Both hardware and software have improved drastically in recent years, leading to inspection machines that are more accurate and versatile than ever before.

By Brian Slone
The value of analytical gear measurement grows as advances in technology allow gears to be measured in ways that help diagnose complex manufacturing problems. Is it enough to measure just index, helix (lead), and involute profile on a gear? Manufacturing engineers want information to help them determine why these three key gear attributes are not within specification, and how these attributes relate to other features in an assembly. Was it the cutter, machine, machine settings, heat treatment, or the gear blank that caused the part to be out of tolerance?

CNC analytical gear measurement systems have traditionally measured index, helix, and involute profiles, but with today’s advancements in probing systems and the improvements in the capabilities of computers and controls, inspection machines can now take advantage of error compensation that allows related geometric features to be measured with respect to gear features. Geometric relationships have become extremely critical and more relevant since many gears used in automotive transmissions today are being laser or high-speed pulse welded to stamped components and assemblies. Perpendicularity and concentricity relationships of gear bores to stamped sheet metal components need to be held to tight tolerances. With a “related features” software program, geometric relations can be monitored in addition to the typical gear attributes.

This added measurement capability decreased the time to troubleshoot processes for gear manufacturers of both traditional—hobbing, shaping, broaching, etc.—and nontraditional manufacturing methods, such as plastic and powdered metal die formed. The latest technology not only helps with today’s problem-solving, but it also allows for efficient support of the machines in the future.

Advancements in CNC analytical gear inspection can be categorized into two major areas of improvement; machine hardware and software.

**Hardware**

An important hardware advancement has been the move away from 1-D LVDT probes to off-the-shelf 3-D probe systems. Utilization of “full floating” three-axis probes have allowed inspection machines to access features previously off limits to a 1-D probe (see Fig. 7). Root scanning is one example of this, due to the need for the probe to read surface normal deviations in multiple axes (see Fig. 9). Measuring in multiple axes without having to manually change probe orientation has enabled features such as roundness and flatness to be measured consecutively during a standard gear measurement. With probe tips available down to .006”/.015mm diameter on these 3-D probes, gears with diametral pitches of 120 (.21 MOD) are now being inspected.

Analytical machines are now using non-contact linear motor drives to power their linear axes, which has eliminated ballscrew drives and other noise generating components such as rotary bearings, belts, and pulleys. This has helped the reliability of CNC machines significantly.
Modular inspection machine designs that are using off-the-shelf technology for their motion platforms insure access to available hardware and electronics now and into the future. Designs now allow for stocked replacement components such as linear guide-ways to be replaced on used machines. The upgraded systems can then be “re-mapped,” yielding a “new” hardware platform with the same mechanical accuracy that it had when the machine was first purchased. Modular machine components can also save on extended downtime due to the quick interchangeable design if there happens to be a component failure.

Software

Probably the most significant improvement to gear metrology equipment in the last decade is in the area of software development. Modern software platforms have been developed to take advantage of the continual changes in PC hardware and peripherals. No longer are customers tied to only one computer or printer brand, making it easy for a machine owner to upgrade themselves when their computer technology becomes obsolete. Motion control-lers can be connected to computers with a single USB cable for easy upgrade of computer hardware.

Windows® has turned what was once an inspection machine for “experts only” into a tool that everyone in the plant could operate. Standard Windows controls and dialog boxes guide even the novice gear inspector through an easy to navigate, step by step data entry process. Once the part parameters are loaded into a Windows-compatible database, an operator can measure a part in a two-step process: 1) select the part to be measured in the database; 2) click “run.”

Another unique advantage of the Windows platform is the availability of context-sensitive help that can be accessed by pressing the F1 key. This gives the user immediate information about software and machine operation.

Analysis to various gear standards has also become much easier with modern software platform designs. The “raw” inspection data is saved, allowing components to be re-analyzed without re-measuring the parts. For example, if a part is inspected to an AGMA standard and the operator would like to see the ISO equivalent, a single keystroke can convert all of the inspection results immediately. Since the data is saved in its “raw” format, future analysis can be done as well.

A major benefit of a Windows software platform is that it allows for open access to the part inspection data files, allowing other third-party software companies to use the data to perform post-inspection analysis that may help the user gain a deeper understanding of the components that they are manufacturing. This is a very easy operation utilizing a true Windows software platform and comma or space delimited text files. Traditional machines have used BASIC interpreters with binary output file formats that aren’t as easy to access by third-party software suppliers, thus limiting the information to end user. The ability to use the Windows environment has opened up an opportunity to do inspections and share data like never before.

Sharing data can reduce the modification time for die manufacturers looking for X-Y plot
information to make the necessary modifications to an existing form die (see Fig. 8). This access can allow for X-Y input into a wire EDM machine for the specific form corrections on the die. With this type of data accessible, the die supplier could make modifications that would be based on the numerical data and not have to run multiple samples to incrementally adjust the die (see case study #1).

A unique feature of the Next Dimension® Series Gear Measurement Machine from Process Equipment Company is the capability that allows the 3-D inspection probe to actually follow the part coordinates as the component part rotates in space on the rotary table. It doesn’t matter if the part datums that are established with the 3-D probe are in alignment with the machine axis or not, since the software keeps track...
Metrology Applications: Case Study #2

Problem: A ground helical gear was measured relative to its bore, mounted on an inspection arbor to verify its quality. The helix traces showed a crossed trace condition, or “wobble,” of the component. The manufacturer showed that the helix traces were to specification when measured on a manual lead checker while mounted to the grinding work arbor. To solve the mystery, the gear was measured relative to several different datum locations to isolate the real issue.

The two additional checks were performed using different datums. First the references were established on the OD at two different heights, and then on the PCD at two different heights. The result of the OD reference showed the same outcome as measuring to the bore; crossed helix traces. The result of the PCD reference showed a different outcome, that the helix traces were in tolerance.

To confirm the suspicion that the gear was not ground correctly to the bore of the gear blank, an additional test was performed to determine if the gear blank face was perpendicular to the bore & OD. Using the “related features function” in the PECO software, perpendicularity was found to be .008 mm when checked to the OD of the part but measured .096 mm when measured relative to the PCD. This verified that the gear blank was correct and the gear was not ground to the gear blank’s axis. (See Fig. 3)

Conclusion: An arbor mounting problem during the grind operation was the source of error. The part was not mounted perpendicular to the grinding arbor.

Thanks to advances in both hardware and software, CNC gear inspection has become easier for operators to measure parts, obtain results, and interpret data to troubleshoot manufacturing processes. With the goal of producing a given batch of components to the required dimensional accuracy with minimum cost and in the least amount of time, advancements in technology need to be continually investigated to find tools that can have a direct impact on our customer’s quality, cost, and delivery.
INSPECTION RESULTS (FIGS. 4-9):

FIGURE 3: GROUND GEAR MOUNTED TO INSPECTION ARBOR

FIGURE 4: REFERENCE OD

FIGURE 5: REFERENCE BORE

FIGURE 6: REFERENCE PCD

FIGURE 9: ROOT SCAN

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To ease communication challenges encountered by companies working with divisions or subsidiaries outside the United States, PECo has developed a language module for its newly released ND300 Gear Measurement Machine. The first language available is Mandarin Chinese. With the module, the user has the ability to view gear inspection results in Mandarin Chinese or English, switching back and forth with just a single key stroke. Accurate translation allows for clear communication of parts parameters and inspection information between engineers having manufacturing operations in both China and the U.S. The PECo language module is also designed to support German, Japanese, Spanish, and other languages to provide true global support to the gear market.

In addition to the language module, PECo has released automatic probe tip changers for the Renishaw® SP600 probe. The automatic probe tip changers eliminate the need for operator involvement in complex part inspections requiring multiple tips thus freeing the operator to perform other duties while the part runs unattended.

The Next Dimension ND300 is the latest advancement in a line of machines and technology designed and manufactured by PECo to support gear, spline, and worm producers and users worldwide.

The latest Next Dimension model, the ND300 CNC Gear Inspection System, is a reduced footprint version of the PECo ND430 with added capabilities for both the domestic and international markets. PECo was the first gear inspection system manufacturer to offer “off-the-shelf” 3-D scanning probe technology from Renishaw when the ND430 was released in the late 1990s. This 3-D capability allows for geometric measurements to be made on rotary components, as well as gears.

With the cutting tool packages complete for most gear generating processes—such as hobbing, shaping, and shaving—PECo is able to support the metrology needs for parallel axis gearing on a global scale.