Laser 3-D scanning is ideal for complex-shaped injection-molded plastic parts, such as this one scanned by a ShapeGrabber laser.

AUTO MANUFACTURING FOCUSES ON VISION

With advances in noncontact, light-based metrology, automakers may now be able to measure every part. Should they?

Bruce Morey
Contributing Editor

"If people ask me what the megatrend in metrology is today, I always tell them it is optical," says Andreas Blind, vice president of Hommel-Etamic (Rochester Hills, MI). This includes any noncontact metrology device that uses light, laser, and sensing devices. Advantages are many, including data volume, speed, and flexibility. While many industries find these qualities attractive, some of the trends in automotive manufacturing—especially in powertrain, a specialty of Blind's company—uniquely benefit.

Why? One fact Blind notes is that automotive manufacturers today face uncertain production volumes with roller coaster demand, up one year, down the next. There are also shorter production runs along with faster product development cycles. With part runs dropping into the 100,000s today from millions in the old days, manufacturers are striving to make their lines as flexible as possible. At the same time, there is a push for tighter tolerances, driven by everything from aesthetics for bodywork to better fuel efficiency in engines. "Automotive manufacturers are competing on quality more than ever, driving advances in production metrology," he explains. Where purpose-built hard gaging could be cost-effective over long production runs, this is not necessarily the case anymore. In response, the company is expanding its offerings in fast and flexible optical metrology, to supplement rather than replace gaging using pneumatic sensors and tactile probes.

The company is also exploiting a somewhat limited definition of what automakers mean by flexible.

There's Flexible and Then There's Flexible

"They want flexible, but not necessarily a [cylinder] head today and [an engine] block tomorrow. They want flexibility within certain, standard limitations," he says. "They want variations within a standard product portfolio." A good example of how Hommel-Etamic exploits this is its Opticline series of optical metrology systems. Designed to measure long, round workpieces such as crankshafts, camshafts, and drive shafts, these systems operate directly on the production floor. An LED light source illuminates a shaft rotating between centers while a high-resolution CCD line sensor captures the silhouetted shadow, digitally measuring the contour as the piece rotates. Designed for 100% inspection, it measures diameters to 2 + D/100 µm and lengths to 5 + L/100 µm, both to ISO 10360. The Opticline C800 series measures workpieces with a diameter of up to 140 mm, a length of up to maximum 850 mm and that weigh up to 20 kg.

Blind also points out that—even as optical noncontact sensing is becoming mainstream—there is still resistance from a significant segment of manufacturing professionals. Engineers are familiar with hard gaging, master artifacts, and gage R&R studies using such devices. "There is a problem with standards in optical sensing. To use a known artifact, to find the ranges and run a repeatability study—it is quite different with an optical system," he says. In addition, occasionally the cost to clean parts to prepare them for optical gaging can become a factor. However, the flexibility and speed of optical gaging offers an unparalleled tool for quality measurement and evaluation of complex parts as well as for manufacturing process control, Blind says.

Photo courtesy Faro

Castings are another ideal part for noncontact sensing and 3-D imaging. Measuring is often done on the production floor near the point of manufacture, though statistical sampling remains the norm in automotive parts.

The increasingly complex, organic shapes of automotive parts is another challenge that noncontact metrology is well suited for. "There are many drivers for this," explains Pierre 'Pete' Aubrey, president and CEO of ShapeGrabber (Ottawa, ON, Canada). "Consumers want better ergonomics and more pleasing aesthetics in their vehicles, which leads to more complex-shaped and curved parts. There is also the driver of better fuel economy, so as cars get smaller and more parts get put on the engine, the engine compartment is getting more packed with components in a small space." In addition, advances in CAD/CAM and multiple-axis machining are giving automakers the ability to make complex, compound curved parts. "In a way, they do it because they can," he remarks.

Measuring such parts with traditional methods may not capture all the data needed, particularly if the part has compound curves, multiple features, and other organic shapes. Enter 3-D laser scanners like the ShapeGrabber line of systems in various sizes. The largest can handle parts up to 4' (1.2 m), such as body panels or car doors. The laser scanner is enclosed in a cabinet and is used by production personnel. Aubrey notes that one only needs to put a part on the scanning machine and ensure that it is stationary during data capture. ShapeGrabber does not require special, precise, locator fixturing because the alignment to datums is handled in post-processing software using the CAD model of the part. "The system is ideal for plastic injection molded parts, castings, and stampings," he says. These are parts with complex, blended curves in today's vehicles. This is where a 3-D scanner is ideal with its ability to deliver measurements starting at ± 0.001" (0.025 mm) of uncertainty.

Automating the Scanning

"It has become easy to implement a 3-D scanner like ours because automating the scanning and post-processing allows nonexperts to use it," Aubrey says. He points out the software used with the system can help with SPC collection and analysis. ShapeGrabber has interfaces to most metrology packages, in particular industry leaders Geomagic (Morrisville, NC) and PolyWorks from Innovmetric (Quebec, QC, Canada).

Automation, such as this robotically operated WL400 white light system, provides options and choices for measuring near or on the production line, especially when the manufacturing line moves from the prove-out stage to full run-at-rate.

"Our sweet spot in the market place is with Tier 2 suppliers—folks making smaller parts that are assembled into vehicles," Aubrey says. He makes no secret that his company is competing with traditional fixed or hard gages still common in this segment of the industry. Although individual gages may be cheaper, and sometimes faster, he also notes they take only six to 12 measurements per part, and one gage is needed for each part produced. In contrast, a ShapeGrabber scanner used with the metrology software is a virtual gage, which is much more flexible. "Hard gages are quite limited in scope and can't handle 'inspection creep,'" he says. This is the increase of production measurement requirements over time, usually due to unforeseen problems and/or rejects down the line. It is much easier to modify a virtual gage than to redesign and retrofit a hard gage.

"Optoelectronic systems are far more flexible than hard gaging, but there are tradeoffs," agrees Roger Zeoli, product manager for Marposs Corp. (Auburn Hills, MI). His company also sees the value in flexible metrology with its noncontact-based Optoquick and Optoflex systems. Both systems use shadow cast technology in a closed cabinet. Again, designed for the shop floor, manufacturers could integrate them into a production line or use them as an audit station, or as a post-process inspection. The Optoquick comes in either horizontal or vertical layouts. Designed for shaft-like parts like crankshafts and camshafts, they both feature a universal reference master located in the machine, with a self-zeroing cycle. Similar to other systems, the number of parts that could be measured is limited only by their physical size and weight. The Optoquick measures parts up to 750 mm in length and from 0 to 155 mm in diameter (measurable.) The M110 Optoflex measures parts up to 800 mm in length and 200 mm in diameter. Both boast measuring uncertainties of less than 2 µm for diameters and less than 6 µm in length. The systems offer Statistical Process Control (SPC) software on both models for analyzing measurements at the station.

Measuring programs are stored electronically and selected for each part. There could be many parts. "Parts are limited only by their size," says Zeoli. He too offers cautions about unbounded or unwarranted notions of flexibility. While the data volumes and accuracies these machines deliver are impressive, there is still a place for hard gaging with traditional touch probes or linear variable differential transformer sensors, according to Zeoli. For example, the Optoquick measures in the axial direction at 20 mm/sec and angularly at 1.5 revolutions/sec. Impressive speed with thousands, even millions of data points. However, Zeoli points out that hard gaging can be much faster. Admittedly, they take far fewer measurement points. However, they are accurate and take less than 30 seconds for similar parts, while it may take minutes to measure a whole shaft optically, he adds.

Design and Production

Automation is a key element for noncontact metrology. Nikon Metrology (Brighton, MI) provides a number of laser scanner and optical systems for use in automotive design studios, research centers, and pilot plants as well as in production plants. "For production inspection, you want something that is as automatic as possible," explains Alex Lucas, product manager for Nikon Metrology. "We deliver many dual-arm CMMs along with our CMM-based laser scanners for those applications. The laser scanner provides advantages in speed, high accuracy, and ease of programming and use." A typical dual-arm CMM include Nikon's LK H brand, such as the LK H-R with rail lengths from 4 to 10 m or more. While equipped standard with a PH10MQ touch probe, these horizontal-arm CMMs can also be equipped with one of Nikon's laser scan heads. "The most popular is the XC65Dx-LS," notes Lucas. "I estimate it is at least 75% of all scanners we sell into production inspection for automotive applications."

The XC65Dx-LS uses a cross pattern of three laser stripes, acquiring a better 3-D view when scanning parts with more complex surface shapes and better able to detect holes and edges. Its measuring uncertainty is 20 μm to 1σ within a 3 × 65-mm field of view. "The real advantage of that over other CMM scanning products is the long standoff distance of 170 mm. That is where LS comes from," says Lucas. This is the maximum distance the sensor head can be away from the surface it is measuring. This provides better maneuverability and makes it easier to program the CMM. "We can also deliver this onto third-party CMMs; we are not limited to Nikon equipment," remarks Lucas. Ideal for sheetmetal and stamped parts, he notes customers are using the XC65Dx-LS to measure parts ranging from individual components all the way to entire bodies-in-white.

He notes that few customers want to exploit the increased speed of scanning for 100% inspection. Most, if not all, prefer to remain with a statistical sampling for production and process control. "3-D scanning provides the capability to measure parts fully. You can compare the measurements with CAD to produce full color, 3-D renditions of deviations. However, production people are not that interested in that," he says, remaining the domain of research labs or engineers engaged in troubleshooting of designs or process. "What most want is to quickly get data they need to track their processes. So we have many customers who replace a touch trigger probe with a laser and sample just a few areas with what might be termed targeted laser scanning and reduce the data down to specific (*x*-*y*-*z*) points for comparisons," he explains. This delivers faster measuring cycles, usually between 50% and 70% faster. He also believes that large-scale plastic components, such as instrument panels, are becoming more interesting for this targeted laser scanning approach, especially involving soft materials that might be deflected by a touch or scanning analog probe.

White Light Systems

White light systems are another device that offers wide-area scanning for noncontact metrology. Under the Cognitens brand, Hexagon Metrology (North Kingstown, RI) offers white light (now actually blue) sensors for 3-D measurements ideal for automotive bodywork. Using fringe patterns, these noncontact/vision systems capture data in up to 500 × 500 mm tiles, delivering measurement accuracy for a one-meter volume at about 25 μm to 2 σ, according to Cliff Bliss, national manager for Cognitens. There is a manual option, the WLS400M, and an automated system, the WLS400A, that work with off-the-shelf robots. Their market niche is bigger parts as well, body stampings and bodies-in-white, according to Bliss.

Photo courtesy Hommel-Etamic America

Fully enclosed cabinets containing optical measuring devices are ideal for placing near or on the production floor.

Bliss sees a difference in how the systems are used. "Historically, the manual system has sold better than the automated system, but I see that changing as time goes on," he says. Manual systems have proven themselves in assembly prove-outs, tool try-outs, and the general development process in manufacturing. Tooling and dies for stampings are measured meticulously during initial first shots, where engineers tune in the die prior to full-run production. They find their use in slow builds, often used to prove-out assembly procedures prior to ramping up to run-at-rate. Typically, at this stage, much of a part is checked and color maps of deviations are created. All parts are checked at this stage.

Photo courtesy Marposs

Constricting measurements to a class of objects, such as shaft-like objects, is a way for automakers to use equipment in a way that is flexible for their needs while maintaining speed and accuracy.

"The automated systems are used when they transition to steady-state production, and we are seeing a definite ramp-up in both inquiries and sales for the WLS400A," reports Bliss. At this stage, he also sees that fewer elements of the part are measured. Sampling replaces 100% inspection and SPC software, such as Hexagon's CoreView Pro is used to analyze and present results.

A New Twist on White Light

Another, relatively new, white light area sensor for metrology is the Faro AMP 3-D imaging system. It exploits Accordion Fringe Interferometry (AFI) and measures data over a 500 × 500 × 220-mm field of view to 65 µm of uncertainty as measured to the VDI/VDE 2634 part 2 specification, according to Chuck Pfeffer, director of product management, Faro Technologies Inc. (Lake Mary, FL). Like white light systems, the AMP is ideal for measuring large parts such as body panels as well as the dies that make them. He reports the AMP system is also used in proving out a stamping process prior to run-at-rate for body panels and car bodies.

Pfeffer particularly notes that the AMP is often used in casting operations. "They use the AMP to measure both the molds used for casting and the cast parts themselves," he explains. Many cast parts go on to finish machining, where they use the AMP sensor to measure the casting before machining, according to Pfeffer. They map each casting to determine variations in actual wall thickness, using that data to fine tune the subsequent machining process. They use the AMP system right on the production floor since it was designed to be stable and robust. An option for the AMP is automation. Some manufacturers, according to Pfeffer, measure cast parts with 100% inspection before machining, though he notes that is infrequently done in automotive. "They usually measure 100% for a run until they're comfortable with the process, letting them find out if the casting process has a problem," he says. After that, they continue to use the system through sampling products and SPC.

What is in store next? "The automotive industry has dabbled in 3-D scanning in the past, mostly in design and design labs. Some of the big OEMs have been using it in assembly inspection. Now, I see a big push from the Tier 1 and Tier 2s to implement 3-D scanning as the basic way to inspect their parts. That is going to be happening in this decade—for all scanning systems," says ShapeGrabber's Aubrey. There is also untapped potential in the data that these systems provide. "When they go into production, they gather metrology data and use it to determine pass/fail criteria on parts. Only when they detect a failure do they look at the data," says Bliss. "But there is a whole universe of how to use that data, from preventive maintenance to even using it to fine-tune finite-element analysis." Although some groups use the data outside the narrow use of metrology, according to Bliss, a more comprehensive look at the data could unlock much more value. **ME**

Manufacturing ENGINEERING
SEPTEMBER 2012