

QUALITY SCAN



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Determine Volumetric Accuracy Quickly

The ever-increasing demand for manufacturing good quality, accurate parts while maintaining high productivity levels is increasing the importance of measuring 3-D (volumetric) positioning errors and compensating for them. Furthermore, machine accuracy is impacted by temperature variations attributed to factors such as the environment, spindle and lead-screw thermal loads, cutting load and coolant, and 3-D positioning errors. But measuring 3-D volumetric positioning errors is difficult and time-consuming when you employ conventional laser interferometers.

We suggest that this problem can be dealt with using a laser-vector measurement technique similar to the ASME B5.54 and ISO230-6 standards for body diagonal displacement measurement, where the laser beam is directed through the body diagonal. This laser-vector technique moves along the body diagonal in operator-specified increments in X only, stops and collects data; moves in Y only, stops and collects data; moves in Z only, stops and collects data; and so on until the opposite corner is reached. This approach allows the collection of three times more data than the conventional technique, resulting in a total of 12 sets of data from four body-diagonal measurements, which makes it possible to determine the volumetric positioning errors. Data collection requires about one hour.

The laser-vector measurement technique enables compensation of a CNC machine's 3-D volumetric positioning errors under various thermal conditions and ambient temperatures. The key to doing so is quick measurement of the 3-D volumetric positioning errors under various thermal conditions, and generation of appropriate error-compensation tables. When thermal conditions change, a different error-compensation table can be generated, or interpolation between two tables can be performed to compensate for any machine error that develops.

Assuming machine temperatures are stable during the hour required for laser measurement, several measurements can be performed at various machine temperatures. Using the measured 3-D positioning errors, a lookup correction table can be generated for each temperature measured. One or several lookup tables can be generated and uploaded to the CNC control. (This step is based upon the assumption that the CNC machine tool's movements are repeatable.)

The laser vector method was verified in Prague, the Czech Republic, on a Czech-made MCFV505OLN VMC by doctoral candidate O. Svoboda. Linear motors are used to drive the cross bed; the machine has two driven axes (X, Y,) and a vertically oriented spindle (Zaxis). Temperature sensors were placed at various locations on the VMC to monitor the temperature distribution on the machine.

The vector measurements were made over a working volume of X=-500 mm, Y=400 mm, and Z=-320 mm. Four setups were made, one on each of the four body diagonal directions. These four directions are ppp (X, Y, and Z are all positive), npp (X is negative and Y and Z are positive), pnp (Y is negative and X and Z are positive), and nnp (X and Y are negative and Z is positive). Based on the measured laser-vector diagonal data, the 3-D positioning errors, including three displacement errors, six straightness errors, and three squareness errors, were determined.

Measurements were taken at various machine temperatures under simulated working conditions.

Movements in X, Y, and Z, and spindle rotation, caused a continuous increase of the VMC operating temperature to levels exceeding ambient. The measured temperature distribution and rate of increase were different for different feed rates and spindle rotation speeds. Measurements were taken at various machine temperatures under simulated working conditions, allowing a better understanding of how 3-D errors change under different machine temperatures and temperature distributions.

Volumetric compensation tables were generated at several specific machine temperatures. Using interpolation, a volumetric error compensation table was then generated to compensate for machine errors across a range of machine temperatures.

Preliminary data indicate that straightness measurements are not sensitive to machine temperature changes. However, changes in the temperature of the VMC caused large squareness errors.

The ability to measure 3-D volumetric errors within an hour makes it affordable for measurement and compensation to be a routine maintenance operation.

Svoboda will present his detailed measurement results; modeling, and correlation analysis in his PhD thesis, which will be published by the Research Center of Manufacturing Technology, Czech Technical University (Prague, Czech Republic) in July, 2007.