# SMALL-PART METROLOGY

*Checking the tiny stuff*

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**Mida OP32 compact probing system from Marposs is designed for CNC micromilling machines, machining centers, and small machine tools. The probe is integrated in the transmitter module and measurement data are transmitted to the CNC via a receiver and an interface.**

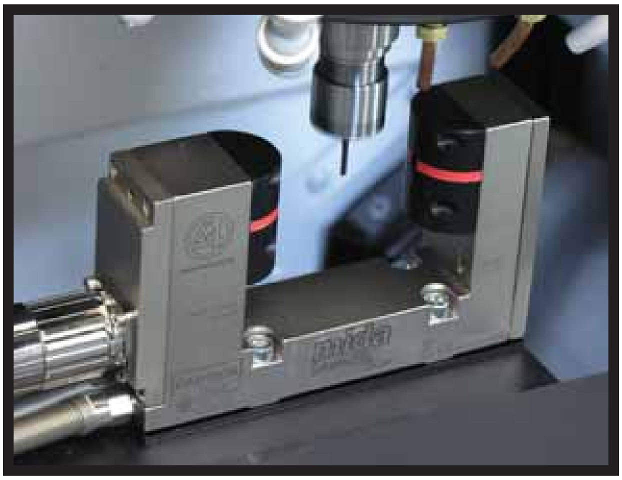
"We think we made the part to spec, but we're not sure," is a complaint sometimes heard from shops specializing in micromanufacturing. But plenty of help is available as a new generation of measuring instruments evolves.

There are two general methods of measuring parts: probing or scanning. Probes are used on parts you can touch. They are also needed on parts with recesses that can't be easily illuminated. For parts that are fragile, must be kept sterile, or are extremely small, some form of light (laser, white light, infrared) is used. Here are some of the more advanced instruments that can take on these tasks.

**Microlution** (Chicago) makes machine tools designed for mircomanufacturing, and has developed a metrology accessory for the Microlution 310-S to evaluate part production. It is a laser-based system for on-machine measurement of geometric features. The unit combines distance measurement in the *Z* axis from a confocal laser with scanning-position information from linear encoders in the machine's motion platform.

This combination gives 3-D coordinates of surface points. Achievable resolution (10 nm distance measurements with a 2µm laser-beam spot size) is said comparable to a surface profiler.

To measure a part, the kinematic mount system on the Microlution 310-S allows the tool spindle to be quickly replaced by the laser sensor with submicron repeatability. Parts can be pallet-mounted so the sensor can scan a number of units for higher-volume production. The point-cloud data generated can be used to determine dimensions and surface condition. The data can also be imported into third-party software packages.



**Marposs has responded to the growing demand for gaging small tools and the increasing number of micromilling machines with the Mida Laser 75 Pico noncontact tool-checking system. It measures tools to a diameter of 10 µm with a repeatability of up to 0.2 µm.**

**The Optiv machine line** from the Brown & Sharpe division of Hexagon Metrology (North Kingstown, RI) is that group's latest offering for inspection capability in the micromachining realm.

"This machine primarily uses vision-based inspection, and can be equipped with a variety of fully functional probes and light sensors," explains Product Manager Gary Hobart. "The Optiv is constructed from a series of "building-block" components to solve the customer's individual needs or applications."

Each sensor, whether it's touch, laser, or white light (WLS), can serve many purposes. But the vision probe is the fastest and most accurate for 2-D measurement. Although capable of *Z* measurement, the vision sensor's accuracy is impeded by the depth of field of the lens without assistance.

System accuracy depends on the sensor being used and the item measured. "A rule of thumb for a vision probe is to estimate a resolution of 0.1 pixel," says Hobart. "Measurement capabilities are in the order of 1/3 of a pixel or submicron level. With WLS, the resolution can be in the nano region, which is higher than the machine's mechanical-movement capability.

"The smallest article that can be measured is 1/3 of a pixel, and with high magnification this would be in the submicron area," he says. With high magnification, precision probing, and WLS light scanning are all linked to CAD inspection, dimensions are easier to determine.

**Many small parts** require optical metrology because they must be measured by a noncontact process. (Many features are much too small to be measure on equipment that makes contact with the part, such as small radii or tinyholes) Mitutoyo America (Aurora, IL ) offers these optical instruments with accuracies ranging from 0.3 to 5 µm. Standard accuracy for Quick Vision machines is 1.5 µm.

"We see a lot of demand for instruments used in R&D work, as well as those that can function well near the machine tools," says Allen Cius, vision product specialist for Mitutoyo "Most are manually loaded, but we can have units that are fed by robots when high volume production is required.

Initially, when you create a part program, you place a part on the stage glass and roughly locate it," he explains. "Next, you can establish an axis or reference point utilizing the automatic edge detection tools. All of the motions you go through while creating a part program are "remembered" and stored as program. If the camera can see it, we can measure it." Once the program is completed it can be used to create automatic part inspections. The user would simply place the part in a holding fixture on the stage, hit a button, and walk away while the vision machine performs all of the measurement requirements autonomously.

There are three types of lighting for vision systems: stage lighting, through-the-lens (also called coaxial lighting), and a programmable ring light. The type of lighting used depends on the complexity of the product and the number of surfaces that must be illuminated.

Stage lighting is the simplest, (this lighting acts much like an optical comparator).

Coaxial lighting comes through the lens and is used chiefly to illuminate the surface of the part.

The most useful lighting is the programmable ring of red, green, and blue LEDs. The different colors make it easier to define edges or changes in part texture. Because the parabolic ring is movable independent of the camera, it's possible to change the angle of light incidence to get the optimum view.

One of the newer designs from Mitutoyo is their Quick Vision Stream (QVS) series which uses stroboscopic illumination instead of a CCD camera to capture images during the motion of the machine. Instead of utilizing the standard CCD sensor a progressive scanning camera is used.

The QV Stream uses a newly developed, high-intensity LED flash illuminator that enables nonstop vision measurement. Precisely when the stage carrying the part reaches a measurement point, a short, high-intensity flash effectively freezes motion. There is no blur, and the part image is captured in full and accurate detail. The resulting images record key coordinates for each part.

"In one application, the QV Stream system was able to check 30,000 small-diameter holes in a solar panel in 45 min," says Cius. "Every hole size, location, and position was recorded."

There are several versions of the QV stream system with working envelopes varying from 300 × 300 × 250 mm to 600 × 650 × 250 mm. Resolution for all units is 0.1 µm

"In other cases, you can't measure on the machine. So, for very small ODs, down to 0.5 mm we suggest an off-line optical system that uses a shadow cast by an infrared light to give a dimension. Measurement accuracy depends on the camera's resolution.

"Another caution: Don't touch the part," says Powell. "Oily fingers or even a worker's body temperature can influence accuracy."

Tools used in micromachining are almost always very small, with 0.0002" (0.005-mm) diam drills are not uncommon. So, it's important to know if they are actually in the machine. "That's why we offer a noncontact laser system that can give the length and diameter of tools as small as 30 µm," states Sharad Mundra, Mida Probing product manager at Marposs.

A wireless probe is useful on small machines. The Marposs unit has a stylus with a transmitter/receiver unit measuring 32 × 50 mm that is hardened for in-machine use.

For measuring parts with inner and outer diameters smaller than 1 mm, Marposs offers the M39S scanning system. It uses an Air-to-Electronic technology to measure in scanning mode inner and outer diameters as small as and to verify the clearance along the total matching surface. The M39S measures and graphically displays information, and detects errors in the diameter, cylindrical form, and matching surfaces of shafts and bores. For example, it would be used to check the clearance between a bore and a shaft having an 0.8 mm diam. There is no contact between the measuring unit and the part.

**"Measurement accuracy**
*depends on the camera's resolution."*

Marposs Corp. (Auburn Hills, MI ) has measuring systems that work with diameters down to 1 mm. "In applying these instruments, we have found that two of the most difficult products in the micromachining area are microbearings and fuel injectors, with measurements commonly made to 0.5 mm," explains Frank Powell, product manager.

One of the Marposs instruments developed to meet these requirements is the Picothruvar through-the-spindle, in-process ID measuring head. This instrument, used on an internal grinding machine and mounted opposite the grinding wheel, can get into small ID spaces to make measurements. Because space is very limited, both the wheel and gage can't fit into the opening, so the gage and wheel alternate in a grind-measure-grind sequence.

"For more efficient grinding operations, the gage incorporates a continuous curve memory," he says. With each reciprocation stroke of the gage, the size is compared with the result of the previous check. The amplifier then calculates the rate of change of part size so that the control output to the machine is triggered at the appropriate time.

"Small bores are one of our biggest problems," says Powell. "Contact gages won't work so you have to go to an air gage. When you use an air gage depends on the diameter-hole depth ratio. For example, the air gage would be essential for a 2-mm bore, 20-mm deep.

Marposs air converter is a device which is part of a measuring system based on pneumatic technology, following principles of pneumo-electronic measure. A dimensional variation of the part to be measured is read by the converter like a pressure variation, which is then transformed into an analog electric signal.

"We find that aerospace components are a strong driver for the micro-machining industry," explains Myles Richard, Managing Director of Metris USA (Brighton, MI). Their main focus is on achieving the highest possible measurement accuracy while thoroughly capturing critical features on parts. The ability to add noncontact laser scanning to an existing CMM provides more versatility. By using a Metris CMM or retrofitting an existing CMM with a Metris laser scanner adds tremendous benefit and increased efficiency for achieving the highest possible results.

The ceramic based, Metris LK-V 876 bridge CMM is one example of a multisensor solution that provides both touch probe and laser scanning on one system. Configured for high accuracy in a lab appropriate environment, this solution is capable of producing results within 2.5 µm (volumetric accuracy 250 millionths, repeatable to 60 millionths) and is test measured according to ISO 10-3-60 standards. "This multi sensor approach allows the micromachining industry to leverage the power of each scanning technology when and where necessary. For example, when measuring a hole feature, you only need three points and a probe works best, but with a contoured surface with many details and features, the non-contact laser scanner and dense data cloud it provides is more suitable," comments Richard.

Metris offers equipment for micro-to-small measurement for high accuracy applications, optical and portable systems for industrial shop-floor environments, as well as large-scale metrology for applications and parts 16-60 m in size.

**Optiva machine from the Brown & Sharpe group of Hexagon primarily uses vision-based inspection, but can be equipped with a variety of additional fully-functional probes including touch, laser, and white-light sensors.**

"Today, laser scanning is still relatively new to many metrology groups, and Metris's ability to help consult, support and educate the customer on the value of this type of technology prior to making an investment is key, says Richard. Often, the perception is new equipment introduces major changes to the buyer's processes, this is where Metris's long term experience and knowledge is critical".

"The power of the PC and growth of video technology have allowed this segment of metrology to advance," says Managing Director Mark Arenal, Starrett Kinemetric Div. (Athol, MA). "This gives a great deal of digital information for image evaluation and complex measurements."

For some time, the optical comparator was the main instrument used in many applications, but parts kept getting smaller and tolerances tighter. Magnification, seeing fine details and features, and efficiency became a problem for many shops. Higher resolution and greater versatility was needed. First came the noncontact video measuring machine, then touch probes and lasers were added for more complex applications. So today you can purchase a coordinate-positioning platform that combines the strengths of laser and optical noncontact, plus the contact touch probes.

The high-end systems are typically more difficult to operate, and require a higher level of training. At the entry level, basic units are easier to operate, like a video comparator or toolmaker's microscope.

"The industry is growing," says Arenal. "There are a lot of ways to do the job, so you try to choose the best system. It's driven both by the application and the results the equipment can generate. You not only get the quantitative data quickly, but qualitative data too.

"For parts with complex contoured 3-D aspects, laser sensing may be a good choice. You get a set of data points that can give you that complex shape. For larger parts with a lot of recesses, the touch probe might be best. Video is best for parts where a touch probe will not reach critical areas with fine detail and magnification is essential."

Size plays a big part. "For an aspirin-size part, sensing typically has to be noncontact. With large parts such as features on an aircraft wing spar, that will most likely require using a touch probe," says Arenal. "Larger format/travel video measurement systems are best when working with large flat or flexible parts. For example, a large, flat part with an etched surface that can't be touched might use a long-travel noncontact machine with a video sensor.

The strength of a video system is in measuring 2 or 2.5-D parts. "Our low-cost video measurement system allows complex measurements, with simple edge detection being a key feature," says Arenal. "It is used chiefly for one-off or low-volume jobs, and is the next step up from the toolmaker's microscope or optical comparator. These machines are designed to be upgraded to motorized operation.

The latest Zeiss offering for the micromanufacturing industry is the F25. This instrument delivers a measurement uncertainty guaranteed not to exceed 250 nm and features both a tactile sensor as well as a state-of-the-art optical system.

With a system using a probe, a key issue is keeping the probe from distorting or moving the part. The Zeiss system has solved this problem by designing a probe system with a measurement pressure of 0.5 mN, which is about 1/200 of that found in most probes. The probe can use spheres as small as 0.12 mm in diameter.

”The biggest challenge when measuring in this low uncertainty is thermal influence,” says New Product Manager, Precision Products, Gerrit deGlee. “To handle that problem, the machine has a scale made from a glass-ceramic material that combines molecules. Some expand when heated, and other contracts, so the net result is virtually zero expansion. The thermal expansion coefficient uncertainty alone would be beyond the accuracy we are trying to reach. These scales also allow us to eliminate thermal sensors which also would contribute to measurement uncertainty.”■

*“For larger parts with a lot of recesses,* **the touch probe might be the best choice.”**