Measurement takes a new vector

Volumetric measurements on CNC machines

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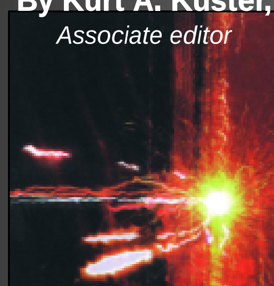
Associate editor



When it comes to checking machine tool accuracy, laser interferometers are pretty much one dimensional. They can detect linear errors in *X*, *Y*, and *Z*, but these measurements aren't enough to get maximum performance out of a machine tool, according to Optodyne Inc., Compton, Calif. What is needed is a way to take measurement into the 3D world, and Optodyne thinks it has the solution.

Laser interferometers use a laser beam aligned parallel to the axis direction being measured to indicate any linear displacement errors as a CNC machine is moved incrementally. But when it comes to machine accuracy, linear errors are only part of the problem. Straightness errors, angular errors, and nonrigid body errors can all impact a CNC machine, degrading its performance.

For each axis of motion, there are two possible straightness errors, one possible displacement error, and three angular errors. On a three-axes machine, there are 18 possible miscues, plus another three for squareness. That's a total of 21 errors, which may or may not be in the direction of the axis motion. This type of misplacement, called a volumetric or vector error, often causes greater inaccuracy than *X*, *Y*, and *Z* axes faults, says Charles Wang, Optodyne's president.

Pinpointing these faults through interferometry is time-consuming, complicated, and expensive. To measure all the possible errors can take a machine out of operation for 16 to 20 hr. In addition, sophisticated equipment and expertise is needed to perform these measurements.

For many shops, the easiest way to deal with vector errors has been either not to or by only compensating the machine on three axes, ignoring factors like guideway straightness, counterbalancing, and weight shift. But as the market demands greater accuracy and tighter tolerances, the need to correct such inaccuracies increases. Already, many controllers have vector-error-compensation abilities, often called cross compensation or sag compensation.

Vector errors can be determined by measuring all the areas of possible mistakes and then compensating for whatever problems are found or, if necessary, making a mechanical repair to the machine. The dilemma has been in finding an accurate, timely, cost-effective way to determine vector errors. Optodyne, says Wang, has done so with its laser vector-measurement system. Using a single-aperture laser head, a flat-mirror target, and a Windows-based software package, the system can do in hours what it once took days to accomplish.

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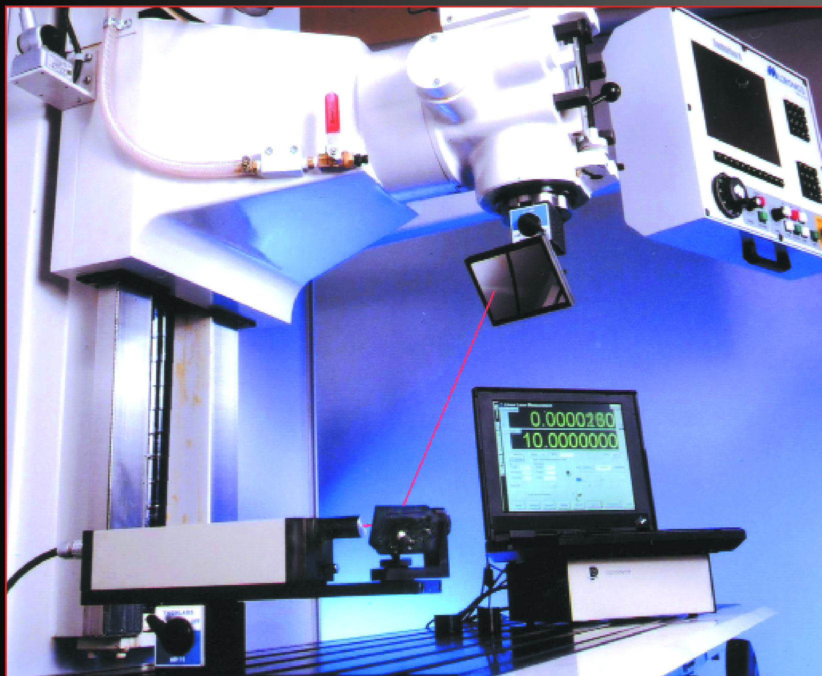


With Optodyne's, laser vector-measurement system, the laser beam is not parallel to the displacement direction. This lets the beam simultaneously measure errors that are parallel and/or perpendicular to the direction of the linear axis.

How it works

In interferometry, the laser beam is always parallel to the movement being measured, and the beam is sensitive only to one type of linear error at a time. With the new technique, the laser beam is not parallel to the displacement direction. This lets the beam simultaneously measure errors that are parallel and/or perpendicular to the direction of the linear axis. To do this, a laser head is mounted on the machine bed, a steering mirror is used to point the laser in a diagonal direction, and a flat mirror is mounted in the spindle.

Next, the machine is programmed to sequentially move the *X*, *Y*, and *Z* axes respectively, stopping after each. The process, which continues until the opposite corner of the machine is reached, repeats at all four corners of the machine. At each pause, data is collected for all three axes. With the conventional method, only one data point is plotted with each stop of the machine.

The measurements collected through the laser vector technique are the sum of the linear errors, vertical straightness, and horizontal straightness. That data is automatically collected and analyzed. Errors along each axis can be pinpointed, plotted, and graphed, and the information saved to generate compensation files for controllers.

"The first set of measurements," says Wang, "may take a little more time than with the conventional method, but it is more effective. You get 12 sets of numbers instead of three." The system gives the user the machine's linear position, its vertical straightness, and the horizontal straightness on each axis. "You get four times more data," Wang says.

Wang compares the two techniques: "The problem with laser interferometers is that they only know the position error of *X*, *Y*, and *Z*. But they don't know if the machine is square or not square. They don't know if the machine is moving straight. They don't know the vertical straightness or horizontal straightness. They really don't know much of anything."

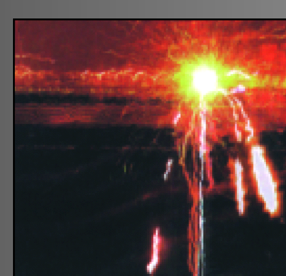
While it may take longer to accomplish the sequential-step diagonal measurements, Optodyne's system saves time by isolating vector errors. With a conventional body diagonal measurement, all three axes move simultaneously along the machine-body diagonal, and data is collected at each preset increment. The information gained by doing a body diagonal measurement with an interferometer can indicate if there is a problem with the machine, but there is usually not enough information to identify the source of the error. For this, additional measuring is required.

With Optodyne's technique, all three axes move one at a time in sequence along the machine body diagonal, and data is collected after each axis moves. This procedure allows errors on different axes to be separated from one another.

Wang calls this a separation of variables and explains its importance. "In mathematics, if you have a function of three independent variables, which are all lumped together, it makes it difficult to solve the equation," Wang remarks. "But now, with this system, the variables are all separated. The data comes only from *X*, *Y*, or *Z*. It's easy to solve the equation and get the result."

Usually, once the four diagonal measurements are complete, there is no need for further measurements with the Optodyne system.

"There are a lot of things you want to know to make a machine more accurate," says Wang. "With this new system, you can do the four diagonal measurements and



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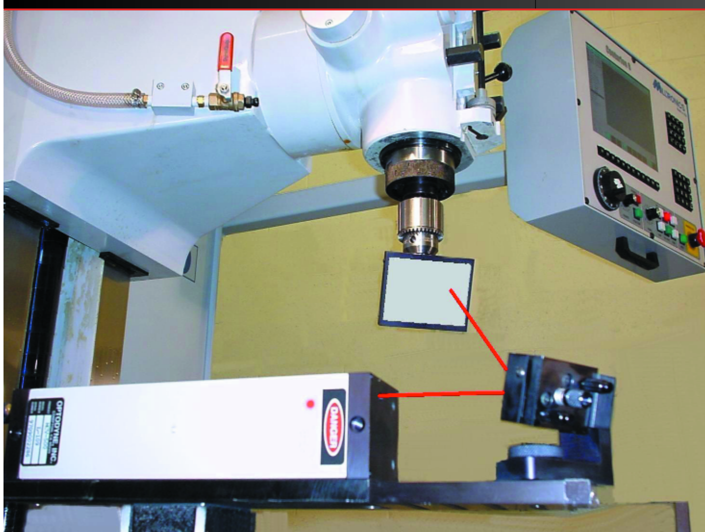
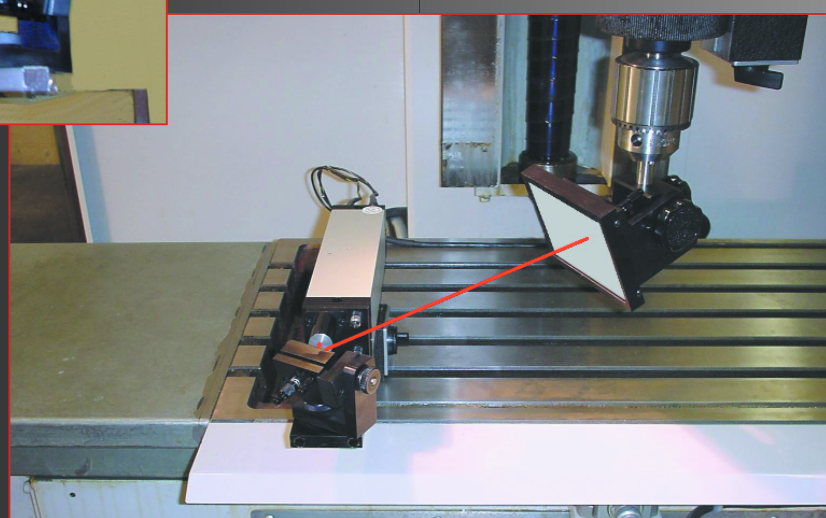
quickly find out what is wrong with the machine. Then you can fix it. If the machine has compensation capabilities, you can enter a new comp table and fix it right away." The new device has proven useful in machine setup, error detection, diagnoses, acceptance testing, scheduled calibration, and ISO 9000 documentation.

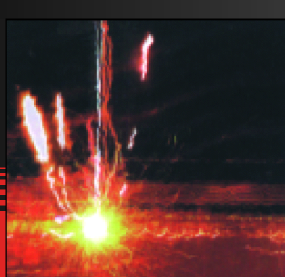


A laser head mounted on the machine bed, a steering mirror to point the laser in a diagonal direction, and a flat mirror target mounted in the spindle are the keys to Optodyne's new method of vector measurement.

"Setups are very easy," says Wang. "B-5 standards (ASME B 5.54) already provide a testing procedure using diagonal measurement. Those procedures say, if the error you measure on a diagonal is very small, the machine is good. If the error measurement is large, there is a problem. The four diagonal measurements tell if the machine's squareness is off, if its straightness is off, or any number of other problems. As a result, a half day of measurements could increase a machine's accuracy by a factor of 5 to 10."

Optodyne tested its new system on a Giddings & Lewis RAM 630 horizontal machining center. The repeatability of vector measurements were examined for six months. A compensation file was then created based on laser vector measuring. The results of the compensation file was a 3 to 4 factor gain in accuracy. In total, the volumetric compensation reduced diagonal volumetric displacement errors from 50 to 14 μ.





Convincing the skeptics

While well received after demonstrations, the equipment itself has raised eyebrows. Large systems, including some that use five lasers, have been the standard for such volumetric-error measurements. Optodyne's new patent-pending system, on the other hand, can be transported in a small carrying case. In addition, the equipment is easy to use, eliminating the need for lengthy training. In fact, machine operators often set up the apparatus themselves. While these factors are a bonus, they have also proved to be a problem.

"Most people don't understand vectors," says Wang. "They don't understand why you would only have to spend a half day to do something that's always taken two or three days. Other times they don't understand why some shops need three big boxes of equipment to do something we're doing with one small box. It makes them a little skeptical."

Another problem is that Optodyne may be ahead of the curve. While many modern controllers often permit volumetric adjustment, some do not. Wang says his company has had discussions with control makers about vector compensation. "They say they have the capability to include it," says Wang, "but most people don't know how to put the right variables into the controller." Despite the obstacles, optional 3D compensation will be offered with some controllers in the near future. ●

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