The Scanning Sensor at the End of Your CMM is One of Your Primary Data Sources.

Innovative Metrology & Styling Solutions

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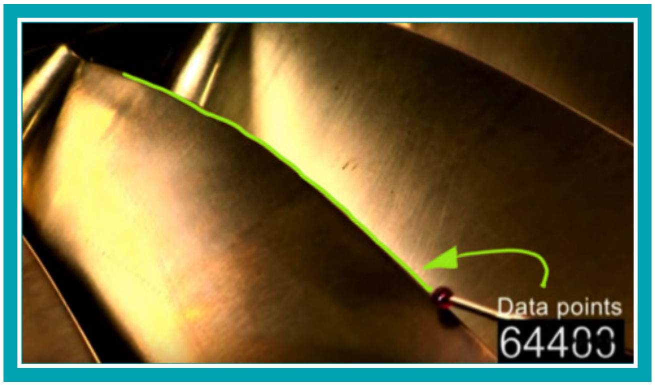
The scanning sensor at the end of your CMM is one of your primary data sources...

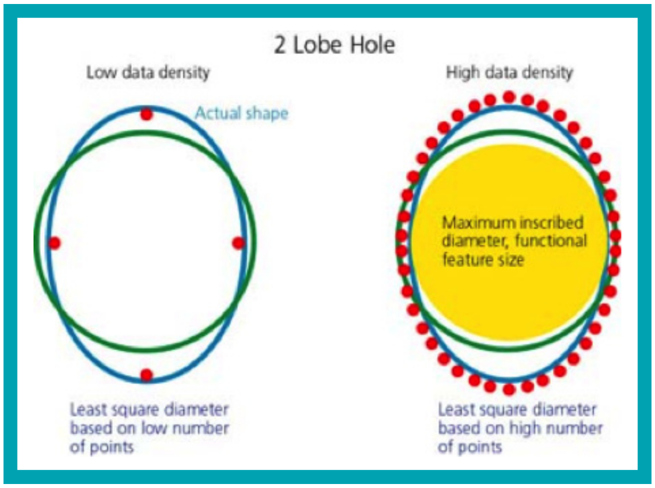
...your company can use to lower the cost of quality and improve your manufacturing efficiency. The quality department generates data that can reduce scrap and rework. It can impact, and even cut down on, unscheduled maintenance. It can even identify defects before they multiply.

Let's face it. Analytics are invading all aspects of our lives from the frequency of oil changes directed advertising to the makeup of your fantasy sports team. Your CMM is no different. It can provide you with tons of data, but how can you make that data work for you?

First, if you have a scanning CMM, you can start making more accurate measurements while reducing the time needed to take those measurements.



Increased point density improves the accuracy of your measurements. When measuring perfectly made parts, probing point locations and point quantities are insignificant. It is as if you are running an off-line simulation of the part with a CAD model – the results are always perfect, we just don't live in that world.



In the example above, it's easy to see why a four-point sample of the actual feature could lead to erroneous results. In this particular case, the quality department doesn't help the process. Actually, it makes it worse by validating a part that could eventually lead to scrap, or worse, a recall.

Another possibility is that the extreme lobing could be an indicator of tool wear, which could be identified and then corrected. This could lead to some type of predictive analysis on tool wear if the same process or part is run on a tool.

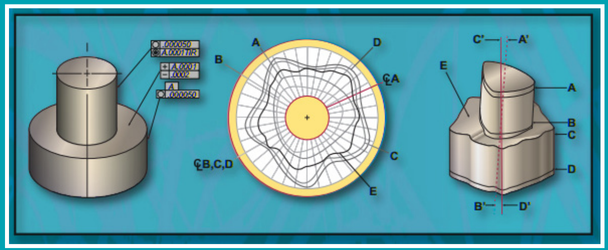
As tolerances get tighter, form deviation and surface roughness begin to play bigger roles in eating up remaining tolerances. Remember, at the beginning of this article we were talking about using the data from your CMM to help solve these problems. Four probing points don't tell the whole story on feature size and feature location. A study measuring an aluminum electric motor housing was run between a scanning CMM and a touch trigger CMM. It was a Gage Repeatability and Reproducibility (GR&R), 29 characteristics in a two-operator, three-trial study. Overall there was an improvement of 11%; reproducibility was ~ 10x better while repeatability was ~2x.

The path to better results can be seen with scanning.

Let's dive into the form part of the equation. We scan with CMMs to control Form Error caused by production processes. Form error is critical with respect to hydraulic seals, bearing load surfaces and mating surfaces of high accuracy precision metal parts.

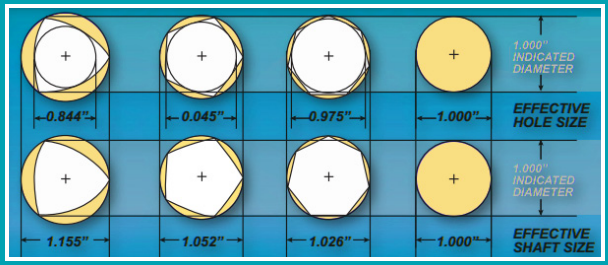
All surfaces of a typical OD are generated with reference to fixed points, axes, or lines of contact in the machine tool, whether it's centerless grinding, lathe centers, steady rests, regulating wheels, tool edges, grinding wheel surfaces, etc. These points of contact are constantly changing. Tool holders flex, there is imperfect rotation, erratic cutting dynamics, tooling wear, lubrication, rotational imbalance and wear; and improper machine tool geometry all contribute to error. Tool holders and holding fixtures slip, belts wear, drive rollers misalign, chucks distort, localized heating, excessive feed rates, and warped out of round stock all add to the problem.

The most common machine tools used in manufacturing are "centerless" and designed to make out of round parts. They contact the production part at three points and almost always generate a 3-, 5- or 7-lobed part. It should be noted that you cannot effectively measure the size of high-precision parts without knowing the shape – the effects of form deviation due to lobing error generated during the machining process. Knowing form error is mandatory when assembling tight tolerance precision parts. The time-honored mistake of "tightening up the tolerance" will not cure the problem. Control of form error will reduce scrap, reduce rework, eliminate waste and save time and money.



Deviations in Machine Tooling

Every ID and OD produced by a machine tool will deviate from perfect roundness to some degree. You can expect lobing errors from 2 to 9 or more around the circumference of a production part. The spacing and number of lobes can be odd or even, regular or irregular and the height can vary.



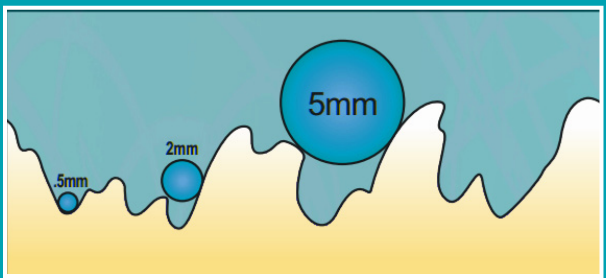
The difference between EFFECTIVE SIZE and MEASURED SIZE

All of the shafts and holes illustrated have a measured size of 1.000 in. across any diameter, but only the truly round parts have an effective size of 1.000 in. The effective size of a hole is the size of the largest truly round shaft that will go into it. The effective size of a shaft or other OD is the size of the smallest truly round hole that the part will go into.

Let's talk about tactile scanning.

There is no need for spraying the part, turning off the lights or putting the part in an enclosure. Just hold the part on your CMM and use a stylus to come in contact with the part.

There are two types of continuous scanning methods depending on whether the geometry of the workpiece is defined or undefined. Open-loop scanning (Known Path) is high-speed scanning used for measuring defined features on parts whose geometry, having few curves and surfaces, allows the probe to maintain contact with the surface. The nominal geometric data in the CMM part program or CAD Data controls CMM motion. Scanning will show the error between the actual surface and the nominal.



A quick note on scanning & ruby tip sizes

When using an analogue probe collecting a large amount of data on circles or lines, caution must be taken in order to avoid mechanically filtering the measured data. This is crucial when attempting to compare scan data with those obtained by another scanning CMM. Probe tip lengths and the whole probe configuration and UPR should be identical. An example is a large diameter probe tip bridging the part, thus mechanically filtering the total profile. A smaller probe tip will yield truer form.

Prismatic features such as IDs, ODs, planes and cylinders can be scanned in seconds and their geometry, dimensions, location and form error reported. Closed-loop scanning (Unknown Path) is high-accuracy scanning, also known as Reverse Engineering. This technique is particularly useful for digitizing undefined, nebulous, non-prismatic surfaces and features. The analog-scanning probe detects changes in the surface directions of the part and adjusts itself to maintain contact with the part (usually complex, 3-D curved surfaces such as turbine blades, molds, etc).

The scanning scenario can be broken down into articulated vs. fixed and active vs. passive.

What is articulation and fixed in terms of CMM probing systems? A fixed probing system is fixed in a position so that it measures in the negative Z direction in most cases for a bridge machine. There are examples of CMM's that are oriented in a horizontal position. But for our purposes, we're going to focus on the majority of fixed-scanning systems. Articulating systems, on the other hand, place the sensor on an articulating holder. It can then be programmed to measure in any orientation that the probe holder allows.

What is active vs. passive scanning? Active scanning is a scanning probe system that can pre-deflect the probe tip to a position. It can measure unknown surfaces easier because it can follow the unknown contour to some extent. It can also program a defined measuring force. You can think of an active scanning sensor as a mini CMM because in some cases, it will be given control of the CMM positioning as it measures.

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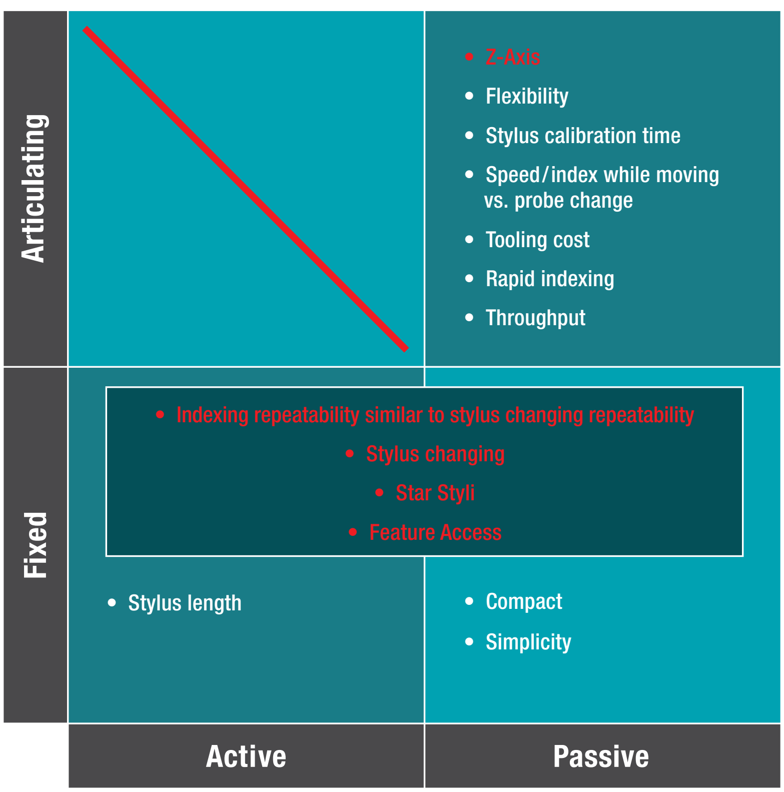
A passive scanning head is moved along the part by the CMM. Or, in a special case of the REVO, the probe head moves in two additional axis so that, in some cases, just the head moves, the machine moves, or both the head and the machine move for a five-axis scan.

Getting back to the majority of passive scanning probe heads for a moment, they use piezos, optics or springs to measure the deflection on the tip. Why does this matter? There are some advantages to the combination of these attributes. First, there isn't a readily available and commercially successful articulating active scanning system. Also, fixed passive scanning comes in two sizes: large and small. The larger passive scanning heads have the capacity to carry styli that rival active scanning heads. The smaller fixed passive scanning systems are unable to carry large star styli configurations, While they can have relatively long extensions in theory, the inability to carry large star configurations means that generally, they are reserved for smaller volumes and thus, smaller parts.

This brings us to the two remaining scanning solutions: Fixed Active and Articulating Passive.



Fixed Active scanning has all the advantages of active scanning, plus the ability to carry long styli. Some of the maximums you can find on the web are 800mm and 600g.

There are a few cases where one could argue that Active Scanning would be advantageous, and that would mainly be in unknown contour scanning in reverse engineering. The fact that a laser line scanner would be faster and better suited to that function could be an argument against active scanning. The point could be made that passive scanning is equivalent in every way that matters to most users and that Articulated Passive Scanning is the best method for increasing throughput and reducing tooling costs.

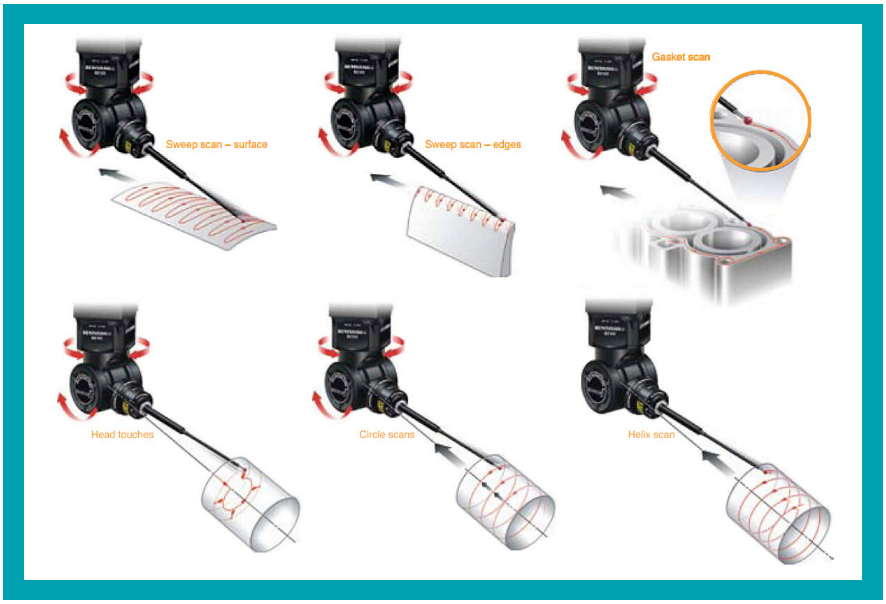
Enter the REVO 5-axis scanning system. The REVO scanning system changes the scanning landscape significantly. The REVO system can carry a variety of additional sensors to meet your needs. Can't touch the parts? Use the non-contact sensor. Need to reach an inaccessible area that a straight probe can't reach? Throw on the traditional 3D scanning module with a "crank" stylus. Have the part fixated and would love to take surface roughness measurements? No problem. Just pick up the surface roughness module and take all the surface roughness measurements you need.

While scanning remains slow in most cases, there are some additional tweaks OEMs can add to existing system to make them scan faster. However, those are always at a premium and not inherent to the base scanning systems. "Oh, you want to scan fast? That's extra."

Even in the cases where you can buy this additional speed for your scanning probe head, it doesn't speed it up in all cases. With the REVO, you have access to that speed all the time. For example, OEMs now tout that their heads will do a helical scan. That's just one of many styles the REVO can use. By combining head moves with machine moves, a whole host of scanning methods can be applied.

Speed of scanning and/or throughput.

At the top of the paper, we talked about Big Data and how you can use your CMM to captures millions of points on the parts you produce. The REVO scans at up to 500mm/sec. It can give you the quantity of data to make you confident in your manufacturing process. In the example of a blisk, it captures nearly 90,000 points off the trailing edge in about 22 secs using the sweep scan-edges method. Assuming you just wanted the leading and trailing edges of the 30 Fin blisk, it would take nearly 5.4 million points in 20 minutes. Maybe this isn't a check you do on 100% of the parts, but imagine what kind of confidence you would have in your process after doing a study on a part.



Now imagine trying to do the same measurements with a star cluster. Without articulation, it would take longer and some of the angles at which the part would be measured would be less than optimal. The Revo can acquire 4000 points /sec; other systems, only 200 points /secs. If a probing system acquired points at that rate, it would take 7.5 minutes to measure one trailing edge. With a REVO you could measure the whole blisk in the time it takes other systems to measure just two blades of the blisk.

This throughput advantage even extends to the simple operation of calibrating the tool tips. You only need to qualify one tip for the infinite amount of positions that are available to measure the same blisk. If it were even possible to use the star cluster configuration to measure the whole blisk, the calibration time needed would be much longer. In reality, however, you may need additional probe configurations to measure the blisk.

Assuming that you could measure it in quadrants, then you would have to qualify four separate configurations and all the styli on the four configurations. You need these additional configurations to prevent shanking of your styli. Infinite articulation means you never have to worry about shanking because your approach angle is not flexible. You would also need time for probe changing as well. At that point, you probably wouldn't even bother using your CMM to provide you with all the process proving data you could get. Worse yet, you may start to compromise because your data-collecting device is the limiting factor to proving out your process.

Compromise on the measurements and you compromise on the confidence. If scanning is good, REVO scanning is the best. It's in the math.

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