

Measurement Management

The secret to meeting today's inspection demands is influenced by the technology and those in charge of operating it.

Matthew Jaster, Senior Editor

Data-driven manufacturing is changing the shop floor in so many unique ways that it's only logical the technology and personnel need to follow suit. Many gear shops are manufacturing additional components in 2019 and many non-traditional job shops are starting to manufacture gears. This presents both a challenge and an opportunity when considering equipment for gear inspection. While we've discussed the merits of dedicated gear inspection equipment in this magazine on several occasions, there are also several inspection alternatives to consider. Many shop floors utilize dedicated gear inspection machines, CMMs, or a combination of both. The answer to your individual inspection needs will come down to cost, versatility, software and the operational benefits. Like a good college English essay, there's no right or wrong answer.

Companies like Mitutoyo, Hexagon Manufacturing Intelligence and Involute Gear and Machine offer a diverse range of inspection capabilities for the gear market. Hexagon Manufacturing Intelligence, for example, offers universal 3D coordinate measuring machines with ultra-high accuracy (in sub-micron range) for highly-specialized applications. The idea is to provide highly universal and flexible-to-use hardware and combine it with highly specialized software, which allows operation for different user levels. "Here you'll find different options that help to individualize the system regarding the use of different sensors, palette measurement and 4-axis scans," said Svenja Schadek, product manager UHA for Hexagon. "Even the ultra-precise measurement of large ring gears is part of the Leitz standard portfolio as the maximum measurable gear size is only limited by the measurement volume of the machine."

What's Out There?

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Mitutoyo offers a diverse catalog for full gear inspection with a CMM equipped with *GEARPAK* software which is a module within the *MCOSMOS* software package. (*MCOSMOS* is Mitutoyo's internally developed CMM software package). According to Derek Sporleder, application engineer at Mitutoyo, *GEARPAK* has modules for the measurement of various gear types from spur and helical gears to bevel and hypoid gears to worm gears.

"The module guides the user through the input of the required gear parameters, tolerance classes, etc. and automatically generates a macro for the

inspection and subsequent evaluation of the desired gear parameters with a detailed report showing graphical results for the tooth profile and lead evaluations, adjacent pitch, cumulative pitch, measurement over wires, and radial run-out to name just a few," Sporleder said.

Mitutoyo also has many different accuracy classes of CMMs as well. This allows for a customer to select a CMM with an appropriate accuracy based on the tolerance classes of the gears they intend to inspect.

"The 3 standard classes of bridge type CMMs that Mitutoyo offers are the Crysta AS series which has an maximum permissible error (MPE) specification of $1.7+3L/1000$ microns with an SP 25 probe, the Strato series which has an MPE specification of $.7+2.5L/1000$ microns with an SP 25 probe, and the Legex series which has an MPE specification of $.28+L/1000$ microns with Mitutoyo's MPP probe. Mitutoyo also

offers several specifically designed inline CMM models as well," Sporleder said.

Involute Gear and Machine Company, located in Chesterfield, Michigan, distributes' gear measuring equipment from Osaka Seimitsu Kikai Co., Ltd., a pioneer in the development of CNC control gear surface measuring equipment.



The Leitz PMM-C combines highly accurate 3D metrology performance with well-proven gear measurement capabilities (photo courtesy of Hexagon Manufacturing Intelligence).

“We provide tooth form measurement of any kind of gear, including parallel axis gears, bevel gears and worm gears, etc.,” said Ryohei Takeda, director, engineering, at Osaka Seimitsu Kikai. “We also provide geometry measurement of gear cutting tools, such as hob, shaper cutter and shaving cutter, etc. as well as 360 degree scanning measurement of gear teeth including tip and root, regardless of tooth form.”

Much of this equipment is different from dedicated gear inspection equipment mainly in their versatility and cost.

“CMMs offer customers the ability to perform inspection of all characteristics that dedicated gear inspection equipment may not be able to evaluate such as geometric position of holes or keyways and perpendicularity or parallelism callouts to name a few,” Sporleder said. “The gear measurement macro that is generated by GEARPAK is executed in a traditional measurement program in MCOSMOS so customers can evaluate all the necessary characteristics in one setup using one CMM measurement program not just the gear parameters themselves.”

Sporleder also said that a dedicated gear system may not be justified for customers who produce a variety of parts where gears are only a portion of their work. “A CMM with a gear inspection software module is a much better alternative. Additionally, most dedicated gear inspection equipment is quite expensive,” he added. “Additionally, CMMs have many options that can be added based upon the needs of the customer. While most gear inspection equipment has a size limit on the size of the gear that can be checked, CMMs can be built to almost any size specification so the range of part size can be much larger with CMMs.

Mitutoyo uses Renshaw probing systems for touch trigger systems and most scanning probe systems so the customer has many options when it comes to probing. Additionally, rotary tables can be integrated into the CMM to improve cycle time as well.

“This gives Mitutoyo the ability to offer a system much more tailored to the customer’s needs such that a customer who wants spur gears and is

comfortable with discreet touch points could be offered a CMM configuration with a fixed probe head and touch probe system whereas another customer that makes various types of spur, helical, straight bevel and spiral bevels gears may need an indexable probe head with a scanning probe system and a rotary table,” Sporleder said.

The most visual difference between

Hexagon’s products and dedicated gear inspection equipment is the machine design.

“A universal 3D CMM offers a rectangular shaped measurement volume, instead of a cylindrical. This set up is ideal to solve any measurement task,” Schadek said. “The design of the machine and range software allows users to utilize Leitz CMMs not only for a dedicated



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solution but also for a wider variety of parts. This enables not only the measurement of gears but also of housings.”

In addition, the independency from a rotary table also allows the physical alignment of parts in any position, not only in vertical but also in horizontal position. For example, long shafts can be measured horizontally and gear rack measurements can easily be carried out.

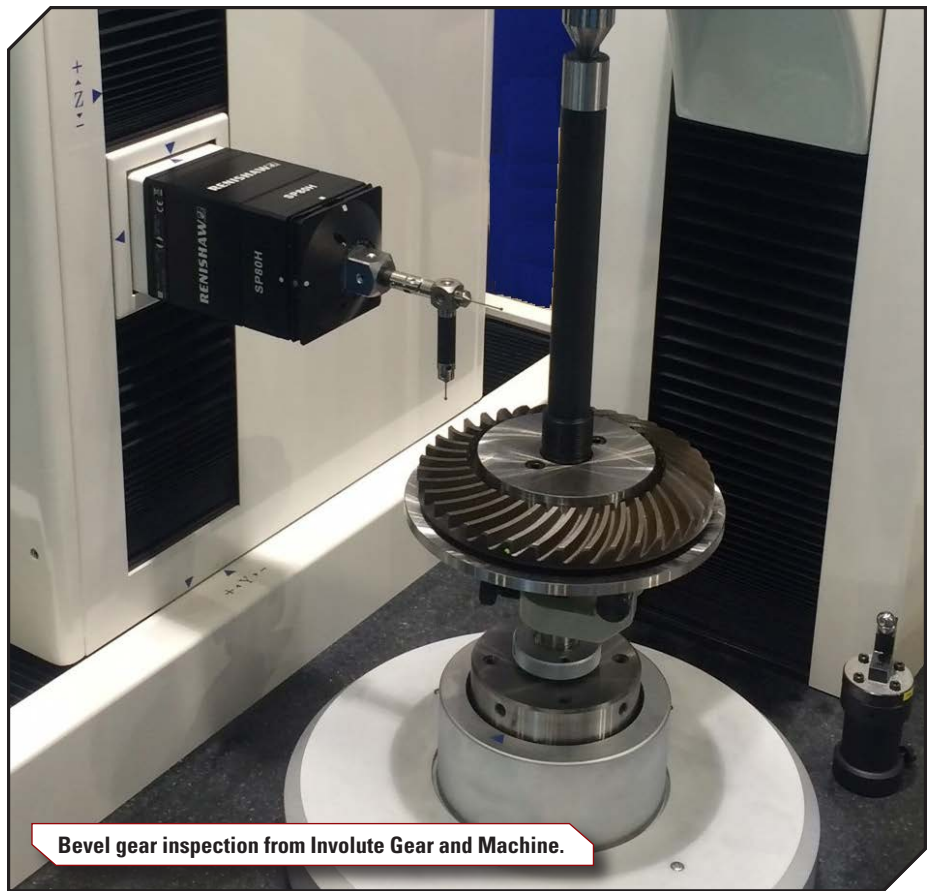
Flexible and automated equipment can go a long way in making the shop floor much more manageable. Flexibility and automation, in fact, are two of the most important market requirements and inspection trends today.

“The trend of flexibility is combined with the requirement to fulfil new and changed measurement tasks with a minimum effort and change of the existing metrological environment. Rotary tables can be used for 4-Axis scanning applications or easy part positioning, but at the same time the same CMM can be used for housings or pallet measurement,” Schadek said.

Leitz CMMs enable users to add new sensors for new measurement approaches quickly and easily with the SENMATION sensor exchange interface. This is also supported by the measurement software *Quindos* that allows adding new modules for a wide range of special geometries with a simple integration procedure.

The trend of automation is closely linked to increasing throughput. This requires taking the whole measurement process into consideration. Automated part loading systems, automated or guided selection of measurement programs, automated evaluation and processing of measurement data all contribute to increased throughput. Hexagon created one particular solution that combines all these aspects which been realized with a German costumer who produces high precision gear racks.

Mitutoyo CMMs can easily be integrated into automated cells. Mitutoyo has a Solutions Group that is dedicated to designing custom fixtures, automation control boxes, and integration in automated cells. A standard package that includes an IO card and a custom designed control box based on the work



Bevel gear inspection from Involute Gear and Machine.

cell requirements can be added to any CMM to begin the process of integrating it into a work cell. “They have a significant amount of experience setting up automated work cells with all types of robots in a multitude of industries and work with the local application personnel of Mitutoyo to provide a seamless integration process,” Sporleder said.

None of these advancements would be possible without a user-friendly software package that can deliver the right inspection tools for machine operators of many different skill levels.

“The developers of the *GEARPAK* software have spent a lot of time developing a work flow that helps guide users through the setup of a gear inspection routine. There are various tool tips that give explanations for each input. The help files for a particular input can be easily accessed and are very informative as well,” Sporleder said.

Mitutoyo also prides itself on the extensive support that is provided free of charge. “Mitutoyo doesn’t have software maintenance agreements for *GEARPAK* or *MCOSMOS*. Free software support exists via phone or email for the life of

the product. Training is included with the purchase of each software module as well so even inexperienced users have ample time to be trained and gain confidence using the software packages,” he added.

Involute Gear gives basic gear dimensions so setup of automatic measurements can be done via its software. Additionally, gear quality can be analyzed according to DIN, ISO or AGMA standards.

Hexagon’s *Quindos* software can be set up to serve purely as an execution tool. Measurement programs can be automatically loaded from a database, either be manually selecting a certain part by ID-number or picture or by integrating devices to automatically read part information e.g. from a data matrix code. This requires a minimum experience on gear manufacturing and metrology.

“A second level of user interaction can be seen in the setup of the measurement programs. Guided by intuitive user interfaces the gear parameters can be entered, evaluation standards defined and based on this information a measurement procedure is automatically created, ready to be executed,” Schadek said.

“On a more advanced level of experience, user can even dig deeper into the creation of the measurement program and setting up evaluation routines. So, interfaces can be defined, and measurement procedures adapted to very individual requirements.”

Furthermore, *Quindos* supports the Gear Data Exchange format GDE which allows data exchange in the whole manufacturing process from design to manufacturing to quality assurance. It includes all geometrical parameters, including modifications and tolerances.

Industry of Change

Sporleder said that the most noticeable changes in metrology divisions relate to automation and a reduced machine footprint. “Each year we work with more customers to develop automated work cells using all types of robots with integrated inspection equipment that not only seamlessly communicates with the robot but also can optionally provide measurement results back to the machine tools for offset calculations and/or part sorting,” he said.

Mitutoyo offers an internally

developed SPC software package named *Measurlink* that can be utilized to monitor the various process control indices in real time as well. The reduced machine footprint pattern has become much more prevalent in the last few years. As the economy has continued to strengthen many companies have been forced to increase production and floor space has become very important.

For several years now, Mitutoyo has offered a KOGAME CMM system which is a very small shop floor CMM that has a very high acceleration and measurement speed and can significantly increase throughput. The measurement volume for that system is 120 mm × 120 mm × 80 mm. The system doesn’t require air and can be put in almost any environment as the temperature range for operation extends from 10 degrees Celsius to 35 degrees Celsius.

“These systems have gained in popularity recently as companies try to squeeze more equipment into existing space and realize that a traditional CMM may in some cases have a larger footprint than is needed. These systems in particular are often found in the work cell right next to the machine tools and can utilize manual part loading or can be integrated into robot fed cells. We also offer larger inline systems such as the MACH 3A which is a high speed horizontal arm CMM for shop floor inspection which can be built into a conveyor system or any other type work cell. A larger vertical inline machine, the Mach V, is also available as well,” Sporleder said.

For Takeda at Osaka Seimitsu Kikai, the push for electric vehicles (EVs) in the automotive industry is definitely changing inspection needs.

“These EVs are getting very popular and the number of gears used is being reduced, but higher quality gears are necessary so there’s a greater demand for precise inspection. In the case of robot applications, smaller sized gears with non-involute profiles are being used, so there’s a higher demand for the measurement of those gears,” Takeda said.

Three important factors can be noticed in inspection today, according to Schadek.



“An increasing demand for higher throughput, the need for higher data density and the holistic use of data,” she said.

A change of sensor technology is noticeable. Besides the well-established tactile scanning sensors, more and more optical sensors are used. They provide a higher data density that allows new and different views on gear measurement with a more surface oriented evaluation instead of a line (profile, flank) centered approach.

These sensors offer higher scanning speeds, so higher throughput can be generated. But still there is a high need for tactile solutions when it comes to the established parameter evaluation.

Another important trend is the use of data. A closer interaction of CMM and tooling machine as well as the design department will be needed. Even the use of measurement data for customer focused spare part supply will be increasing.

All of these factors hint at a future where connectivity and smart manufacturing will increase the diversity and flexibility of the CMM. Takeda sees

an inspection industry in the future where closed loop data communication between design, manufacturing and inspection exists.

Sporleder said that Renishaw will continue to develop new probing systems and so with the development of the 5-axis touch and scanning probes that have the ability to index to any angle like the PH20 and REVO systems, that should continue to help improve gear inspection and reduce cycle time as the cycle times when measuring parts with those systems are always considerably shorter than more traditional probing systems.


Additionally, measurement programs continue to get more automated. Mitutoyo currently has a software called *MiCAT Planner* that utilizes Product Manufacturing Information (PMI) which is machine readable tolerances that are imbedded in the 3D CAD model. “If these tolerance callouts are semantically referenced to the model, the software can read them in and automatically write an entire inspection program by analyzing all the available probe configurations on a particular CMM and

choosing the best option for each feature automatically,” he said.

Sporleder believes as the standards for this type of information continue to develop, undoubtedly gear inspection will fall into this category.

“I certainly can see a time in the somewhat near future where all of the information for the gear can be written into a CAD model of the part in a machine readable fashion such that it can be read into the software automatically and a measurement program generated even faster than can currently be achieved using the existing *GEARPAK* module,” Sporleder added.

Schadek sees an increased demand for more universal CMMs with a wider variety of sensors to reduce the number of different inspection systems that can be found around the GMM, e.g. surface inspection. This follows the requirement for increased throughput. So, most inspections can be done with only one measurement system. This reduces handling times.

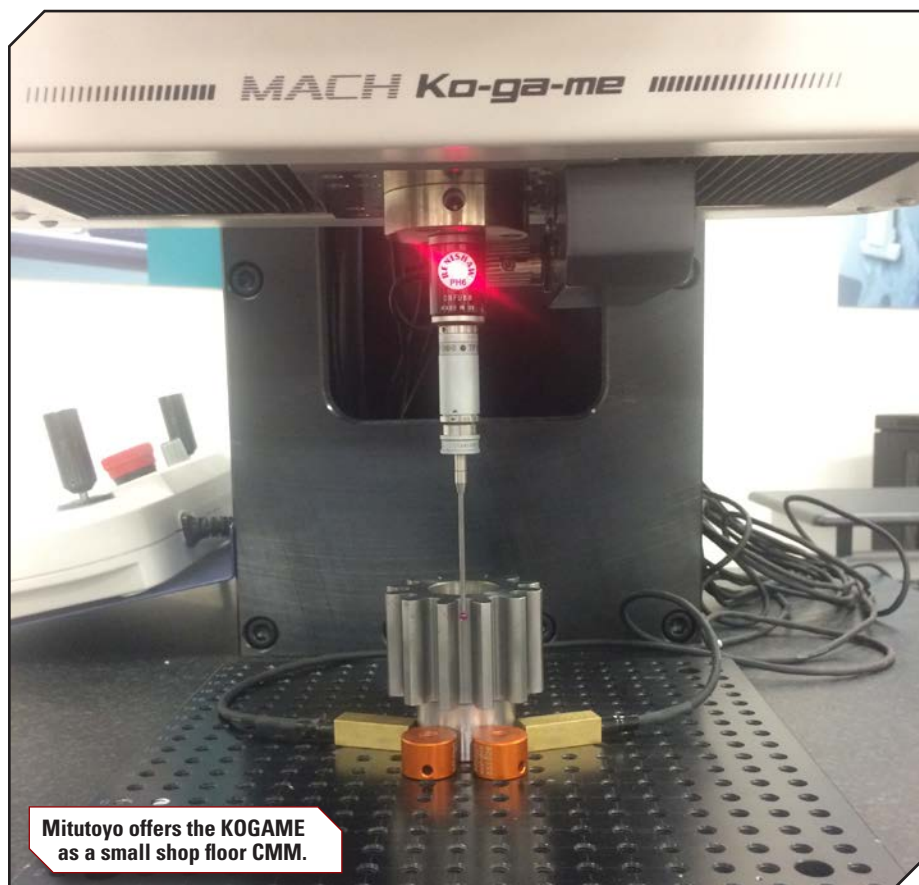
“In conjunction with this approach, data evaluation and processing will get a stronger focus. The feedback loop, not only to production (closed-loop), but also to the engineering department will get of more importance,” Schadek said. “Furthermore, information that has been generated from gears that have been in use will be needed to be feedback to the information gathered during production to create a more holistic view.” 

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