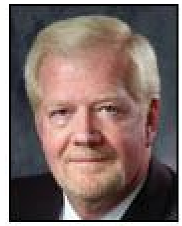
Manufacturing ENGINEERING

October 2008 Vol. 141 No. 4



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Quality Scan

Simplifying Volumetric Error Correction

Characterizing the errors in the entire working volume of a CNC machine tool can improve how well parts made on it comply to their design drawings. Characterizing the errors of a CMM can reduce its uncertainty of measurement, improving its measurement accuracy. Entry of the error-map data as correction factors essentially linearizes stage motion. Although full working volume characterization is a worthy goal, the process for error-mapping these systems has been lengthy and tedious, requiring setup and analysis by skilled technicians.Taking a machine tool out of production for 1 ½ – 2 days to perform volumetric calibration is not very attractive to any shop.

Any device with motorized stage motion, whether machine tool or measuring machine, has some amount of nonuniformity of motion in any or all of its axes. Measuring these nonuniformities allows the resulting information to be used for error correction, essentially eliminating the original error and improving overall accuracy. However, there are 21 rigid-body errors in any three-axis orthogonal machine (six errors per axis plus three squareness errors). Traditional techniques for generating an error map handle one axis at a time, using devices such as laser interferometers. This approach requires precise mounting of the laser and reflector so reflected light hits the detector over the entire length of stage travel in that axis (motion of the reflector along the axis of the laser light). Measuring other axes requires disassembling and reassembling the setup.

Mechanical mounting of the laser and retroreflector is just one part of the error correction process. CNC programming is required to "exercise" each axis. This step is pretty straightforward until diagonal motion of two or three axes at a time is considered. All in all, complete error correction has been tedious.

An error-mapping and calibration instrument developed by PTB (Physikalisch-Technische Bundesanstalt—Germany) and NPL (National Physical Laboratory—UK) can map the entire volume of a system from a few, fixed positions, simplifying and speeding the process. Etalon (Braunschweig, Germany) has introduced this instrument to the commercial market, and our company now offers it in North America.

The company's device resembles a gun turret, projecting a laser beam that tracks a cat's eye retroreflector mounted to the spindle of the machine tool or CMM. From one location it can track the retroreflector over ±200° of azimuth and -20 to + 85° of elevation, over a range to 10 m. It keeps the laser beam continuously linked between the instrument and the retroreflector on the machine spindle as the full range of machine motion is mapped.

The heart of the system is a fixed, high-precision sphere with form deviation of less than 50 nm. It acts as the reference reflector of an interferometer with 1-nm resolution. The sphere is mechanically and thermally decoupled so it provides a fixed center reference during movement of the tracking mechanism, essentially making the measurement insensitive to guiding errors in the azimuth and elevation axes of the device. Using a retroreflector simplifies alignment, because light returns on-axis regardless of the angle at which it strikes the retroreflector.This behavior allows the spindle to move throughout its range without any user involvement with the process.

The mapping process is based on interferometric distance measurements between the stationary sphere fixed to the base and offset points fixed to the machine spindle. During mapping, the machine moves through a set of positions in a spatial grid that encompasses the entire working volume of the machine, while the distances are recorded by the interferometer. Nominal distances are directly calculated from the positions of the reference point and the three axes, and machine errors appear as differences between the measured and nominal distances. When the errors are systematic, the differences can be used to evaluate the parametric errors through a best-fit calculation.

Calibrating both the machine tool used to make the part and the CMM used to measure it, can lead to higher confidence and greater productivity. In addition, the system and its software are designed to meet the requirements of the emerging ISO 10360-2 and ISO 230 standards.