Accurate Measurements with Portable CMMs: Best Probe Practices

Portable CMMs are a great way to take fast and accurate measurements, especially on features that are otherwise difficult to measure due to their location or accessibility. This technology saves enough time and money that these devices frequently pay for themselves in a year or less.

HOW DO THEY WORK?

All Portable CMMs use encoders to measure in three dimensional space the center position of a ball probe with a known diameter located at the end of the CMM. Contact with the feature is made by the ball probe, a measurement point is taken, and software calculates the contact point's position in space with an accuracy of up to 5 microns. However, in order to minimize uncertainty, proper setup procedures – including the choice of the right probe – must be used.

BALL PROBE OPTIONS?

There are many options available when choosing a ball probe. Geometry, sphere specifications, and shank properties can affect the accuracy of the measurements, the ease with which they are taken, or the robustness of the measurement system. This has resulted in an almost unlimited number of combinations that can overwhelm someone unfamiliar with the technology. However, with a little experience, a user can become adept at choosing the right probe by ensuring that it has the properties appropriate for their application.

SHANK MATERIAL, DIAMETER, AND LENGTH

The shank of the probe should provide as much stiffness as possible. When taking measurement points, if the shank deflects, measurement error is introduced. Fortunately, this source of error is easy to minimize. First, the shank material should be made of a stiff material such as stainless steel, carbide, or carbon fiber. The next consideration is the length and diameter of the shank. The ratio of the length of the shank to its diameter should be as small as possible in order to minimize shank deflection when touching the feature being probed.

Put simply, it is good practice to keep the shank as short as possible and the diameter of the probe as large as possible. However, the nature of the features being probed will, to a large extent, dictate both of these properties. If the feature is a relatively small diameter, say 4 mm for example, the sphere needs to be about 2 mm in diameter maximum in order to probe it conveniently. This means the diameter of the shank needs to be about 1 mm or less in order to minimize "shanking" - the recording of a point when the shank touches the part, but the probe itself is not in contact with the feature. If the feature is also located in a crevice of a relatively deep hole, then the shaft must be long as well.

Such a setup could, however, introduce a few microns of uncertainty into the measurement. Nonetheless, a portable CMM is still a reliable option for taking such readings as these types of measurements are difficult or even impossible to do with other types of technology.

PROBE MATERIAL, SIZE, GRADE, AND GEOMETRY

The size and geometry of the probe used for any inspection plan should be determined by the application itself. The material of the part to be measured and the location and size of its features dictates the probe that should be used. Each of these characteristics can be examined separately and then the collective information can be used to determine the best probe for each particular job.

PROBE MATERIALS

There are two predominant ball probe materials available: ceramic and silicon. Ceramic metrology spheres are made usually from either Alumina, synthetic rubies, or zirconia.

Alumina, which is the common name for the polycrystalline form of the chemical compound Al_2O_3, is a durable, lightweight (4.0 grams/cm3) material.1 (Polycrystalline materials are those composed of many smaller crystallites oriented in a random fashion.)2 Alumina exhibits good general wear characteristics and, therefore, can be used in many applications.

Synthetic rubies have a similar chemical structure to Alumina, but their makeup is monocrystalline — implying that they are composed of one continuous crystalline structure.3 Synthetic rubies are one of the probe materials of choice because they exhibit good wear characteristics. Two exceptions to this general rule are scanning applications with aluminum parts or those made from cast iron. Because aluminum tends to wear off onto the ruby sphere during use, the sphere will become larger and distorted over time if used on aluminum pieces. In contrast, cast iron tends to degrade ruby by wearing it down through use.

Zirconia, the common name for the compound ZrO_2, is a hard substance with durability and wear properties similar to rubies. It is a slightly more dense material at 5.89 grams/cm3 but is not susceptible to the issues with aluminum and cast iron parts. These properties make zirconia one of the best materials for portable CMM probes.

SIZE

Typically, the best results are achieved when the largest practical probe is used for the application. Obviously, as the feature size shrinks, the probe diameter must get smaller as well in order to ensure proper contact with the feature. A good rule of thumb for the smallest recommended probe size for a given diameter is provided in the table below:

Point probes should not be used unless necessary due to small feature size or accessibility issues. The reason is that, in spite of their name, they do not truly come to a point at the end since an actual point cannot exist in the real world. This means there is some uncertainty about where the actual point's location is when measurements are taken. Further, the small radius or curvature that does exist at the end of the probe is prone to breaking or wearing away easily when it comes into contact with features. This means they need to be replaced often.

Feature Diameter:	Probe:
<3mm	Point probe
≥3mm to <6mm	2mm
≥6mm to <10mm	3mm
≥10mm	6mm or larger

GRADE

Portable CMM ball probes typically use grade 5 spheres. This means that the diameter of the ball is known to +/- 5.63 microns with a sphericity of +/-0.13 microns.4 Some manufacturers are now measuring and stamping the diameter of the probe right on the ball probe itself, accurate to 1/10 of a micron. This further reduces the uncertainty in measurement results.

GEOMETRY

Curved probes and extensions for normal length shank probes are also available. These probes are designed to access regions that are unreachable using standard calipers, optical comparators, or micrometers. This makes them very useful, but they also introduce uncertainty since they will flex more readily than shorter, straight length probes. For features that are calculated using best fit methods such as circle diameters, cone angles, and flatness of planes taking a few extra points is helpful. More points will tend to average out some of the uncertainty in any one single point's measurement.

SUMMARY

Portable CMM technology now offers remarkable possibilities for reduction in measurement uncertainty. Additionally, these devices can take measurements in hard to reach places with ease, giving the user confidence in their results. Choosing the right probe for the application at hand is a good way to minimize error and quickly obtain the results needed – thereby saving the user time and money over conventional inspection methods.

REFERENCES

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2. http://en.wikipedia.org/wiki/Polycrystalline

3. http://www.renishaw.com/en/6423.aspx

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