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Getting the Most from Multisensor Metrology

Most articles about measuring devices, instruments, or systems describe what they do and how they work. The manufacturers of these systems want readers to know about the innovation and technology that went into them. However, the missing part of such articles is how to use the measuring system to get the information that the user needs to make decisions. This article looks at multisensor metrology from a user's perspective.

Manufactured components that go into higher-level assemblies need numerous dimensions verified to be sure that they will fit together properly later in the manufacturing process. Stand-alone parts must be of proper size and shape with appropriate radii, thicknesses, and feature relationships for proper appearance and functionality. Modern manufacturing processes and computer-aided design (CAD)

What Is Multisensor Metrology?

Multisensor metrology is dimensional measurement on a measuring machine that utilizes two or more different sensor technologies to acquire data points from features and surfaces of a part to perform more measurements than would be possible on a machine using a single sensor. Most multisensor allow the manufacture of parts with complex curves, intricate features, and critical relationships. Injection molding and five-axis machine tools produce three-dimensional parts with important dimensions on every surface and in every opening, hole, or recess.

machines are motorized and use software that repeats predetermined measurement sequences without the need for user interaction.

The manufacturing engineer determines which features and dimensions to measure. For example, the diameter of a through-hole in a machined metal part may not be critical, but the position of its center relative to a datum might be. Or the converse might be true. Or both the diameter and its location may be critical. In addition, with today's CAD software, it can be tempting to put tight tolerances on dimensions that do not warrant those tolerances.

Those needs can vary, depending on where the part is in its life cycle, and where it is in the manufacturing process. For example, a new part typically goes through a detailed first-article inspection. This measurement process not only verifies that the part dimensions are in specification, it also verifies that the manufacturing process is capable of producing the part properly. Later, when the manufacturing process is stable, a smaller set of measurements may be performed during audit inspections on samples from the production run. Those measurements are attributed to other parts in the same batch or production run. Dimensional measurements are also performed as final inspection and at incoming inspection on the customer's side. Where, when, and to what degree measurements are made depends on the value of the part. Only when properly dimensioned and toleranced drawings calling out particular features or dimensions are available can the capabilities of available measuring devices be assessed so that the proper tool is used for the job. Quality, reputation, and costs are all affected by part measurements.

Deciding how to measure

Most manufacturing companies have some number of measuring devices available from the day that they start operation. These range from hand gauges, micrometers, and calipers, up to a coordinate measuring machine (CMM) and maybe an optical comparator. Those tools are purchased to support a particular level of manufacturing, with its associated tolerance and accuracy requirements. Over time, new manufacturing equipment may be purchased to machine more complex parts that need to meet tighter tolerance requirements. It can be tempting to do all the new measurements with the available tools already on hand. However, it's easy to reach a point where the measuring capabilities simply can't keep up with the latest requirements.

Even if the existing measuring tools are determined to be capable of the new measurements, there can be cost implications. Certain measuring devices are good at particular measurements. Verifying all the necessary dimensions may require using several measuring devices that may be located in different parts of a shop, or in use for other parts, or that require a particularly skilled operator who may not be available. Shops striving for lean operations can encounter bottlenecks in any of those places. Time wasted in moving a part to different measuring machines or waiting in a queue until a machine is available contribute to the total cost of that part (time is money). In addition, the delay in getting the measurements may increase scrap if the process continued and the delayed measurements determine that the process was out of control.

Why can't one sensor do all the measurements?

A skeptic might think that multisensor machines are simply attempts to get manufacturers to buy more measurement equipment. Perhaps a golf analogy will explain the true value of multisensing. A round of golf requires the use of a variety of clubs, each capable of hitting the ball different distances. Although it's possible to play a round of golf with a single club, the score would probably not be very good. The same concept applies to measuring devices. Think about a touch-probe CMM. Although it uses one measurement technique (touch triggering), it supports probes of different lengths and tips of different sizes. Such a CMM can be considered a golf bag with a set of clubs. And that may be all you need until the rules change. Introduce parts with increased complexity, tighter tolerances, critical depths, edge positions, and angular relationships, and that set of clubs (probes) may no longer be adequate.

Instead of a CMM, consider a video-measuring machine. Video excels at measuring edges it images with its magnifying optics. A zoom lens allows measurements at different magnifications. Software tools can measure single points, edges, arcs, diameters, and more. These capabilities are the set of clubs in the video golf bag. A limitation of video is that it can only measure what it "sees." A critical bore perpendicular to another surface may be inaccessible for video measurement. However, a multisensor video system can use the touch probe to probe the perpendicular bore while using video on the top surfaces and get data from the part for all the necessary measurements.

Do measurements all at once

Coming in from the golf course, consider multisensor metrology. The motivation behind multisensor measuring machines is cost reduction for the people who use them. Doing all the necessary measurements in one setup on one machine cuts total costs in many ways: the part is handled less so that risk of damage or loss is reduced, potential bottlenecks while queuing at several machines are eliminated, fewer fixtures are required, utility costs for one machine can be less than for two or three separate machines, personnel costs are reduced with training for one machine vs. the knowledge needed to operate different machines, and service and calibration costs are lower, and spares for one system cost less than what might be needed to support several systems. Finally, there is the value of the measurements themselves. Measurements performed on a calibrated multisensor measuring system are more reliable than cobbling together diverse sets of measurements done on several different machines.

A typical multisensor configuration includes a touch-trigger probe, video/vision measurement, and possibly a laser. Referred to as sensors for simplification, the first requires contact with the part, and the others are noncontact. Other sensors can also be integrated into some multisensor measuring systems. Some microprobing technologies provide access to intricate features or details that are simply too small for touch-trigger probes. White-light scanning probes provide an alternative to lasers with small spot sizes and very high resolution. To make it even more interesting, some sensors can be used in different ways. For example, unlike touch-trigger probes that acquire data a point at a time, there are scanning touch probes that acquire data points from surfaces continuously as they are scanned across. Typically, lasers and white-light probes can also be scanned, or provide single points from surfaces. Good metrology software handles the deployment and use of all the sensors, and uses their data equally for measuring the most complex feature relationships, distances, and angles.

Choosing the right sensor

Having a multisensor measuring machine available is like having a well-stocked toolbox. Hammers, wrenches, pliers, screwdrivers, and saws are ready for the tasks at hand. Some choices are obvious. Use a hammer to drive a nail (although a wrench might do it). Loosen a bolt with a wrench (although pliers might do it). Tightening a screw takes a screwdriver--but a Phillips or slotted? Even the choice of which saw to use depends on whether you're cutting framing lumber or doing finish carpentry. What's the point? The selection of which sensors to use for multisensor metrology can make a difference in the quality and reliability of your measurements. So how do you decide?

Properly measuring what's important

It all starts with the part drawing. The designer or manufacturing engineer determines which dimensions, positions, surfaces, and angles need to be measured. With increasing use of geometric dimensioning and tolerancing, datums and feature relationships are clearly identified along with their nominal and tolerance values. The drawing shows what needs to be measured. The series of illustrations seen in figures 1 through 4 on page 30 show areas on a single part best measured by each sensor technology.

Note that the part has an assortment of holes and slots, surfaces at different depths, and some intricate detail. We assume that the part will be placed on the multisensor measuring machine as shown. For most measuring systems, whether with video as primary and additional sensors, or a CMM with touch probe as primary and additional sensors, the "probe" is typically above the part. Although the part may be mounted in a rotary in some systems, this discussion assumes that the part is mounted in place and remains there throughout the measuring process.

Selection of the sensor to use depends on the characteristics of the feature to be measured. Remember that data points about the part are used for measurements regardless of the sensors used to derive them. Let's consider features of this part to measure with each available sensor.

Figure 1 shows a complex machined part and its corresponding CAD model. Selection of sensors depends on the features to be measured.

Figure 1: Photo and CAD Model of a Complex Machined Part

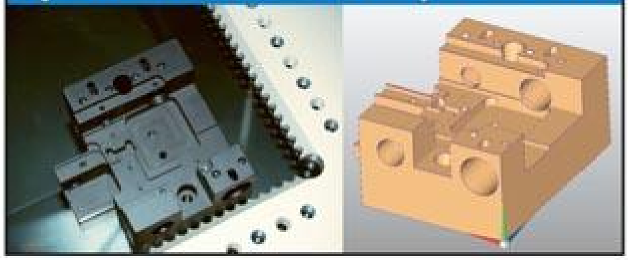


Figure 2: Close Up of Edges in CAD Model of a Complex Machined Part and Corresponding Video Measurement

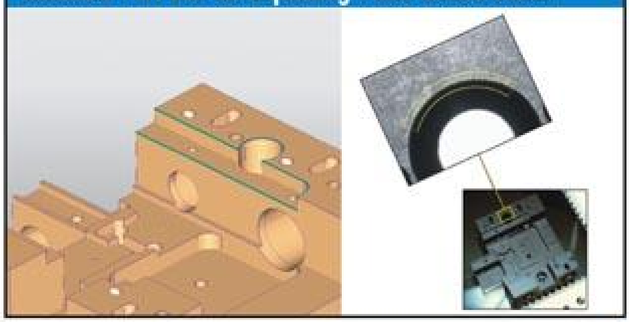
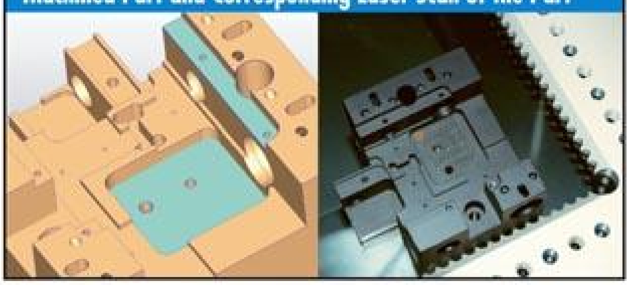


Figure 3: Close Up of Planes in CAD Model of a Complex Machined Part and Corresponding Laser Scan of the Part



Assume that the blue-highlighted edges in the CAD model seen in figure 2 need to be measured to determine the relationship (distances) between them. Either of those edges can be assumed to be the intersection where perpendicular surfaces meet. In such a case, a touch probe can collect data points on each of those perpendicular surfaces. The software then fits those sets of points to planes and intersects the planes. Those intersections represent those edges. The through hole and the edge radius complicate this otherwise straightforward process. Fortunately, it is possible to measure those edges directly with video, which excels at edge measurement. The edges appear to be parallel to the worktable and thus perpendicular to the optical axis of the video sensor. A good edge has obvious contrast from its surroundings. With proper lighting, each of these blue edges can be measured directly with video. Because video measurement is typically magnified, the system may have to step along each edge, acquiring edge points along their lengths.

Figure 2 shows a video measurement of an arc segment on the actual part. Certain video tools can automatically follow an edge, collecting points even if it has changes in direction. This example also shows that even though each edge lies in a different plane, they still can be measured with video.

On the same part, figure 3 shows two areas in blue that form planes which must be parallel to each other. In addition, it is necessary to know how far each surface deviates from a plane (its flatness). The best sensor for this is a laser. Its focused point can be scanned across each plane, acquiring point clouds of data. Each set of data can be fit to a plane. Deviations from each plane can be measured. In addition, the relationship between the planes can be compared to determine their degree of parallelism. Not all lasers are created equal, and this part has characteristics that make laser selection important. Note the perpendicular surface between the two planes. Measuring the larger plane requires adequate working distance to avoid collisions with the higher surface. See the laser spot and its path in the photograph of figure 3. Measuring that plane close to the perpendicular surface may be a problem for some triangulation lasers because that surface may block either the incident or reflected light. Some through-the-lens lasers can measure up to the base of the perpendicular plane.

This part also has some holes that are perpendicular to the top surface when the part is in this position.

If we want to measure the perpendicularity of the cylindrical axis of one of these holes to the surface the hole is drilled into, a touch probe is the best tool for the job. As seen in figure 4, points on the plane can be probed, and a star probe can then collect points along the cylinder walls. Those sets of points are fit to a plane and cylinder, respectively, and their angular relationship is measured.

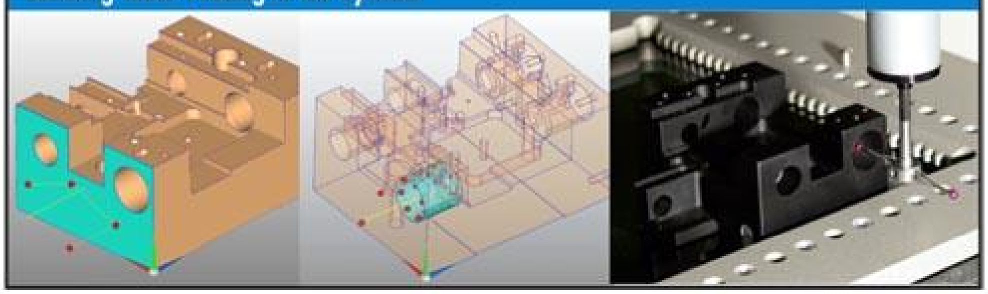


Figure 4: Plane and Perpendicular Cylinder in CAD Model of a Complex Machined Part Showing Touch-Probing of the Cylinder

All of the measurements described can be performed on one multisensor measurement machine with the part in a single location. None of the sensors is best for doing all of these measurements. Selecting the best sensor for each aspect of the total job depends on understanding what each does best. Using sensors properly can provide highly reliable measurements with far less effort that can show up positively on your bottom line. Who would have thought metrology could do that?
