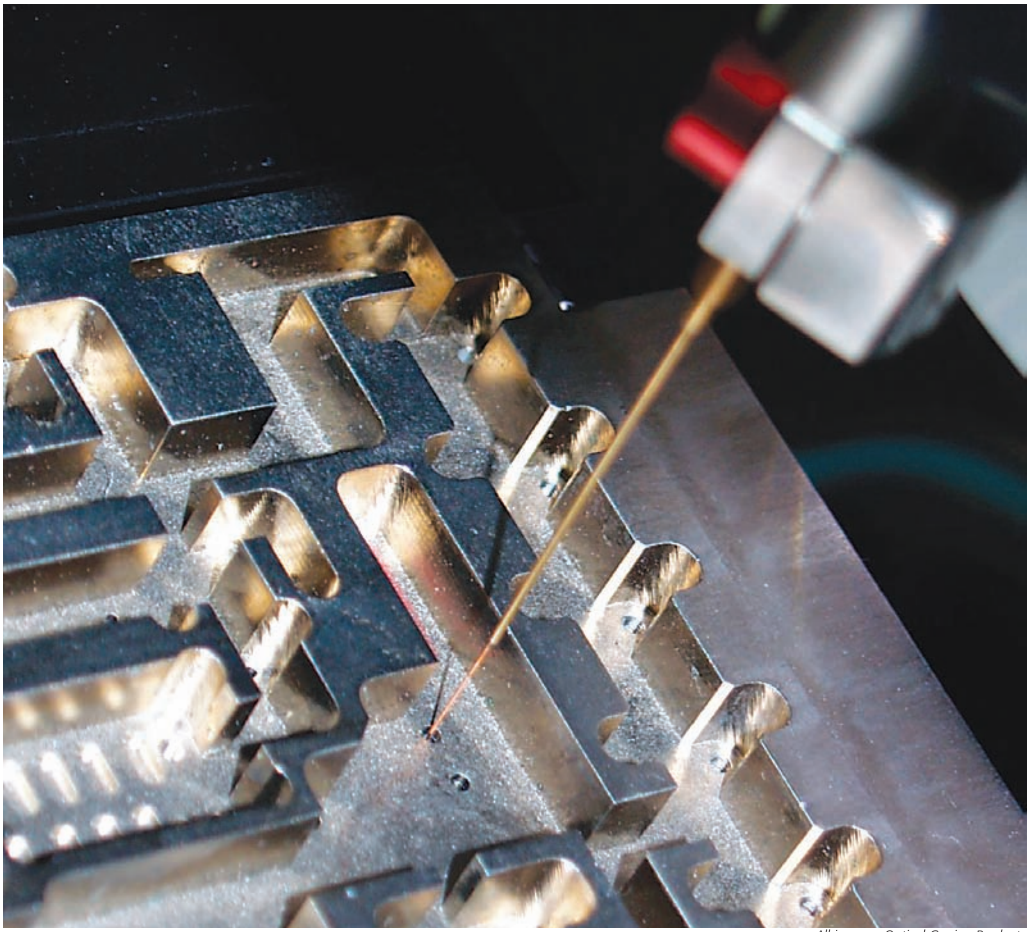
By Bill Verwys,
Optical Gaging Products Inc.

# Three ways to measure microparts



All images: Optical Gaging Products

Feather Probe from Optical Gaging Products uses changes in micromotion to measure various surfaces. Here it is used to measure a small hole made by EDMing.

Fabrication of micro components and devices often requires specialized metrology to confirm that critical dimensions meet design specifications. The fit and finish of microparts can affect the quality and performance of higher level assemblies and, ultimately, customer satisfaction with the supplier and its products.

Traditional metrology systems can perform some of these measurements. By teaming them with specialized sensor technologies, they can address even more microscale dimensions. These multisensor measurement systems combine the strengths of two or more sensor technologies in a single inspection system, allowing them to measure a part in one setup—an important benefit in many micromanufacturing operations. Multisensor system software controls the measurement process and uses data from all the sensors to verify that the part meets design specifications.

## Three predominant methods

There are three predominant measurement methods for dimensional metrology: video (measurement of features imaged by an optical system and camera), laser/point source (measurement of surfaces with a laser or similar light source and associated detection of reflected and scattered light) and tactile (use of a touch-trigger probe that registers a measurement via a triggering mechanism when the probe contacts a surface).

The noncontact sensors—video and laser/point source—measure surfaces and edges, while tactile probes reach part features inaccessible to the noncontact sensors, such as the walls of slots and holes.

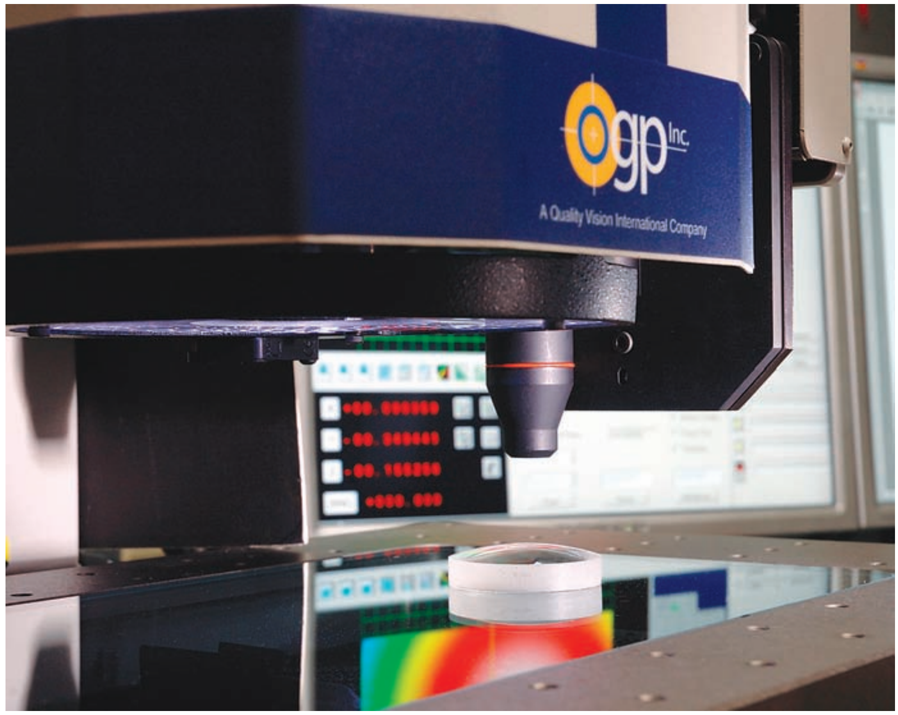
Tactile sensors, or touch probes, physically contact the surface to register a measurement.

Noncontact measurement means that a sensor does not physically contact the part. For example, video measurement captures an image of the part and then analyzes it. It's analogous to taking a snapshot and measuring that image. Laser measurement sends laser light to the surface, which reflects and scatters that light. The light is collected by a detector whose output is used to measure surface form, shape and position.

A video measurement system can measure microscale parts if its optical magnification is high enough. Image processing software uses subpixeling algorithms to determine image details within the optical field of view (FOV) with submicron precision. This technology is excellent for measuring edges, and the relationships (distances) between them, at the microscale.

Video measurement is limited in what it can measure perpendicular to the plane of the FOV. For example, a video measuring system can determine a step height by focusing on the step's top surface then focusing on the bottom surface and calculating the height difference between the two surfaces. However, it cannot provide information about the vertical wall that separates those two surfaces.

At the macroscale, a CMM touch probe is often used to measure these perpendicular surfaces. Traditional touch-trigger probes determine a measurement by triggering a switch as the probe tip is brought into contact with a surface. That technique is fine for rigid materials, but may be inappropriate for soft, pliable and deformable materials, such as some plastics and gels. In addition, touch-trigger technology does not easily scale down to the microscale because a thin trigger stylus may bend before a trigger is registered, making the position of the stylus tip uncertain.



Rainbow Probe from OGP uses chromatic analysis of reflected white light that is effective even when scanning a transparent surface.

Even when using a small-scale touch-trigger probe, the tactile measurement process requires that the probe be moved towards the surface, deflect slightly on contact and back off to trigger the measurement. For microscale parts, that travel distance requirement can be greater than the diameter of a hole being measured. In addition, when a probe enters a deep or narrow opening, the probe stylus may contact the top of the opening before the mechanism is triggered by tip contact (this is known as a shanking error).

## Microprobing technology

Fortunately, there is a variation on probing technology for micromeasurement that requires no stylus deflection. Essentially, the probe tip and stylus are scaled-down versions of traditional touch probes. But unlike traditional touch probing's triggering requirement, a measurement is registered when a change in the microprobe's constant motion is damped. Available with styli as small as 0.125mm in diameter and 10mm long, as the tip approaches the object to be measured, its micromotion is damped by its proximity to the part surface. This threshold-crossing change in micromotion is registered as a point measurement.

Since there is virtually zero deflection, the microprobe can measure details without the risk of shanking error. A microprobe is so sensitive that it can measure flexible or deformable materials. In fact, it can measure the surface of a liquid without disturbing the surface. And the technology allows the probe to approach the workpiece surface from any direction.

Noncontact point sensor technologies are also useful for micro-applications. One technology, the scanning white light probe, has both high lateral and height resolutions. Like a laser sensor, light is emitted, strikes the surface and is reflected. Its specialized electro-optical detector device analyzes the optical spectrum of reflected white light to determine the position of a surface. This spectral analysis gives sensor height resolutions to fractions of a wavelength of light.

In a motorized multisensor measurement system, the point of light is kept in focus automatically as it scans a surface. The metrology software tracks the X, Y and Z positions of the focal point within the machine's measurement volume, allowing it to quantify changes in surface heights as the focused point of light—which is a few microns in diameter—scans the surface. The combination of a small focal point and fine height resolution (to 0.01µm) makes the white light sensor appropriate for measuring intricate feature relationships. An example is the body of an injection-molded watch, with its various surface heights and widths. The scanning white light probe can verify critical dimensional relationships without contacting the part.

## Calibration is key

In multisensor measurement systems, each sensor is calibrated and ready for immediate use at any point in the inspection process. Measurement software includes calibration routines for that purpose. The routines are typically performed when a sensor is changed, such as when replacing a probe stylus and tip. Calibration tells the system where the probe tip is within the machine's measurement volume.

Dimensional-measurement software can analyze data from any of the sensors to verify critical dimensions. The software uses measured points, no matter their source, to construct quantified relationships that compare that part with a design drawing. For example, points from the circumference of a circle are connected by the software, which then calculates the pertinent dimensions, including diameter, radius, circumference, out-of-roundness and position relative to other part features. In the same way, points from edges of the part can be connected by lines that are then measured for parallelism, spacing and straightness.

Another advantage of multisensor measuring machines is that they have these measuring resolutions throughout their measuring volumes. In the case of video multisensor measuring machines, measurement volume typically ranges from as little as 100mm × 100mm × 50mm (X, Y and Z) to as much as 1,500mm × 1,200mm × 200mm or more. Video measuring systems have the high-resolution positioning mechanics required for high-magnification imaging of specific part locations anywhere within the system's measurement volume. Many systems incorporate motorized zoom lenses to provide a range of FOV sizes. Magnified areas range from tens to hundreds of millimeters square. Positions of features within those FOVs are determined to fractions of the size of individual pixels in the cameras.

An important fact about video measuring systems is that they are able to relate these highly accurate FOV measurements to one another. High-resolution linear scales in the machine's X, Y and Z axes allow measurement software to associate imaged features anywhere within the measurement volume to micron-level accuracy. In other words, modern video measuring systems do more than measure within a single magnified field of view—they provide quantitative data about microscale details over macro distances.

Video multisensor measurement systems combine the advantages of magnified imaging (for accurate determination of edges) with laser and white light point sensors for high-resolution profiles of surface forms and contours. They also incorporate tactile technologies that can inspect features that video and point-light sensors cannot image or access.

Metrology software uses measured points from all the sensors to derive dimensions that can be compared to design drawings for process verification and quality control. The use of multiple sensors on a single measuring machine allows it to take more measurements than would be possible on a single sensor-based machine, and offers the advantages of single-part setup and the coordination of all the sensor data in a common metrology software application.

Because of these benefits, multisensor measurement is popular in traditional manufacturing. And, thanks to advanced sensor technologies, these systems are finding application in micromanufacturing as well.

**About the author:** Bill Verwys is applications engineering manager for Optical Gaging Products Inc., Rochester, N.Y. Telephone: (800) OGP-GAGE. Web: www.ogpnet.com. E-mail: info@ogpnet.com.