Repeatability and Accuracy of the Harbor Freight® Caliper

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Version 3

Executive Summary

The spec sheet for the Harbor Freight Caliper is discussed with respect to repeatability and accuracy. Temperature effects are investigated.

Conclusion

These calipers have zero error immediately following a zero set. This error can quickly approaches ±100% of the reading yet remain in spec before falling back a more reasonable limit.

Key Reference

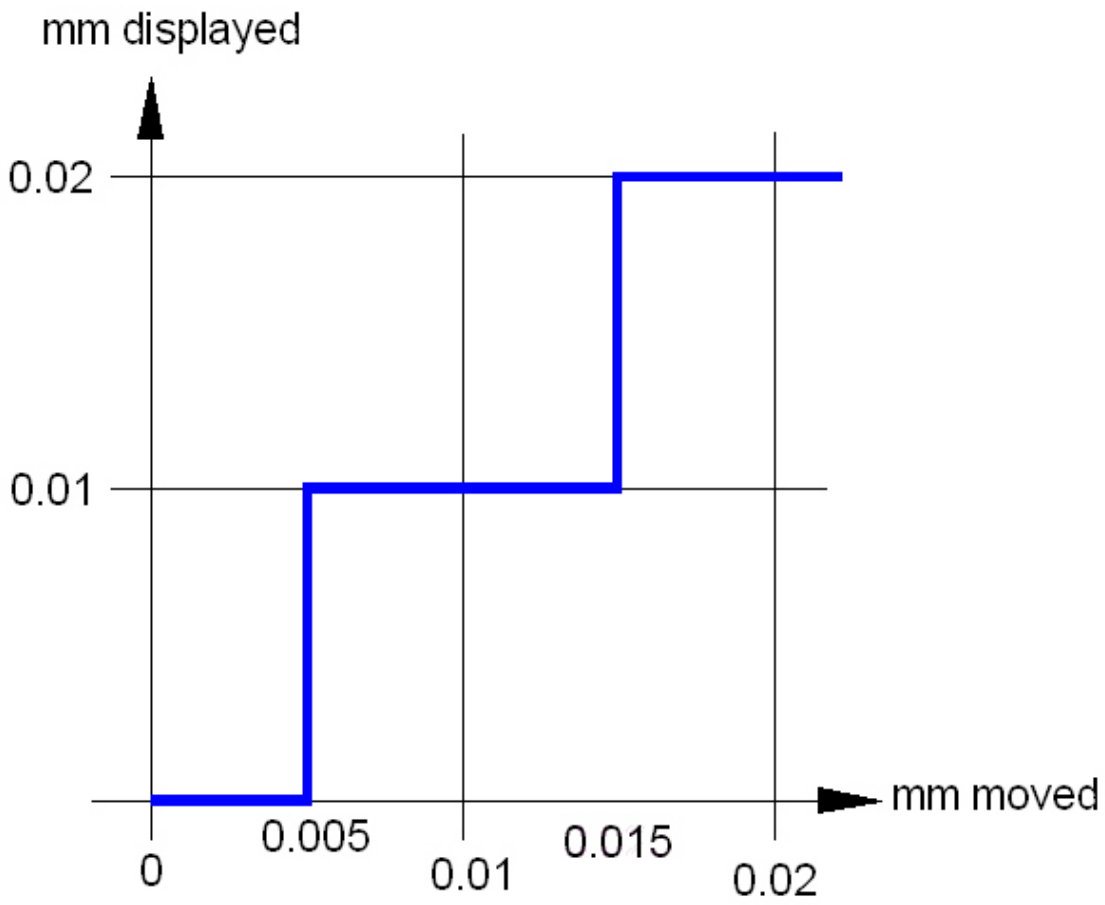
The following discussion refers to information found in the user manual supplied with each Harbor Freight caliper. You can view it on-line at http://www.harborfreight.com/manuals/47000-47999/47257.pdf

Repeatability

The spec essentially says that the caliper is repeatable to its smallest displacement indicator. In inches mode, that is to the nearest 0.0005". When in metric mode, it is 0.01 mm.

Consider what this means.

When we set our *ideal* caliper to 0 mm, we see the display read 0.00 mm. The reading will be 0.01 mm when we have moved 0.01 mm.



Now reset the caliper to 0 and slowly open the jaws. When me have moved to 0.005 mm the display will change from 0.00 to 0.01 mm. This is the point where we have an equal magnitude of round off error.

The display should stay at 0.01 mm until we have moved to 0.015 mm at which point it should jump to 0.02 mm. This is another point of equal magnitude round off error.

Note that this round off error is due to having a limited resolution of the display and has nothing to do with caliper accuracy.

Accuracy

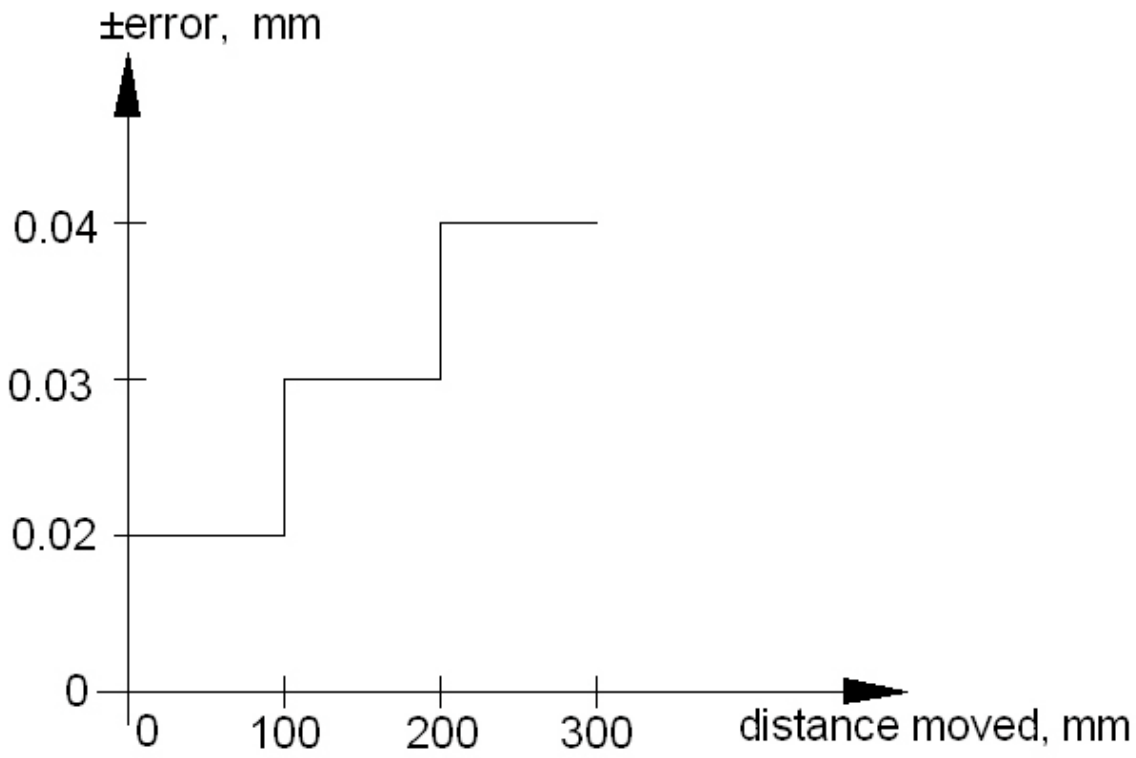
The spec sheet does a nice job of describing caliper accuracy. It uses metric to do it so I have chosen to stay with metric for most of this article.

The big picture

The errors listed below are limits. The actual error can vary between ± these limits.

Error, mm	After moving a distance, mm
0.02	0 to 100
0.03	100 to 200
0.04	200 to 300

Graphing this information may provide more insight.



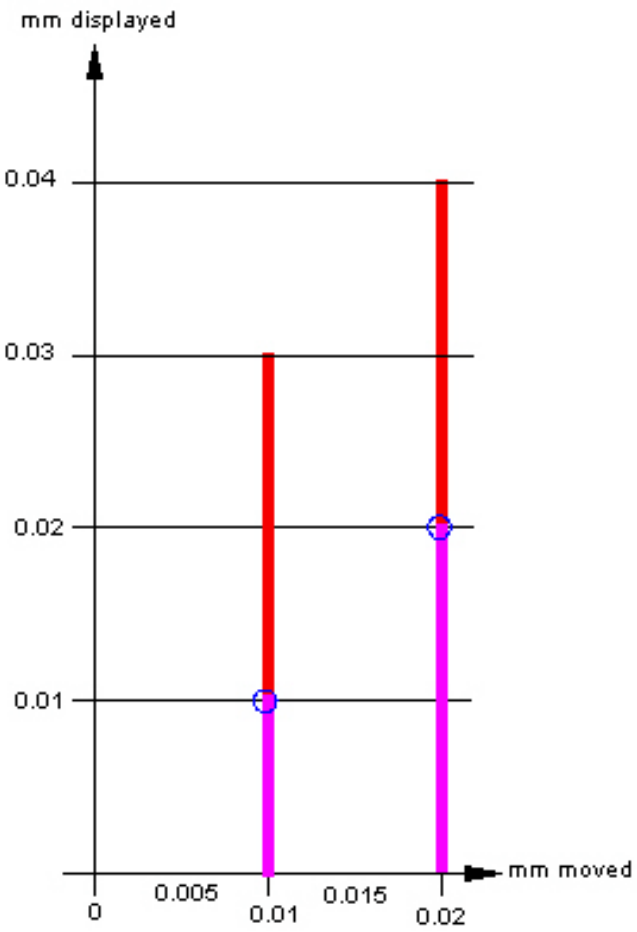
Between a distance moved of 0 and 100 mm, the actual error for a given caliper is bounded between ± 0.02 mm. When we move to between 100 and 200 mm, the actual error gets new boundaries of between ±0.03 mm. Clearly there is a component of the error limit that is a function of distance moved.

For a long time, it bothered me that I can set zero and have no error at that point yet move away from zero and suddenly incur an error of ±0.02 mm.

After much discussion on-line plus lots of "think time", I started to gain an understanding of what was going on here.

Caliper Behavior around a Zero Set

Let's take a close look at the error limit graph near our zero set.

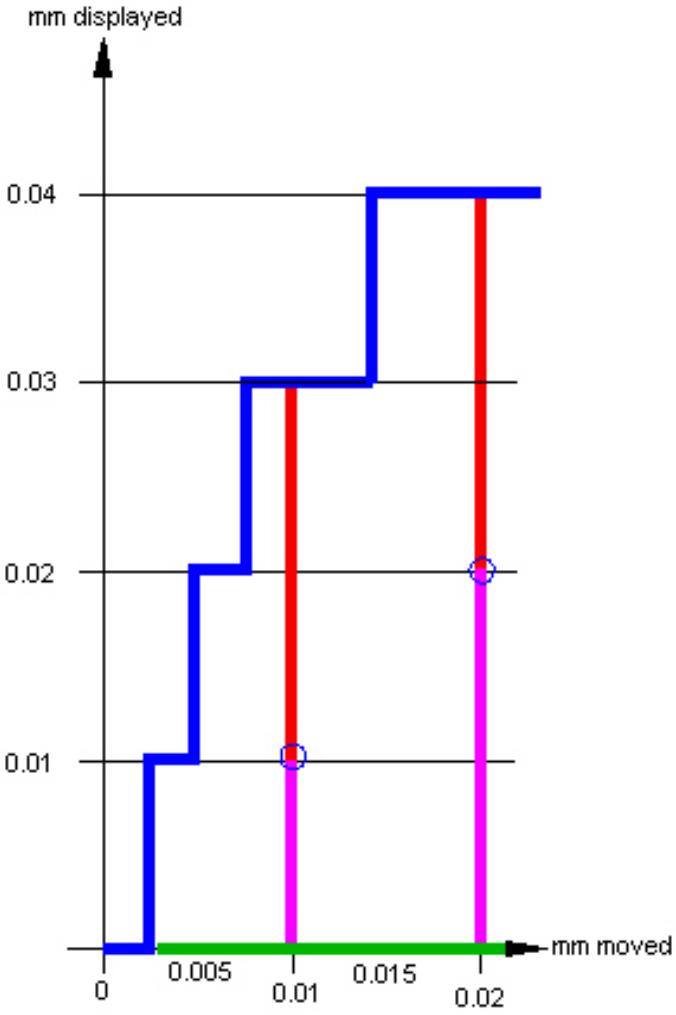


Ideal behavior is marked with the two small circles. The thick vertical bars are our uncertainty due to our error limits. The red part of each line shows possible values that are between ideal, 0 error, and the maximum of +0.02 mm. The purple line segment shows possible values that are between ideal and the maximum of -0.02 mm.

A bit of common sense is in order here. I did not put error limits on my zero set. When the caliper's jaws are fixed and I set 0, the jaws are exactly where they where an instant ago, when I hit 0.

We can even apply a bit of common sense at the point where the caliper has moved to 0.01 mm. Yes, the error limit is ±0.02 mm but we can't read a negative value from the display by moving a small positive distance. Independent of accuracy, as we open the caliper's jaws, the displayed number always either stays the same or get bigger.

For starters, let's focus on the worst-case maximum error limit and how it effects our 0.01mm indicator. This limit is shown below with the blue line. When we open the caliper from 0 to 0.01 mm, the display could read up to +0.03 mm and still be within the error limit. Moving along to 0.02 mm could cause the display to read up to 0.04 mm.



Now think about what this does to the display. At zero set it must read 0 but by moving 0.01 mm it must read 0.03 mm. It can only get there by first showing 0.01 mm and then showing 0.02 mm. Clearly the error associated with each 0.01 mm step can be large. For example, we could read 0.03 mm yet move less than 0.005 mm. We just have to display 0.03 mm at or before a movement of 0.01 mm.

If we are already displaying 0.03 mm when the caliper jaws are at 0.01 mm, the display only has to advance one step as we move to 0.02 mm and display 0.04 mm.

The worst-case negative error limit says that we could go from zero set all the way out to 0.02 mm and still see zero on the display. This limit is shown with the green line running across the bottom of the graph. Repeatability doesn't mean much if the display never moved off of zero.

To recap, accuracy and repeatability don't look so great near a zero set. We start out at 0 error but quickly expand our error limits to ± 0.02 mm. The maximum error limit says we can move the caliper jaws 0.02 mm and read a movement of twice this value. The minimum error limit says we can move 0.02 mm and see no change in the display.

Reality Check

Yes, things can be this bad but I've never seen it. What really matters is what *your* caliper does in this range. That behavior is, in part, a function of the placement of copper fingers bedded into the body of the caliper. You can fully close the caliper's jaws, set zero, and measure 0.01 and 0.02 mm shims. This will breathe a bit of reality into the discussion.

Do understand that these calipers have a short term and long term stability. What you measure down in this range may not be the same an hour later.

Now, if you open the caliper to say 10 mm and do a zero set, all bets are off. You are now relying on a different group of copper fingers. But if you measure a known thickness and set 0, it will be valid to add your shims and do a local calibration again.

If all of this is just too much bother, stick with the stated error limits and get back to making chips.

Temperature effects

A test was run to see how temperature effects these calipers.

The caliper was put in the fridge overnight and sat at 40°F. A pair of 1-2-3 blocks were bolted end to end and sat at a room temperature of 80°F. The cold caliper was used to measure the warm blocks and I saw 6.0005".

Next the blocks sat in the fridge for 4 hours. The caliper was at room temperature and was again used to measure the blocks. The warm caliper on the cold block read 5.9995".

In the first test, the caliper was cold so should contract. This would produce a measurement on the high side and we got that. In the second test, the block was cold so it should contract. This would produce a measurement on the low side and we got that too.

The fact that the first test produced an error equal in magnitude to the second test implies that there is no temperature compensation in these calipers. If cooling the blocks caused an error much greater than when the caliper was cooled, it would imply that there was temperature compensation.

This demonstrates that a 40°F change in the shop acting on a 6" block of steel can cause a 0.0005" error. At least in my shop the change is around ± 2°F so is not an issue.

What Next?

This article will only improve if member of the hobbyist community send in their questions, comments, and most importantly, challenges. I welcome these inputs. All of us are smarter than any one of us.

Thanks go out to Paul Alciatore and many other members of the Home Shop Machinist BBS plus Chris of the Shumatech Yahoo group for their contributions to this effort.

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