➤ BY CHARLES RUSSELL

Controlling Quality

Using on-machine inspection to check part quality can reduce lead times.

In the not-too-distant future, QC inspection might happen like this: After a machine tool cuts the part, a laser will scan it for dimensional information that is captured and downloaded to the CNC. Within the CNC will be an interfaced statistical process control software program that downloads the dimensions. If any of the part's dimensions are trending away from preset tolerances, the program will make the necessary offsets to the cutting program or alert the operator. Then the SPC program will command the machine's CNC program to check the tooling to make sure it isn't broken or experiencing excessive wear.

Also, if needed, the SPC data will be shared with a central computer and sent throughout the plant or even to a location thousands of miles away. This is all done within seconds, making on-machine QC inspection the most efficient way to check a part.

Will this really happen in the future? Actually, except for the laser and high-speed scanning, this type of on-machine QC already exists.

Renishaw

A Renishaw MP700E probe checks a part's location.

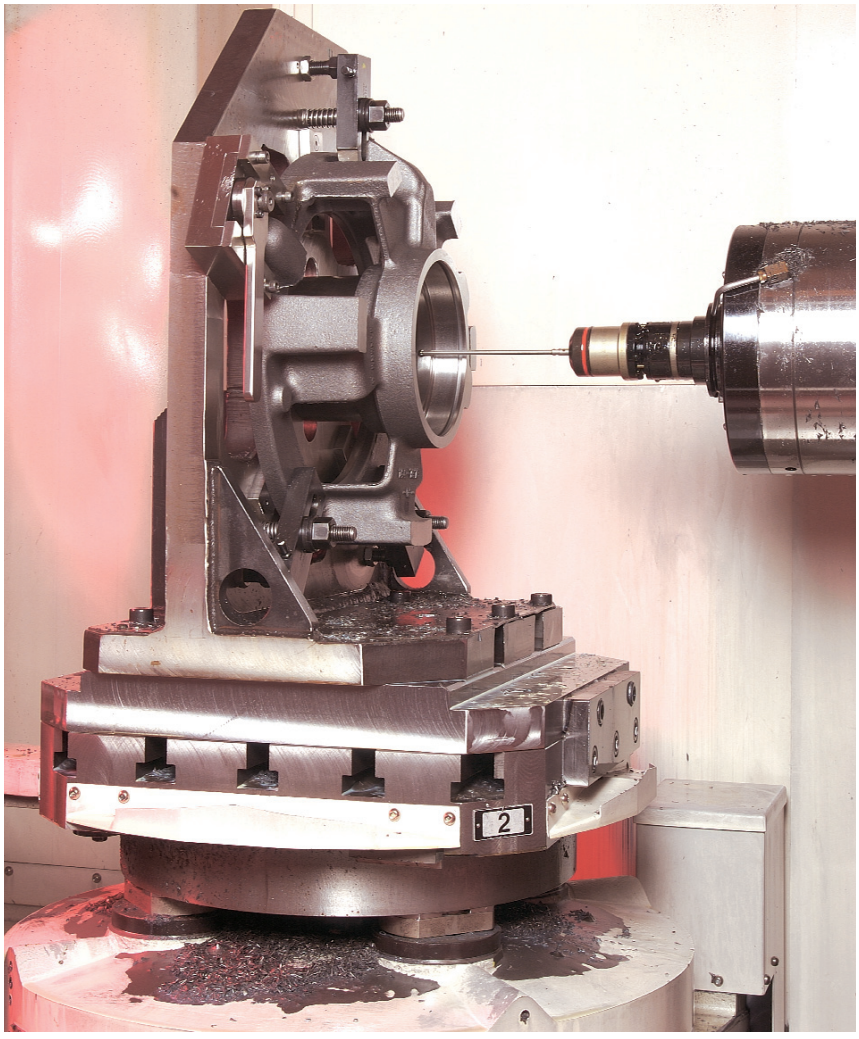
In the Beginning

On-machine QC actually started out with the introduction of probes used to detect part location. If a probe could determine exactly where the part is located in a workholding fixture, why

couldn't it be used to take dimensions from the part and do what a coordinate measuring machine does. All this would take is software to do the SPC/CMM work, along with deducing how to qualify a machine tool's accuracy.

But why use a machining center to do QC inspection? Wouldn't it be better to let the QC department do it and keep the spindle running to make more chips? Robert Whiting, president of Die Namic Tool & Design, Jackson, Mich., a manufacturer of stamping dies, said having a machining center do a CMM's work would solve many problems.

"Suppose a stamping press crashes a die on the third shift," he said. "You have workers that can fix it and quickly get the press running again, but no one can qualify the repair because the QC department, where the CMM is located, is closed. Even if it was available, the machine tool operators couldn't run it, because they don't usually have the training. Now you have a press that is shut down and wasting money. With on-machine CMM capability, the new or reworked die can be checked, qualified and back in service before the QC department personnel show up."



Marposs

A housing is checked for bore diameter accuracy.

To be able to use a machining center for on-machine QC, the machine must be qualified for accuracy and support, while supporting National Institute of Standards and Technology (NIST) traceability standards for this process. Otherwise, the QC dimensional data gathered by a touch probe is only as accurate as the unknown accuracy of the machine, which means that it might not be accurate enough to meet part-print specifications.

The next hurdle to doing on-machine QC inspection is making sure the machine is accurate both linearly and within its working volume. Machine movement is complex. For example, for each axis of motion there are six possible errors: three linear errors and pitch, yaw and roll angular errors. On a 3-axis machine, there could be 18 errors. There are three errors for squareness, for a total of 21 possible errors, on one 3-axis machine. These linear errors determine the machine's accuracy.

"Usually, you can't measure a part on the same machine that cut it, because there could be wear and tear on the machine that could make dimensional information inaccurate," said Charles Haddock, vice president of Shadow Automation Inc., Chino Hills, Calif. "Also, the machine's CNC thinks it knows where the spindle or bed is when the axes are moving, but the tool in the spindle could move several thousandths the wrong way along one of the axis because of wear and then move back again and make an improper cut. Then using a probe, the same thing happens and that error is not compensated for, because the probe won't catch it."

A laser calibration device that maps out the machine will catch that axis error. ISO and NIST require that a CMM, or similar equipment, be calibrated with an independent, NIST-traceable apparatus. Precision gage blocks and ball bars are acceptable provided they are NIST-certified and come with a calibration certificate. Also, the rule for measurement is that the device being calibrated, such as the machine tool, has to be up to 10 times more accurate than the applicable tolerance.

"Typically, to calibrate a machining center you use a linear type of laser and each axis is measured for flatness, squareness, pitch, roll and yaw, which are the typical calibration routines required to make precision parts," Haddock said.

Volumetric Accuracy

However, he added, this does not check the volumetric accuracy of the machine. These checks only provide information on the machine's linear axes. If there are errors, then they can

be compensated for in the CNC. This updates independent, linear compensations within the control, but it doesn't tell the operator how accurate the machine is, which is a mandatory CMM quality requirement standard to support QC buyoff.

The machine needs to be checked for its volumetric accuracy. By determining volumetric positioning errors, a lookup correction table can be generated for the on-machine measurement software to compensate for the machine positioning errors.

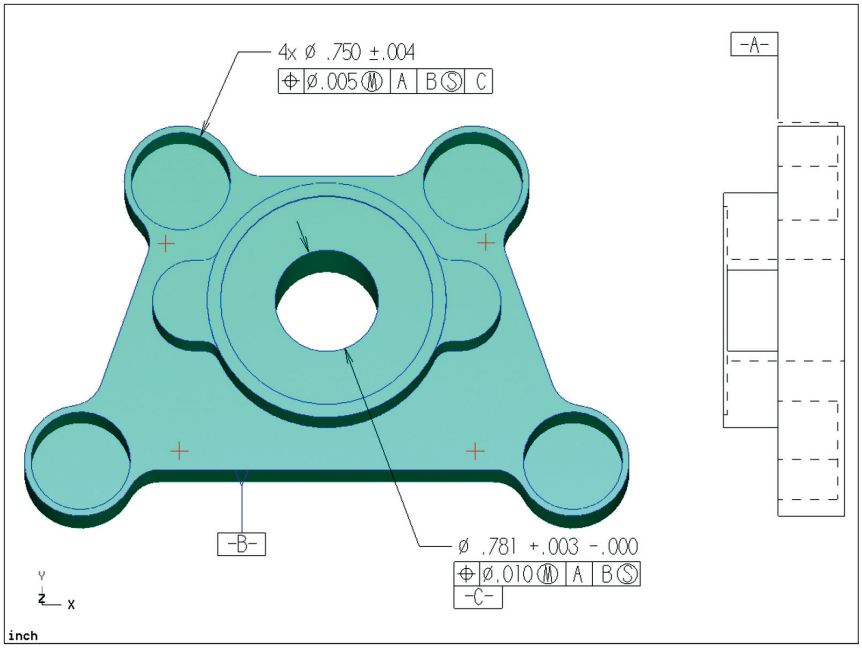
Dr. Charles Wang, president of Optodyne Inc., Compton, Calif., has developed a method to measure machine volumetric accuracy. "Traditionally, manufacturers have ensured accuracy of parts with linear (1-D) calibration of the machine tools used for making them," he said. "But linear calibration is inadequate for ensuring accuracy of 3-D parts." Optodyne's Laser Vector Technique for 3-D volumetric calibration and compensation using laser-doppler calibration equipment can check a machine's accuracy.

Purchasing this fairly simple-to-operate laser equipment can be an expense easily justified, provided three or more machines require routine volumetric calibration. However, a service bureau can also be contracted to check the machine's accuracy.

One such service bureau is MD Calibrations, Hope, R.I., which also manufactures proprietary equipment to make machine tool qualification simpler and faster. Renishaw Inc., Hoffman Estates, Ill., also has equipment to measure the volumetric accuracy of a machine.

With a volumetrically calibrated and compensated machine, the volumetric positioning errors can be tabulated as lookup tables or compensation tables and stored in the CNC's memory to correct measured probe positions. However, being a new technology with a fairly high level of sophistication, only a few CNCs are available to support this capability. Therefore, using an offline system may be required, which not only corrects probe data volumetrically, but can be applied to all existing machines as is. By using volumetric error correction to eliminate inherent errors in the machine tool geometry and positioning, accurate dimensional measurement is achieved. With volumetric error compensation, a machine provides the same high accuracy as a CMM and satisfies the NIST-established 4:1 gage-accuracy ratio.

Once the machining center is qualified for accuracy, the next step is purchasing a probe to take part measurements by using the machine's spindle. Many machines are already sold with probes and the software needed to do part location checks that support the Dimensional Measurement Interface Standard (DMIS) specification requirement to support the machined part inspection process, followed by data output deviation inspection report results, which can be easily exported and charted in most off-the-shelf SPC systems.



A 3-D CAD model used as a part inspection master model, such as a blueprint, in the Metrolosys program.

A touch probe, integrated into the machine measuring loop, can determine workpiece or tool dimensions. A probe stylus moves when it contacts the part being measured, and a signal is generated by the probe and transmitted to the CNC. Once the probe touches off on the part, it tells the CNC program what the relevant location information is, which is then stored in the program.

Haddock said: "A probe is nothing more than a switch, but how it toggles on and off to trigger a measurement can be done in a number of different ways, such as using infrared light. Repeatability is the only important factor to judge or select a probe to be used for on-machine QC work. This information must be checked and compared before you purchase one."

Software for QC

Another element to using a machining center for on-machine QC is the software to capture the dimensional data from the probe and then doing something with it. This was a real problem for many years, according to Haddock. "Software available for a machining center to be used as a CMM was very expensive, and only large corporations that had multitudes of machine tools could afford it."

Although probe companies offer software that allows an end user to gather dimensional data, the software doesn't offer the capabilities to be used as a full SPC or CMM-type program. However, Marposs Corp., Auburn Hills, Mich., does offer software called Instant Productivity Cycle that allows its probes to capture part dimensional data and use it to make tool offsets for wear either by the operator or by

automatically interfacing with the CNC. It will even compensate for thermal growth of the machine.

Another software option is called Metrolosys from Shadow Automation. "This inspection software can transform any machine tool into a CMM," Haddock said. "With it, manufacturers can implement a quality process performed before, during and after machining, which allows critical errors in design, CNC programming or setup to be caught on-the-fly. Also, the machine tool, in effect, with its larger area, is able to measure much larger parts than a CMM. End users can create full geometric dimensioning and tolerancing inspection procedures and generate critical GD&T inspection reports directly from their CNC machine tool touch probe."

Metrolosys is a CAD-based programming and reporting system for machined parts. Based on the DMIS programming language, Metrolosys quickly enables a CNC milling machine to be used the same way a CMM is used. Any CNC milling machine that is probe-ready can take advantage of these capabilities.

The inspection software provides independent volumetric error mapping and advanced high-speed probing methods, and automatically generates inspection G-code. Users can easily program an inspection process for the machine offline. The operator runs the program and sends the probing results back to the QC department to automatically create GD&T inspection reports according to the ASME Y14.5 standard.

Actual Application

More than 10 years ago, Pratt & Whitney's jet engine plants in Middletown, Conn., began inspecting and verifying parts on machine tools. Many factors were involved in this decision, but the main motivation was the need to make 100 percent accurate parts in the shortest cycle times. Different calibration, probing and process control techniques make this possible.

Jeff McCoy, production technical leader, said Pratt manufactures large jet engine containment cases that enclose the front, middle and rear of the engine, which have typically a tolerance of ±0.005". The company also produces large titanium, Waspoloy, Hastex and stainless steel parts. To qualify the machines, Pratt doesn't really check the accuracy of the whole machine to measure a part 100 percent complete per current GD&T standard quality requirements.

McCoy said: "We also check both sides of the part, a diameter band that we are machining within. Then we document what band we are checking in and these are the only parts we can machine. A different part with a different diameter would have to be requalified for the machine's working area. We qualify our machine tools every 6 months."

Originally, the plants were doing QC work on a CMM or building gages to check parts on the machine tool. "When you are machining a high-dollar part, you make semifinish cuts and take a measurement," McCoy said. "Then you adjust for tool wear or part deflection. You aren't going to cut it exactly where it's needed, and there are a number of variables that can cause this. Then the operator uses a gage to check the part. If a tool offset is needed in the machine, and the operator types in 0.010" in the controller instead of 0.001" you just lost a $100,000 part."

Instead, the plants use a probe to inspect the part, and it automatically updates the offsets on the machine. They actually program the probe within the CNC using the machine tool software macros and automatic machine tool inspection software that they modified.

The following companies contributed to this report:

Die Namic Tool & Design
(517) 787-4900

Optodyne Inc.
(310) 635-7481
www.optodyne.com

Pratt & Whitney
(860) 565-4321
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Shadow Automation Inc.
(949) 388-2310
www.metrolosys.com

"Probing has saved us a tremendous amount of money," said McCoy.

To get the best improvement in part quality, on-machine probing makes inspection part of the production process outside of the QC department, yet controlled and operated remotely within the QC department. While also supporting the same process requirements, probing offers the QC department a new inspection tool, with an extension to reach and measure parts on the shop floor. This allows a CNC machine tool to verify part accuracy without the need for a CMM. It's a growing application for process improvement, giving benefits such as shorter cycle times, faster setup, tooling verification and tool-wear compensation while making a major contribution to part throughput and cost reduction. △

About the Author

Charles Russell is a Michigan-based freelance writer specializing in manufacturing and engineering.