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Viewpoints

There's No Simple Volumetric Accuracy Standard

The *Viewpoints* article in the July 2007 issue of *Manufacturing Engineering* highlights an important need of industry, namely a standard for defining and assessing the volumetric accuracy of machine tools. While drawing attention to this need, however, the article makes significant generalizations as well as technical misconceptions that may mislead the reader. We wish to correct these technical misconceptions, and provide a summary of recent efforts to address this important subject.

The error motions of machine tool slides (linear axes) are classified into three categories: linear displacement error, horizontal and vertical straightness errors, and angular errors (yaw, pitch, and roll). All six error components contribute to the positioning of the slide within the machine tool's work volume. Straightness error is defined by ASME B5.54 and ASME B5.B7 standards "as the deviation from straight-line movement that a displacement indicator perpendicular to slide direction exhibits when it is either stationary and reading against a perfect straightedge supported on the moving slide, or moved by the slide along a perfect straightedge that is stationary." By this definition, straightness error is a linear motion along the direction perpendicular to the axis of intended motion of the slide. Therefore, straightness cannot be measured in angular terms (radians or arcsec). The straightness errors result from many imperfections in the fabrication and assembly of machine components, some of which also cause angular errors. Therefore, when measuring straightness errors, one has to take into account angular errors of the slide.

A paper by James B. Bryan, recently selected by *Manufacturing Engineering* magazine as the subject of its annual Masters of Manufacturing profile [July 2007], clearly explains the relationship between the angular errors and straightness measurements. The Bryan Principle is articulated as follows: "The straightness measuring system should be in line with the functional point whose straightness is to be measured. If this is not possible, either the slideways that

transfer the straightness must be free of angular motion, or angular-motion data must be used to calculate the consequences of the offset." Because in the presence of angular errors the straightness measurements are affected, one cannot speak about only straightness errors without referring to the slide's angular errors. Otherwise, the straightness measurements indicate the behavior of the slide at only the measurement location. Since different length cutting tools and different workpiece sizes result in different "functional points," straightness measurement carried out at one particular location—without consideration of other influencing angular errors—would not represent the machine behavior in the total machine work volume. Therefore, unfortunately, there is no reliable short-cut method (or single parameter) that can be used to assess the volumetric accuracy of machine tools.

Realizing the industry need for assessment of volumetric accuracy of machine tools, both the ASME B5-TC52 committee and the ISO/TC39/SC2 committee have been studying this issue for the last few years. So far, the discussions and efforts point to the fact that there is no single summary parameter that can be used to describe machine tool performance. There are, however, some tests prescribed by the standards to combine several error sources, and assess the behavior of the machines under such conditions.

Circular tests using telescoping ball bars and linear-displacement tests along body and face diagonals of machine work volume are good examples of such tests. Nevertheless, while these tests provide multiple parameters, none of them can be used alone to assess the full volumetric accuracy of the machine. In its recent attempt to provide help to industry in this respect, ISO/TC39/SC2 has come up with a draft volumetric-accuracy definition that results in six different parameters. This definition is being reviewed by the standards committees of ISO member bodies; industry comments are welcome.

In summary, machine tool accuracy assessment requires complex sets of measurements. Therefore, any attempt to derive a single figure-of-merit for comparing machines, without having the proper measurement method(s) to complement the value, could not only mislead prospective buyers, but also be the impetus for unfair advertising among competing manufacturers. For example, optimizing a machine to achieve a single superior figure-of-merit without sufficiently focusing on other critical measurements/parameters could lead to selecting a machine that doesn't perform well when machining parts.

References:

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ISO/CD 230-1.4:2007 Test Code for Machine Tools—Part 1: geometric accuracy of machines under no-load or quasi-static conditions.