Discussion Related to Caliper Accuracy

The following emails were posted between 3/30/2011 and 3/31/2011 on the Yahoo BBS mill_drill. They amplify and challenge my original discussion of the Harbor Freight digital caliper. I always welcome such discussion.

Thanks to Paul Alciatore and Curt Wuollet for the following extremely helpful information.

Rick Sparber

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Rick,

I have seen your discussion on this before. In fact, I am one of the ones that you gave credit to at the end for contributions. I don't remember my specific contribution, but thanks for that.

Your discussion of accuracy is a bit simplistic. I suspect the HF instructions were written to be simple and really do not attempt to analyze the various sources of error individually. Nor do they do a good job of breaking those errors down by distance. You go to some trouble examining the first few hundredths of a mm from the zero point. In this, you try to apply the +/- 0.02mm spec to that short range. I don't believe that it applies to that low range. You state that the spec sheet reads "After moving a distance, mm" and next to 0 to 100mm in that column, they give the +/-0.02mm spec. I believe what they are saying is that if you move a FULL distance of 100mm, from 1 to 100mm on the scale, then you can have that as the maximum error. Without going into an analysis of the actual sources of error in such an instrument, it would be a lot more reasonable to assume that the actual error is approximately linear from 0 to 100mm with the value at or very near 0 at the 0mm point and gradually increasing to the max at the 100mm point.

You could then extend in a linear fashion from +/-0.02mm at the 100mm point to +/-0.03mm at the 200mm point. And again, continue the linear estimate from 200mm to 300mm. Actually, with the numbers shown, the line would be straight from 100mm to 300mm.

But, as I said, this is a very simplistic analysis and does not consider the factors individually. First of all, it is a way of lumping all the factors into one simple figure and virtually guaranteeing that the error will never exceed the amount given. That does not mean that it is going to ever approach those values at any particular point on the scale, least of all in the area that is near the zero set point. Also, in all digital devices there is always a +/- one count error added to the other error estimates. This is to account for the step nature (which you illustrate nicely) of any digital device. But this is not the least count shown on the display, but rather the internal least count which is much smaller. It is omitted here or just included in the stated figures.

I imagined a linear graph of POSSIBLE error values above. In reality, if real devices were tested, the actual error values would probably follow a smoother curve. It may raise more rapidly near zero and then level off to reach the 100mm value given. Again, from 100 to 300mm it would also be slightly curved, rising faster near 100mm and slower at 300mm.

The real error factors would include, but not be limited to:

Temperature: This would be fairly linear due to expansion.

As a subset here, there would changes in the sensitivity of the pickup devices with temperature. This would not be linear.

Accuracy of the internal steps in the manufacturing process. This would have two components which would add together:

The overall or long term (distance) accuracy. This would also be fairly linear.

The individual variation of the individual steps. This would be more or less constant at all scale values.

The +/- one count error

Long term ageing effects

Errors due to parallax of the jaws. This would depend on technique and the object being measured and would be fairly constant over the full range for similar objects and users.

As you can see, a really good graph showing all of these and any other factors that I have failed to think of, would be very complex. This is why they just provide the three simplistic values you puzzled over. For parts of the stated ranges, these values are way too high for any real caliper ever produced but true to their word, the real calipers do meet these specs. Part of this is the CYOA philosophy.

To apply the above to your analysis of the first 0.01mm step, I would estimate that temperature expansion would be all but undetectable. The error due to the change in sensitivity or the pickups is probably within +/-5% for a wide temperature range. The long distance error of the scale at the 0.01mm point would also be all but undetectable (I would say 0.0001mm at the very most). The step variation would probably be well within +/-10%. The one count error would depend on the size of the internal counts, perhaps another +/-10% if they are 0.001mm steps. Long term ageing effects would be very small for this short distance and again undetectable by anything either you or I are likely to have. Assuming we are measuring shim stock with good technique, jaw parallax would also be very low. So, the total possible error would be the sum of the above factors: 5% + 10% + 10% and perhaps a generous allowance of 1% for the undetectable. That gives a total possible error of 26% or about +/- 0.0026mm. And this would be the maximum error I would ever expect. At the maximum error in the negative direction, this would give a reading of 0.01mm for real values of 0.0024mm to 0.00124mm instead of the theoretical range of 0.005mm to 0.015mm. If all errors were in the positive direction, this range would be 0.0076mm to 0.0176mm.

This analysis also shows the rather rapid increase in error values at points near zero. We have seen an immediate increase to 1/8 of the 100mm value at the first point where the scale shows a value above zero. There are 9999 more 0.01mm steps to get to 100mm. This case of the first 0.01mm step is the worst case error

on a percentage basis and that percentage error will decrease as you go higher on the scale.

I guess my main point is that you can't take the data sheet values on face value. You must add some common sense along with a realistic analysis of the sources of the errors. A further analysis of some additional points near zero (0.02mm. 0.05mm. 0.1mm. 0.2mm. 0.5mm, etc.) and perhaps out to 50 or 75mm would very likely give you an error curve as I described above. You would probably reach the +/-0.01mm point somewhere around 33mm point and not get to the full +/-0.02mm until you get to the 100mm point.

My analysis above is not based on any measurements of actual calipers, but rather on assumptions that are reasonable. So, don't be surprised if the actual calipers vary from it. Perhaps someone can buy 100 or 1000 Chinese calipers (different brands I would hope) and make actual measurements.

Paul A.

Working to accuracy better than .001, very soon the DRO resolution and accuracy are not the limiting factor anyways. I'll bet the vibration displacement, spring, heating, and half a dozen other factors swamp the position repeatability. Try just milling a surface flat to within .0005". Especially with manual feed, I wouldn't worry about the scale too much.

Regards

cww

You are quite right: there are many factors in the overall accuracy of the work. But these factors must be addressed individually or at least they must ALL be addressed if you are going to improve that accuracy. We were only discussing the accuracy of the scales. It has been said that your measuring system should be better than the accuracy that you are trying to achieve, perhaps as much as ten times better. So using a scale that is only twice as accurate (0.0005" vs. 0.001") as the desired work tolerance is questionable. I, for one, would like to know the real numbers for such scales and this information cannot be determined simply by looking at their data sheets or specifications.

Paul A.

Paul,

Now I recall some of this past discussion. If it is OK with you, I would like to copy your entire email and put it into a pdf that will be next to the original article on my web site.

Rick

Rick,

Certainly, go right ahead. I have already posted it on a completely public web site.

I need to check out the rest of your site.

Paul A.