

Technology White Paper

HAND-TOOLS vs. PORTABLE CMMs

Historically, hand-held measuring instruments have been popular among machinists, QC inspectors, and engineers. These instruments have been around for many decades, are familiar to users, and have long provided trusted results. However, there are pitfalls inherent with these devices.

For example, calipers – one of the most widely used hand-held instruments in use today – exhibit measurement error through a phenomenon known as the Abbé principle.¹ This principle states that unless the measurement object is aligned perfectly along the axis of the calipers, there will be an angle induced with device use creating a source of error. However, this error can be approximated. Consider the scenario shown in figure 1 to the right.

The calipers will show a measured value based on distance AB. The part is actually CD in length. The difference between AB and CD is the Abbé error or “E”. This can be computed as follows: $AB - CD = E = F \tan(\beta)$ where F is the offset distance between line segments AB and CD and β is the angle induced. ($\beta = 10$ arc seconds in figure 1 above.) To simplify the calculation, β can usually be substituted for the value $\tan(\beta)$ since $\tan(\beta) \approx \beta$ for small angles. When measuring in units of radians, we can take advantage of the fact that $4.8 \mu\text{M}/\text{M}$ is approximately equal to 1 arc second value.

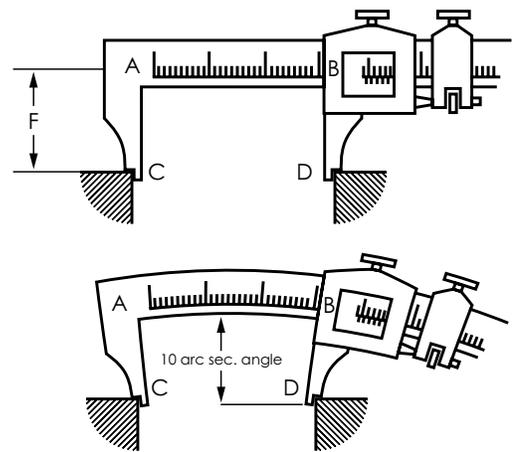


Figure 1

The example above indicates that there will be approximately $48 \mu\text{M}$ of error due to Abbé error alone. Abbé error is a consequence of the deflection of the calipers and results in a measurement that is larger than the length value of the part in question.

Another consideration with calipers relates to the stack up of errors that occur in their specification. To pass calibration, a dial caliper with 0.001 inch resolution must be accurate within 0.001 inch for length measurements and allow no more than 0.001 inch for parallelism error. But the measurement of a large part can be affected by both errors. In such a case, the possible error is ± 0.002 inch.²

Because of the inherent issues with calipers, micrometers continue to be popular alternatives. In particular, micrometers avoid Abbé error by aligning the screw and graduated drum of the micrometer to the length being measured. In mathematical terms, since the offset, F, is zero, $F(\beta) = 0(\beta) = 0$. However, screw

micrometers are still subject to errors in the drum threads. These errors accumulate over the distance traveled.



In particular, two sources of error induced by the threads of a screw micrometer are thread waver due to rotation, often called “drunken thread,” and slop in the threads causing imperfect meshing of the integrated male and female threads, called “backlash”.³ Such errors are due to the nature of their design, implying that many sets of micrometers of all different sizes must be kept, maintained, and calibrated at great expense in order for them to be useful in a variety of conditions. Even still, they are not able to measure certain features, such as inside diameters, very well.

Micrometers also suffer from measurement error resulting from the user themselves. When the device is over-tightened, the micrometer or measurement object can be deformed – sometimes permanently. Over the course of time, the anvil and spindle both can become worn and less and less parallel to each other. Both of these issues can affect measurements adversely.

Finally, environmental factors can affect the accuracy of micrometers as well. Temperature fluctuations not only cause expansion and contraction of the device (and the measurement item), but constant up and down temperature cycling can permanently change the length of the micrometer spindle, anvil and even the nature of the threads. This occurs due to stress relief in the metal at the time of manufacture.

PORTABLE CMMs

As technology has advanced in both hardware and software, portable CMMs have been developed that address some of these accuracy issues. Some devices have uncertainties as low as 5 microns and are repeatable to six microns. They can weigh as little as twenty pounds or less and be moved around a shop at will. Using a hard or touch probe of known diameter, points are recorded as the probe touches the surface of the feature in question. Since the diameter of the sphere is known with high precision, the software compensates for the probe’s diameter and records the position of the center of the probe. In this fashion, points are taken until enough data is collected for the software to determine lengths, diameters, angles and other geometric properties.

The software also allows dimensions to be calculated from measured features and calculated features. Some software packages even have GD&T functionality allowing the user to decrease the amount of time



spent inspecting a part by as much as 80-90%. Still others allow CAD models to be imported and parts to be inspected against them.

For parts that are manufactured in quantity or will need multiple users to inspect them, such as often happens in a multi-shift environment, routines can be written and saved. This decreases user to user variation and saves time since the routines can be used as often as needed. The results can be saved and reported electronically or printed out in a format that satisfies both customers and ISO standards.

CONCLUSION

For more than a hundred years, hand tools provided quick and reliable measurement results for machinists and manufacturers alike. However, as parts and products became more sophisticated, the inherent errors associated with these hand tools became increasingly unacceptable. The emergence of portable CMMs that provide higher accuracy, easier reporting, and tracking of results has addressed this need in the marketplace while cutting the recurring costs associated with periodic calibration of hand tools.

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