IN PROCESS INSPECTION IMPROVED WITH LASER CALIBRATION.

Inspecting parts with on-machine probing is a growing technique for process improvement, which reduces cycle time, while improving quality. However, critics have been quick to point out that any positioning error occurring during machining is most likely to be repeated during inspection. By laser calibrating its machine tools at regular intervals, Apollo Tool & Die Company, of Rochester, New York, has eliminated positioning errors and proven its on-machine probing process, leading to reduced cycle time and costs.

Apollo Tool specializes in making prototypes with CNC equipment, including water jet, wire EDM, VMCs and HMCs. Typically, production is three pieces or fewer with very quick turn-around times and tight tolerances, within ±0.005" are as big as the tolerances are ever allowed. Optodyne MCV-500 Laser Doppler calibration equipment has been utilized for three years to calibrate all of Apollo Tool's CNC machines and has enabled on-machine probing for final inspection. Rich Sayers, Apollo Tool & Die’s programmer explained, “We have one machine, an AWEA bridge mill, for large parts that we use with a probe to check accuracy of the parts. Instead of using a CMM, we inspect the parts on the machine that we’re using to cut them. When our customers require a final inspection, by dialing in the machine with Optodyne’s laser, which is calibrated to NIST standards, we are able to guaranty accuracy.”

Inspecting Parts

Typically, final inspection of parts is made with a coordinate measuring machine (CMM) in an off-line operation. However, the process of removing a part from the machine tool, mounting it to the CMM and then sending it back to the machine tool,
requires additional part handling and setup for any correction, which increases overall process time. Since CNC machine tools and CMMs have many features and characteristics in common, such as computer controls, servo-driven positioning elements, programmability and sophisticated software based capabilities, with on-machine probing they can provide in-process control, first part inspection and final inspection.

By measuring the size and position of features machined during the cutting process with a probe, a machine tool can provide in-process control, allowing the operator to perform other tasks while the machine tool is in operation. Additionally, some controls can be programmed to monitor the process with a probe and automatically apply cutter compensation, eliminating operator intervention.

First-part inspection with on-machine probing eliminates lost production time caused by manual inspection, especially when the operator needs to break down the setup for part inspection, and then reinstall it, if there is any final machining needed.

Utilizing on-machine probing for final inspection can eliminate offline inspection altogether. For example, by using probing cycles to compare final dimensions of a machined feature to a known dimension of a traceable article mounted in the machine, the CNC can make a comparison that determines if the specified tolerances were achieved. As a result, the control can automatically decide to: proceed with machining, adjust the tool geometry, adjust the home position, etc.

A recent job at Apollo Tool called for machining and inspecting a fairly big aluminum part, 54" x 54" by 9", which looks a lot like a hex when it's finished. The part had a lot of features, including big pockets, lots of holes, counter-bored holes and side windows made on another machine. Total cycle time is about eight hours. Mr. Sayers explained, “Most CMMs auto align, so accuracy is not an issue, nor is realigning the part
on our machine. The big issue is the cost of a CMM that will hold a part this size and weight. It would cost close to half a million dollars, while a probe costs $10 to 15 thousand."

Laser Calibration

Since gage accuracy requires a ratio of 4:1, machine-measuring accuracy must be four times more accurate than the specified part accuracy. In order for on-machine probing to meet this requirement, the accuracy performance of the machine must be verified. Conventional laser calibration of machine tools requires measurement of displacement or ballscrew errors, which can be compensated by the controller. Because thermal expansion can lead to distortion errors, the material temperature change will cause the lead-screw to grow and distort the machine geometry. Consequently, it is recommended to take several measurements at various times of the day.

Over time most machines will loosen up. Recognizing this, most quality programs, as well as ISO 9000, require calibration of machine tools at least once a year. Mr. Sayers said, “We try to check our machines every six months. If we check it every six months and it’s not loosening up at all, we can figure that it’s going to be pretty consistent. On some machines we only run certain jobs, and we check those machines more often. Not every job has super tight tolerances. We check those machines once a year. Our boring mills are a little bigger, heavier and a little slower and seem to fall out of tolerance sooner than other machines, so we know to check them sooner.”

Based on Optodyne’s patented Laser Doppler Displacement Meter (LDDM) technology, the MCV-500, utilized by Apollo Tool, reflects a modulated laser beam off of a movable target. The beam is detected and processed for displacement information, which can be utilized to create a lookup table, enabling the control to compensate for
Mr. Sayers said, “Before purchasing the Optodyne equipment, if we had a problem, we had a service that dialed in our machines. But it’s expensive to bring an outside service technician in. With the Optodyne equipment, we could calibrate when we needed to and keep the history of the machine at all times, which lets us trust the machine more.”

Setups are very quick with the MCV-500, because there are only two components to align, the laser head assembly and the target. Because an offset for a return beam is not required, only two components have to be aligned: the laser head with a single-aperture for emitting and receiving the beam and a flat mirror that acts as the target. The 2” x 2” x 8.5” compact laser head is 10 times smaller than a laser interferometer system and is calibrated and traceable to NIST and includes Windows analysis software that supports NMTBA, VDI, ISO and ASME B5.54 standards.

According to Mr. Sayers, “You have only five things to plug together, so it’s a quick setup. Maybe an hour at most. The AWEA takes 5-6 hours to calibrate, and it’s not usually out. If you constantly check the machines they don’t fall out of tolerance. At first, we had to write programs, but now we have set programs that allow us to check for consistency. The equipment is pretty straight-forward to use. It took me about a day to learn and it’s been very reliable. I’m the programmer for the CNC machines and do the laser calibration for all the machine tools, except for the wire EDM machine, which is done by its operator. The technician who used to do our calibration would bring in suitcases full of equipment. We carry the MCV-500 in a brief case.”

**PROBING SOFTWARE AND LOOKUP TABLE**

Most CNC machine tools have software available for on-machine inspection, which enables a probe to be held in the tool changer and/or spindle just like a cutting
tool. Consequently, the machine tool has the capability of being utilized, similar to a CMM for inspection, to measure the dimensions of the part. With a calibrated and compensated CNC machine tool, the positioning errors can be tabulated as lookup tables or compensation tables. The software can reference the tables to correct or compensate the positions measured by the probe.

With calibration and compensation, inherent errors in machine tool positioning are eliminated, enabling accurate dimensional measurement. As a result, the CNC machine tool satisfies the 4:1 gage accuracy ratio, approaching the same high-accuracy as a CMM. Instead of checking parts after the machining operations, on-machine probing makes inspection a part of the process.

Conclusion

The growth of on-machine probing is being driven by costs, a shift to flexible machining, shorter lead times, tighter accuracy specifications and automated processing, as well as with advances in probe technology, improved machine repeatability and sophisticated CAD/CAM software. The concerns are that the on-machine probing diverts machine time away from making chips, can be answered by measuring productivity in terms of total in process time, rather than machining cycle time. Mr. Sayers said, “The Optodyne equipment cut our cost of calibration and we can do the calibration whenever it suits us, so we’re not concerned with taking a machine out of production at an inopportune time. We don’t spend an excessive amount of time trying to get within a 0.0001” or 0.0002”. If the machine is within 0.0003” or 0.0004” and it’s repeating every time, the accuracy is good enough for our process. Some of our machines are better than they were before we started using the Optodyne equipment.”