

Laser displacement measurement

CHARLES WANG

**TAKING CARE OF PROBLEMS EARLY
MEANS THAT REPAIRS WON'T COST AS
MUCH AND THEY WON'T CONTRIBUTE TO
OTHER MORE SERIOUS PROBLEMS**

Competition in global manufacturing today requires improving machine tool performance to achieve higher productivity, better quality and less downtime. Calibrating machine tools to catch errors before they appear in parts enables manufacturers to produce higher-accuracy parts, reduce assembly time and lower warranty costs. To keep up with the speed and increased accuracy requirements, the machines have to be kept within tolerance, which means laser volumetric calibration and compensation are very important.

Regularly scheduled calibration can help identify problems with machine tools such as bad bearings, ballscrew problems, and loose gibs and so on, enabling shops to schedule maintenance and reduce downtime, particularly during critical production runs.

Positioning errors in straightness, squareness, angle and non-rigid body errors determine the performance or positioning accuracy of machine tools, coordinate measuring machines (CMMs) and precision instruments. The characterization of a machine movement is complex. For each axis of motion, there are six errors: linear, vertical and horizontal straightness, pitch and yaw and roll angular errors. For a three-axis machine, there are 18 errors plus three for squareness, a total of 21 errors. A complete measurement of these errors is time consuming and can take from two to three days. Hence, the key is the measurement efficiency. It is impractical to stop production and spend two to three days for the calibration. However, using a laser vector technique (patent pending), three displacement errors, six straightness errors and three squareness errors can be determined in a few hours instead of a few days.

3D positioning errors

Machinists know that calibrating and compensating just the linear position is not enough, because it will not catch all the errors. By calibrating and compen-

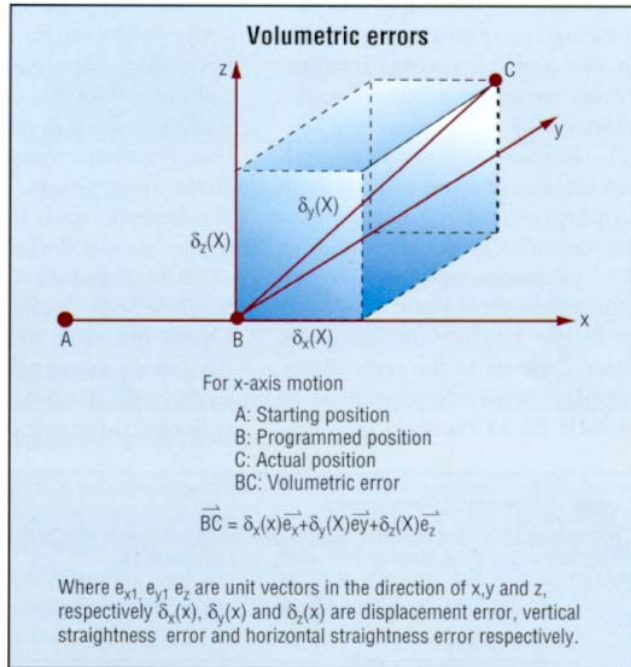


FIGURE 1. What is a volumetric error?

sating volumetrically, you get a much more accurate machine. Volumetric calibration of CNC machines provides a check of the machine tool's overall accuracy and, by compensating for these errors, enables tighter tolerances to be achieved.

A displacement error is the (1-dimensional) positioning error in the same direction as the axis direction. The volumetric (3-dimensional) positioning error is the positioning error in a spatial direction not necessarily in the direction of the axis motion. Hence, this error is a vector and its three components are the linear displacement error, the vertical straightness and horizontal straightness (see Figure 1).

Using a conventional laser interferometer to measure these errors is complex, time consuming and costly. The problem is how to measure all these errors accurately and quickly.

Vector measurement technique

The basic concept of the laser vector measurement technique is that the laser beam direction (or the measurement direction) is not parallel to the motion

of the linear axis. Hence, the measured displacement errors are sensitive to the errors both parallel and perpendicular to the direction of the linear axis. More precisely, the measured volumetric positioning error is the displacement error (parallel to the linear axis), the vertical straightness error (perpendicular to the linear axis), and the horizontal straightness error (perpendicular to the linear axis and the vertical straightness error direction) projected to the direction of the laser beam (see Figure 2). Because the errors of each axis of motion are the vectors with three perpendicular error components, we call this measurement a "vector" measurement technique.

In practice, first point the laser beam in one of the body diagonal directions, similar to the body diagonal displacement measurement in the ASME B5.54 standard (see Fig-

ure 3). However, instead of programming the machine to move x, y and z continuously to the next increment, stop and take a measurement, the machine is now programmed to move the x-axis, stop and take a measurement, then move the y-axis, stop and take a measurement, then move the z-axis, stop and take a measurement (see Figure 4).

As compared to the conventional body diagonal measurement where only one data point is collected at each increment in the diagonal direction, the vector measurement collects three data points, after each axis movement, such that three times more data is collected.

Then point the laser beam in another body diagonal direction and repeat the same until all four-body diagonals are measured. Because each body diagonal measurement collected three sets of data, there are

12 sets of data, enough to solve the three displacement errors, six straightness errors and the three squareness errors.

For conventional body diagonal measurement, the displacement is a straight line along the body diagonal; so a laser interferometer with a retroreflector as target can be used to do the measurement. However, for the vector measurement, the displacements are along the three axes. The trajectory of the target or the retroreflector is not parallel to the diagonal direction. The deviations from the body diagonal are proportional to the size of the increment X, Y or Z. A conventional laser interferometer will be way out of alignment even with an increment of a few millimeters.

To tolerate such large lateral deviations, a Laser Doppler Displacement Meter (LDDM) using a single-aperture laser head and a flat mirror as the target can be used. Because any lateral movement or movement perpendicular to the normal direction of the flat mirror will not displace the laser beam, alignment is maintained. After three movements, the flat-mirror target will move back to the center of the diagonal again, hence, the size of the flat mirror has only to be larger than the largest increment.

Advantages and applications

The major advantages of the vector measurement technique are simplicity and efficiency. Data collection is automatic and three times more data are collected in a single setup, with the calculations done using a notebook PC. The results can be plotted or tabulated. On a machine with a work volume of one cubic meter, all four diagonals can be measured in two to four hours. The vector measurement technique has made high-accuracy volumetric calibration affordable. Because a machinist can operate it, it makes laser calibration and compensation possible for shops with fewer employees and modest budgets.

There are many advanced controls where the squareness errors and

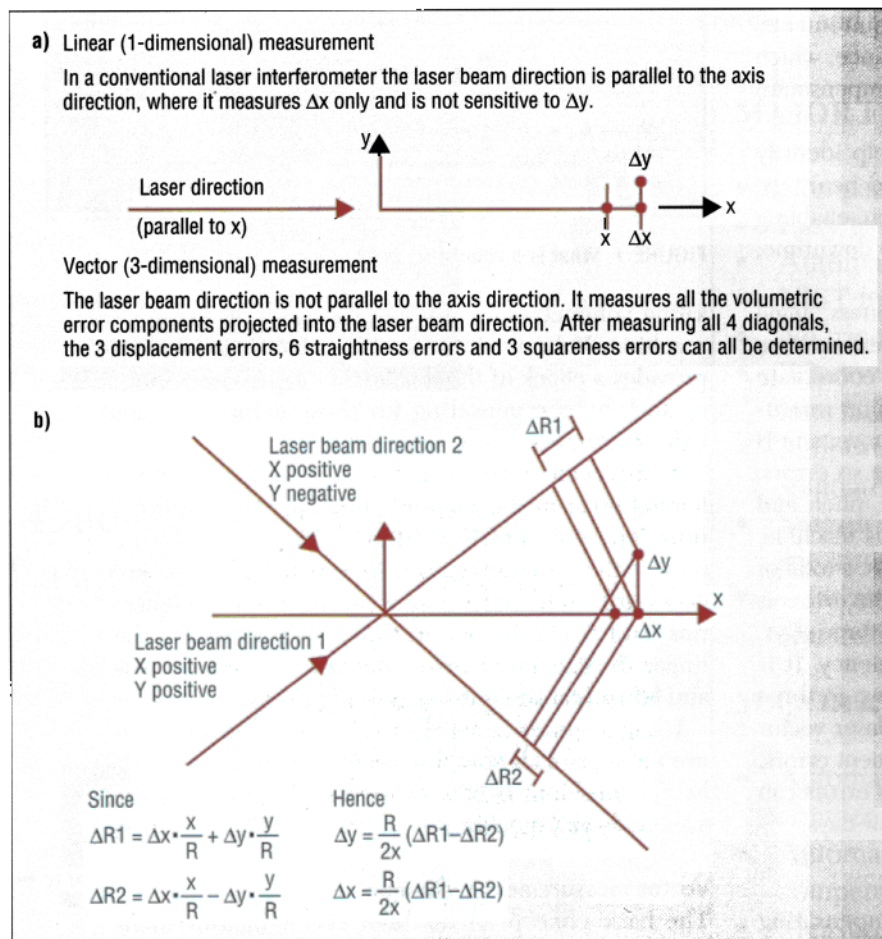


FIGURE 2. What is the vector (3-dimensional) measurement?

straightness errors-sometimes called non-linear errors, sag errors or droop errors-can also be compensated. However, using a conventional laser interferometer to measure these errors is complex, time consuming and costly. This is one of the major reasons these errors are not compensated. The other reason is time. With the cost of machine time, most companies are not willing to invest the 16 to 20 hours required to measure all these errors.

Now, using the vector measurement technique developed by Optodyne, the linear displacement errors, the vertical straightness errors, the horizontal straightness errors and the squareness errors of all three axes can be measured in a few hours. For some controls, such as Fanuc, Siemens, Giddings and Lewis, Milltronics and others, the volumetric compensation files can be generated automatically. After loading these compensation files into the control, the volumetric positioning accuracy can be improved by a factor of three to ten. Hence, the volumetric compensation becomes a viable option.

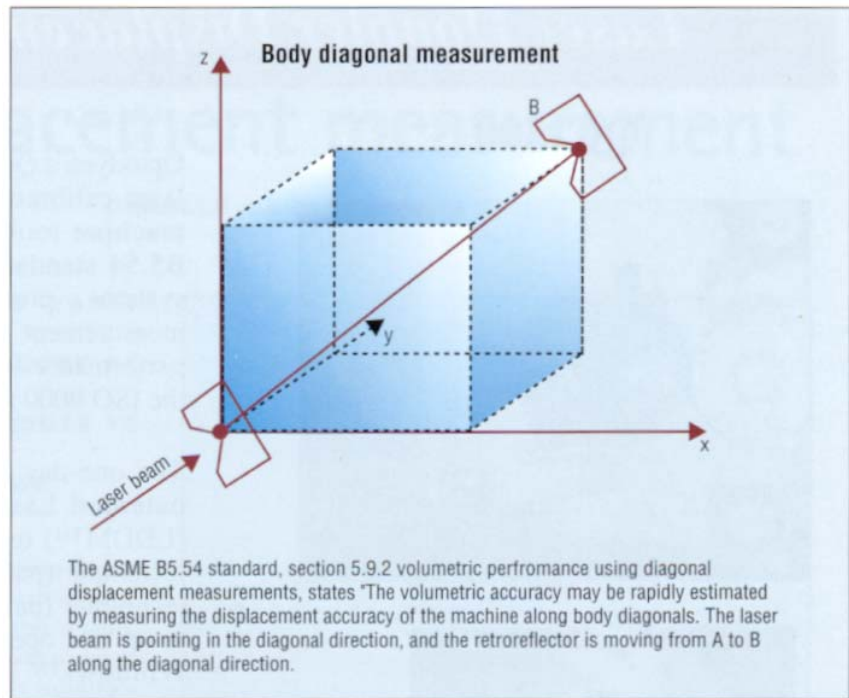


FIGURE 3. What is the **body diagonal displacement measurement** ?

Using laser vector measurement, the volumetric positioning errors can be measured easily and a lookup correction table can be generated for the on-machine measurement soft-

ware to compensate the machine positioning errors volumetrically, thereby improving the accuracy of on-machine probing, and making it a viable process.

Charles Wang is the president of optodyne Inc., Compton, CA. He can be reached at Tel: (310) 635-7481.

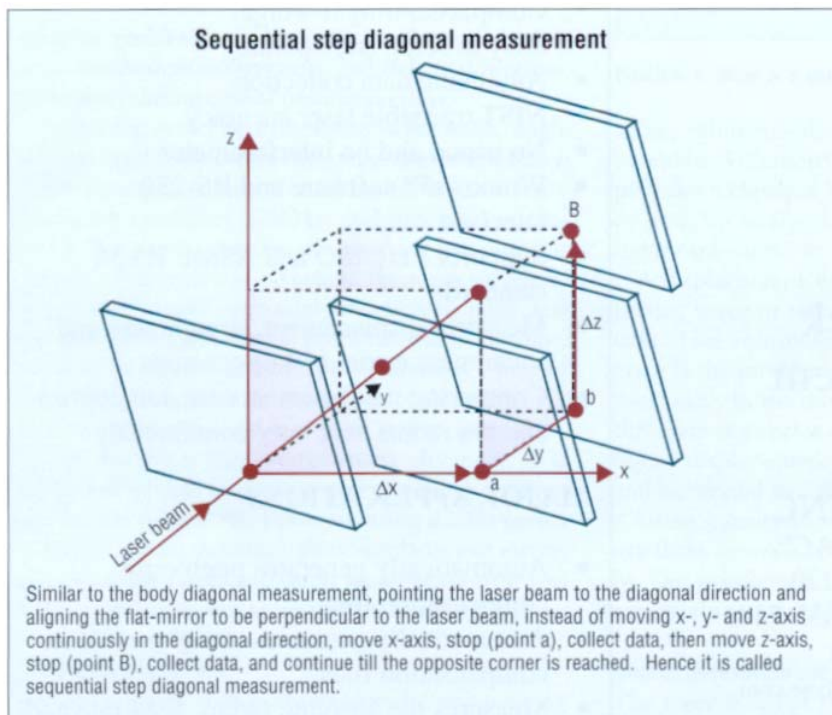


FIGURE 4. What is the sequential-step diagonal measurement?

REFERENCES

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