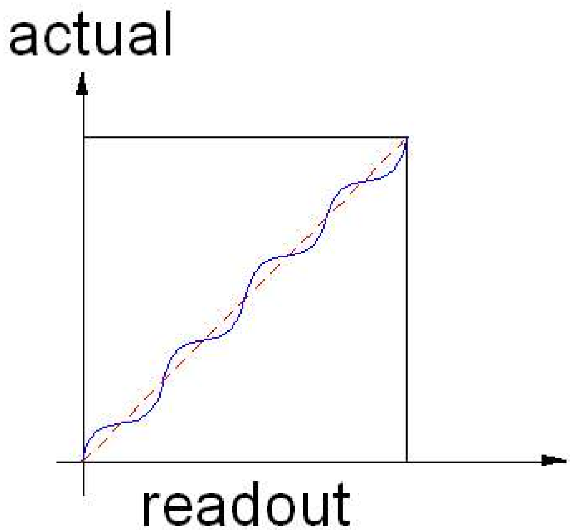
The first error source we will look at is the threaded rod. It might have come from the factory perfect but after that first drop to the floor, things are a bit off. We may still be able to set zero and 1", yet things don't look so good between these limits.



In this picture we have a red dashed line that represents perfection. The blue line is reality. Note that there is a range of values that are wrong. Yet the rest of the mic's travel is close to perfect. This kind of error implies damage to some of the threads on the rod.

Error Source #2

Our second error source is the threaded sleeve. My mic advances 0.025" per revolution of the thimble. If the threaded sleeve is damaged, then the error will vary over the 0.025" distance and then repeat.



Note that the deviation from ideal repeats as we open the mic. In this case, it is likely that you can set 0 and 1" perfectly yet have trouble at other points.

Real Data

The following measurements are with my mic. Before using each spacer block, all surfaces were wiped with a clean rag moistened with instrument oil. This oil is very thin.

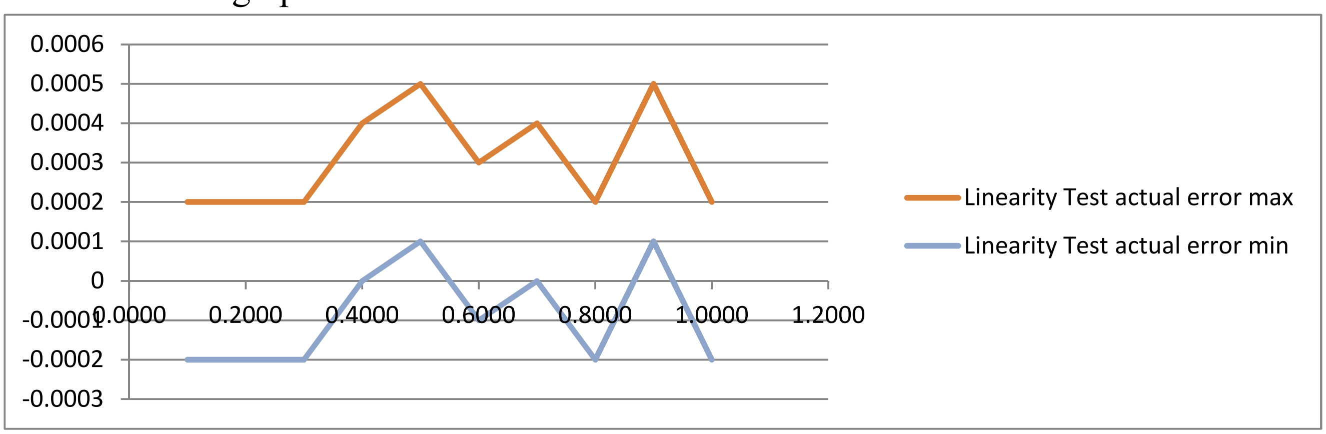
1" Micrometer Calibration Test

set 0 and read 0.0000"	est operator error is +/-	0.0001
set 1" and read 1.0000"		

Linearity Test

spacer value	mic reads	mic error	number of Spacer Blocks	reading error +/-
0.1000	0.1000	0.0000	1	0.0002
0.2000	0.2000	0.0000	1	0.0002
0.3000	0.3000	0.0000	1	0.0002
0.4000	0.4002	0.0002	1	0.0002
0.5000	0.5003	0.0003	1	0.0002
0.6000	0.6001	0.0001	1	0.0002
0.7000	0.7002	0.0002	1	0.0002
0.8000	0.8000	0.0000	1	0.0002
0.9000	0.9003	0.0003	1	0.0002
1.0000	1.0000	0.0000	1	0.0002

In the third and forth lines you see that I tested my mic at 0 and 1" and it came out perfect. Then I started my Linearity Test and you can see that the mic error varies between 0 and 0.0003". There is an uncertainty of about +/-0.0002" here which is included in the graph below. I connected the dots to make it easier to follow.

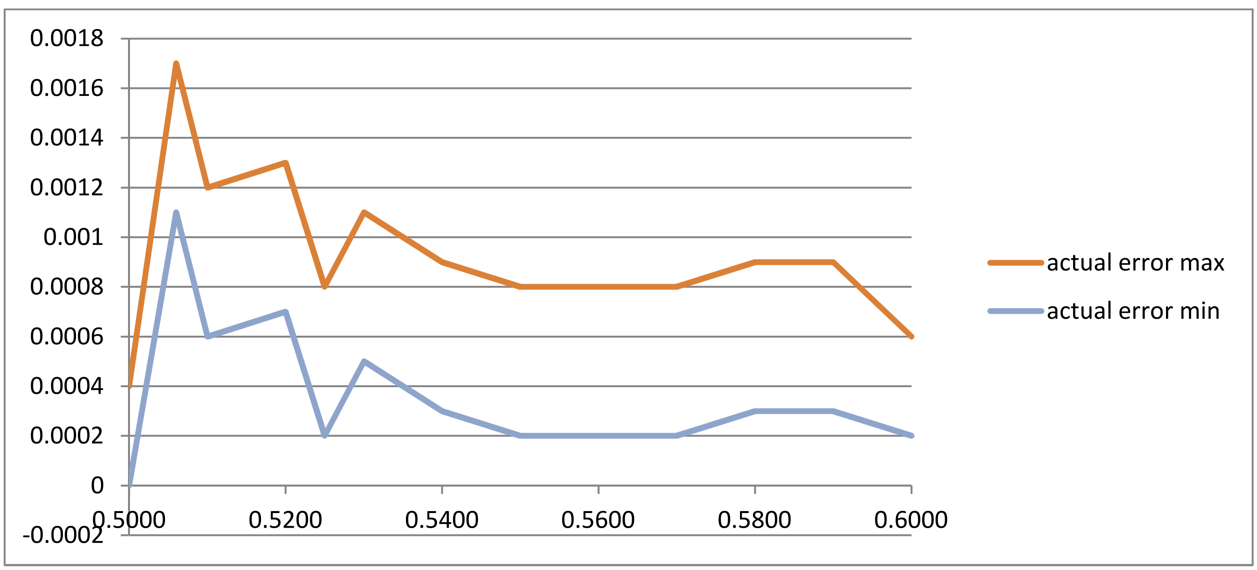


The actual reading is bounded by these two lines. A few readings could be perfect but most do have some error.

Threaded Sleeve Test

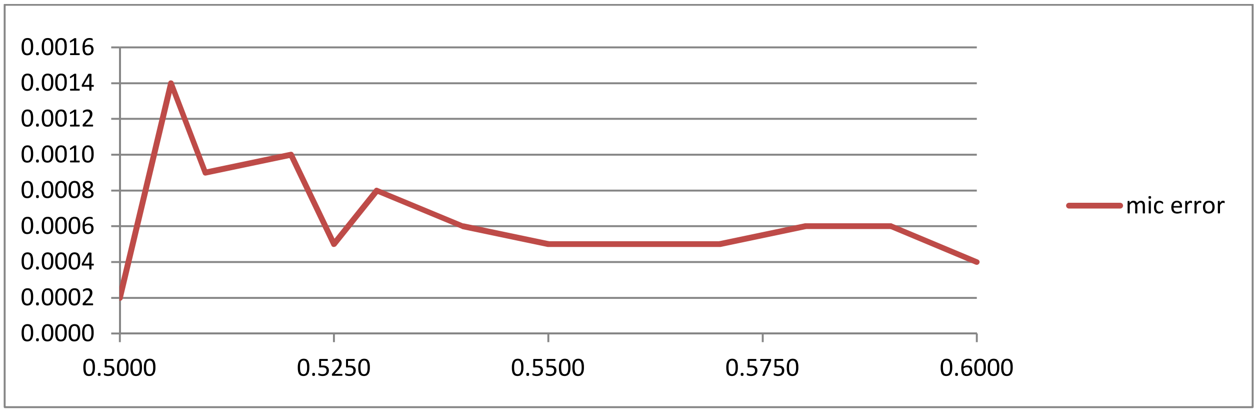
spacer block(s)	mic reads	mic error	number of Spacer Blocks	reading error +/-
0.5000	0.5002	0.0002	1	0.0002
0.5060	0.5074	0.0014	2	0.0003
0.5100	0.5109	0.0009	2	0.0003
0.5200	0.5210	0.0010	2	0.0003
0.5250	0.5255	0.0005	2	0.0003
0.5300	0.5308	0.0008	2	0.0003
0.5400	0.5406	0.0006	2	0.0003
0.5500	0.5505	0.0005	2	0.0003
0.5600	0.5605	0.0005	2	0.0003
0.5700	0.5705	0.0005	2	0.0003
0.5800	0.5806	0.0006	2	0.0003
0.5900	0.5906	0.0006	2	0.0003
0.6000	0.6004	0.0004	1	0.0002

I arbitrarily chose to look closely at the values between 0.5000 and 0.6000". The errors are much larger than in the previous test.



Note from the above tests that when I measured my 0.5000" spacer block for the Linearity Test, I got 0.5003" +/-0.0002" but when I did it for my Threaded Sleeve Test I got 0.50002" +/-0.0002". They are within the uncertainty limits. Similarly, when I read 0.6000" for the linearity test, I got 0.6001" +/-0.0002" yet for the Threaded Sleeve Test I got 0.6004 +/-0.0002" . This too is within the uncertainty limits.

It is hard to see any correlation with the position of the thimble with the above graph but let's just look at mic error versus thimble position.



The horizontal axis has a tick mark at each place that the thimble reads 0. Note that the graph has a local minimum at each of them. This implies but does not prove that errors in the threaded sleeve are the cause of this error. However, it does illustrate that we do have a lot more error than might be assumed by just looking at a few points.

Now, don't slam your beloved mic into the trash if you get similar results. You know more about your mic and can work within its limitations. When in doubt, use your Spacer Blocks .

If you have repeatability far better than mine, you might want to consider buying gage blocks which have an accuracy better than +/-0.0001".

Another Error Source

After the initial publication of this article, JR Williams pointed me to an optical instrument that tests the parallelism of the mic's anvil and spindle contact surfaces. You can see this amazing instrument at

https://www.mitutoyo.co.jp/eng/pdf/E4329_QuickGuide.pdf and turn to page 9.

It got me thinking. Although not as sensitive, I can use some Dykem Hi-Spot on the anvil and see how much prints onto the spindle. Clearly I have found another error source. I don't yet know how much error it contributes but by mic'ing on the blued area and then on the clear area, I should be able to tell.

This dye test is more about how congruent the surfaces are than if they are flat. Another test would be to use the Dyken Hi-Spot on the anvil and then mic one of my Spacer Blocks . Ideally the anvil would print a nice solid circle on the faces of the Spacer Blocks .

Brian Lamb of the Valley Metal Yahoo group, pointed out that since the spindle turns as it hits the anvil, the dye will smear. That is likely. So if the dye covers some of the surface, it is proof that the surfaces are not congruent. If the dye covers the entire surface, we don't know if it is in full contact or just smearing.

Acknowledgements

I wish to thank JR Williams for his suggestion of using an optical instrument to check the contact surfaces. Thanks to Brian Lamb for pointing out the limitations of using Dyken Hi-Spot to test the contact surfaces. Thanks to Dave of the Gingery_Machine BBS for the two articles. "Mike E" supplied the URL that points to documents that deal with measurement uncertainty. Thanks to Justin Clift for finding a broken URL. Thanks to "pmailkeey" for suggesting improvements in clarity plus finding broken URLs.

What Next?

I have ventured out on the very thin ice of metrology before. After a minor blood bath, I have learned a lot and corrected the document to the satisfaction of at least most experts. My desire to learn more has again overcome my aversion to pain. So if you have a criticism of this work, I do welcome it. As always, I welcome your questions and comments. All of us are smarter than anyone of us.

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