Multisensor Measurement—*Making Sense of it All*

Multiple capabilities add up to multiple measurements of complex parts.

BY FRED MASON

It has been common practice for manufacturers to have separate measurement machines that excel at particular measurements. Today, driven by both economic and technological forces, the best of class of traditionally separate technologies are combined in multisensor measurement machines.

Multisensor measurement machines have existed since the 1980s, in response to changes in manufacturing technology. In an effort to reduce part counts, manufacturers use computer-aided design (CAD) and engineering tools to design parts with unique, complex shapes and tight dimensional tolerances. New multi-axis machine tools, EDM technology, advances in injection molding and other manufacturing technologies are turning out sophisticated parts with numerous physical features that have critical shapes, sizes and locations. Often, tiny features must have accurate relationships with bores or surfaces that are inches away or on opposite surfaces. Correct performance of the final product depends on each part meeting the design specifications in the CAD file.

Complexity of the part is one thing, but it is not the only thing. No matter the product or market, manufacturers also face increased pressure to reduce costs. To aid in this, machine tools now incorporate automatic tool changers, pallet loading systems and rotary indexers to reduce setup and handling times and increase throughput. However, some companies strive to achieve economies in manufacturing throughput but then subject their parts to traditional serial measurement practices.

The same considerations that go into reducing manufacturing time apply to reducing measurement time such as minimizing part handling, reducing the number of fixtures, cutting foot traffic between measurement machines and freeing up floor space. Because one machine can do most of the manufacturing, why not have one machine that can do most of the measurements? That's what multisensor measurement machines are all about.

Some companies may think that is what coordinate measuring machines do. Unfortunately it is not that simple. It is important to understand what particular sensors can and cannot do before jumping to conclusions about what measurement tool to use.

In video measurement, cameras have more pixels and better signal-to-noise ratios so imaging is improved. Innovative LED illumination improves edge detection. Digital signal processor technology speeds image processing. In laser technology, laser diodes have reduced the size

TECH TIPS

- Multisensor measurement machines feature the capabilities of different technologies in one machine.
- Well-designed multisensor measurement systems make it easy to create routines that automatically change sensors, rotate the part and track data.
- Software can integrate the data collected by the different sensors and generate the most precise measurement data possible.

Close up of a star touch probe extending through the LED illuminator of a video measurement system. An off-axis laser scanner is visible in the background. ***Photo: Optical Gaging Products Inc.***

and cost of sensors. Improved detectors and electronics have extended laser measurement ranges. Contact probes come in a wide range of sizes and sensitivities, and change racks allow for probe changes during a measurement routine.

Today, innovative systems based on these technologies incorporate these advancements to extend their measurement versatility and provide more value. However, even with these advancements, each of them can do things the others cannot. None of these individual technologies can do all the measurements that today's parts require.

Technological pros and cons

Each sensor system has its own pros and cons. Here is a look at the different technologies and how best they can be used.

- Video measurement systems excel at noncontact measurement of edges. In dimensional metrology, an edge is defined as the boundary between two areas of interest. Some-times it is where surfaces meet to form an edge, and sometimes it is simply a change in intensity because of color, surface type or gradient change. A video measuring system uses a camera sensor to acquire images of a part that are then analyzed with software. Automatic video systems have precision stages to move each feature into the imaging field of view either by moving the part to the optics or the optics to the part. This requires accurate stage motion and a rigid structural design to maintain the spatial (XYZ) relationships of all the features.

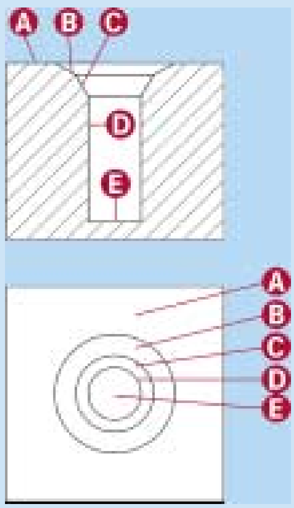
High-quality zoom optics, built specifically for metrology, have fewer optical aberrations than simple imaging lenses used in more forgiving machine vision applications. They can change magnification to capture high data density for small and large features. Computer numerical control (CNC) stage control allows video measurement to trace the edge of a part that is hundreds of times larger than the optics field of view. Autofocus makes sure features present the sharpest image to the camera sensor. A variety of illumination techniques are used to get the best contrast image for every measured feature. Edges and through-holes can be backlit. Programmable ring lights, made up of individually selectable rings and segments of LEDS, allow control of angle and direction of the light to highlight surface details as edges. Video measuring systems employ special edge-detection algorithms to identify and measure edges, including powerful weak-edge algorithms to find and analyze faint or subtle features while ignoring extraneous debris. And, video measurement is fast. Hundreds of data points around the circumference of a hole can be acquired in 1 second.

Video, however, can't measure everything. To measure an edge, the system must be able to image the edge. Although rotary indexers can present features on the part to the optics, sometimes the working distances of the optics or characteristics of the part prevent correct imaging. In a simple example, a counterbore may be deeper than the focus depth of the optics. This is where other sensors can help.

Simple Multisensor Application Example

Consider the part in the figure below with two chamfers (B, C) around a hole (E). They are concentric and have edges that can be imaged and measured with video. This provides the width and concentricity of each ground surface relative to the center of the bore.

Now consider measuring the angular relationships of those chamfers (B, C) relative to the plane (A). Edge measurement alone does not provide that information. Touch probes are physically too large to supply the required data point density.



Although video can do this measurement with focus points, a laser scan is the best tool for the job. Scan the laser across the plane and into the hole. The small spot size and rapid data acquisition speed provide sufficient data points so the resultant profile can be analyzed with software tools to measure the angles of the chamfers. The advantage of the laser in this case is that it acquires data across the surfaces, not just from edges.

Run multiple laser scans in parallel and get a map of the entire area. The laser's small spot size allows it to acquire numerous data points across each chamfer—far more than would be possible with a contact probe.

The complementary aspect of a touch probe becomes apparent on this simple part. Consider the walls of the bore (D). Because video measures edges, it can determine the edge of the bore near the top surface (where C and D meet) and bottom (where D and E meet). However, video may not be able to resolve possible changes in the shape of the bore along its depth. For example, is the bore perpendicular to the surface plane (A)? A laser cannot scan the walls of the bore (D) because the laser light cannot strike and reflect from its surface.

Now consider a touch probe. It can extend into the bore and acquire points throughout its depth. Such a measurement can be important if that bore is the reference against which all the other measurements are dependent.

This example of a simple manufactured part shows how the combination of sensors in a multisensor measurement system can combine to fully characterize important dimensions in a way that would be difficult or impossible for any one sensor-based system alone. Apply these concepts to parts with multiple complex geometries and the need is even more apparent.

Comparison of Major Multisensor Measurement Technologies

	VIDEO	TOUCH PROBE	LASER
Strengths	Edge detection	General purpose sampling	Surface information
	Fast data acquisition of edges	Surface information	Fast data acquisition over surfaces
	Noncontact	Access to internal features	Noncontact
Weaknesses	Features must be able to be imaged by system optics	Slow data acquisition Physical contact	Performance can be surface dependent

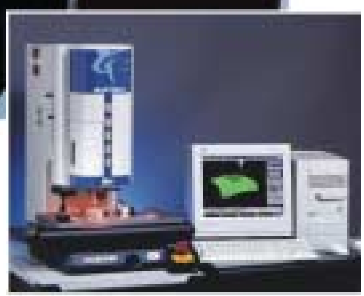
• Lasers also perform noncontact measurement. Several laser measurement techniques such as triangulation and Foucault knife-edge methods utilizing dynamic or null sensing can be used provided they can capture reflected laser light. Depending on the method, the reflected laser light strikes a detector that determines the image position, intensity or light distribution. That detected data corresponds to the position of the surface relative to the sensor. As the surface is scanned, either by moving it past the laser or moving the laser over the part, variations in surface height are detected and presented as a surface profile. This makes lasers suitable for contouring and shape measurement, where the surface can be defined as the boundary of a volume, as opposed to an edge.

Lasers have limitations too. For example, they can detect edges, but only at the spot where the beam passed over the edge. With video measurement, hundreds of points along the edge are captured simultaneously.

The benefits of combining the two technologies are obvious from this simple example, but there are other aspects to their complementary relationship. One example is using video to determine where on the part to scan with the laser.

• Touch probes collect data points about a surface from any point they contact. This means that as long as a feature is accessible, it is a candidate for probing. Probes are available in a wide variety of tip sizes and stylus lengths. A small probe on a long stylus can reach the bottom of a bore that may be beyond the range of both video and laser.

Touch probes have several limitations that prevent them from doing the entire measurement job. The probe can be physically larger than the feature being measured, perhaps too big to access the desired area. While scanning probes are available, traditional probing measures a single point at a time. The probe must approach the part surface, come in contact and back away to acquire each data point. This can be time consuming when collecting data points about a complicated part.



Multisensor measurement systems are available in a range of sizes from compact, benchtop models to large format systems. ***Photo: Optical Gaging Products Inc.***

How systems are different

Integrating data from a variety of sensors in a single measurement machine means that orchestrating the acquisition of those data points and analyzing them is vital to its efficient operation.

On the acquisition side, ease of programming is the consideration. An operator should be able to call upon any sensor at any point in a routine. The system software should acquire and retain the data from those sensors for subsequent analysis or output. Well-designed multisensor measurement systems make it easy to create routines that automatically change sensors, rotate the part and track the data so any operator can do the measurements.

On the analysis side, well-designed software provides numeric and graphic representations of the part. CAD import and export, form fitting, graphic models that can be manipulated, data transfer to reports or spreadsheets, and more, should all be integrated into the software so the calculations are automatically made during the measurement process.

Advances in sensor technology continue

Video, laser, and touch probe technologies are just three of the sensors that can be used in a multisensor measurement system. Extensions and enhancements of all these sensor technologies continue. For example, new metrology zoom lens designs incorporate aspheric optics, making them fully telecentric throughout their zoom range. This offers accuracy advantages along with the versatility of a wide range zoom lens that provides the correct resolution for every measured feature.

Several laser measurement technologies are available that are either offset from the optical axis, or work through-the-lens (TTL) of the video system. Each excels at particular applications.

In touch probe technology, there is

Is an edge a surface?

In dimensional metrology, an edge is defined as the boundary between two areas of interest. Sometimes it is where surfaces meet to form an edge, and sometimes it is simply a change in intensity because of color, surface type or gradient change. The geometry that these "edges" define can be extracted by measuring the actual transition with edge detection. Alternatively, data points from two surfaces are used to determine the theoretical edge location by calculating where two surfaces intersect.

A surface can be defined as the boundary of a volume. That volume is sometimes a geometric shape such as a plane, cylinder, cone or sphere. More often, however, a surface is a higher order curve made up of Non-Uniform Rational B-Splines (NURBS) or point coefficients. The metrology world has dealt with geometric shapes because they can have a nominal value and tolerance associated with them that defines the quality of the feature. But how can we control quality on parts solely composed of these complex surfaces? Multisensing uses multiple sensors to acquire data from the surface and edges, and compares the form of these surfaces to a nominal CAD file using modern fitting techniques. Multisensor machines measure both types of boundaries.

In today's advanced manufacturing environment, it is increasingly necessary to measure both surfaces and edges. That is where multisensing systems excel. Video excels at edge transitions, single point probing excels at prismatic element measurements, and laser scanning and continuous contact probing excel at surface contouring. How many parts have only one of these requirements?

continuous contact scanning. Similar to a laser scan of a surface, rather than probe a single point at a time, continuous contact acquires surface contours as the probe passes over a surface. It can work on surfaces that scatter laser light or are simply inaccessible to laser or video. Motorized probe heads add another level of flexibility to access critical part features. And, new sensor technologies will add to the versatility of multisensor measurement systems as they evolve to meet the changing needs of today's manufacturers.

Video measurement continues to meet the needs of manufacturers worldwide. Additional sensors expand its measurement capabilities to meet the demands of producing increasingly complex parts. Multisensor measurement is the multipurpose tool for the 21st century. Q

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