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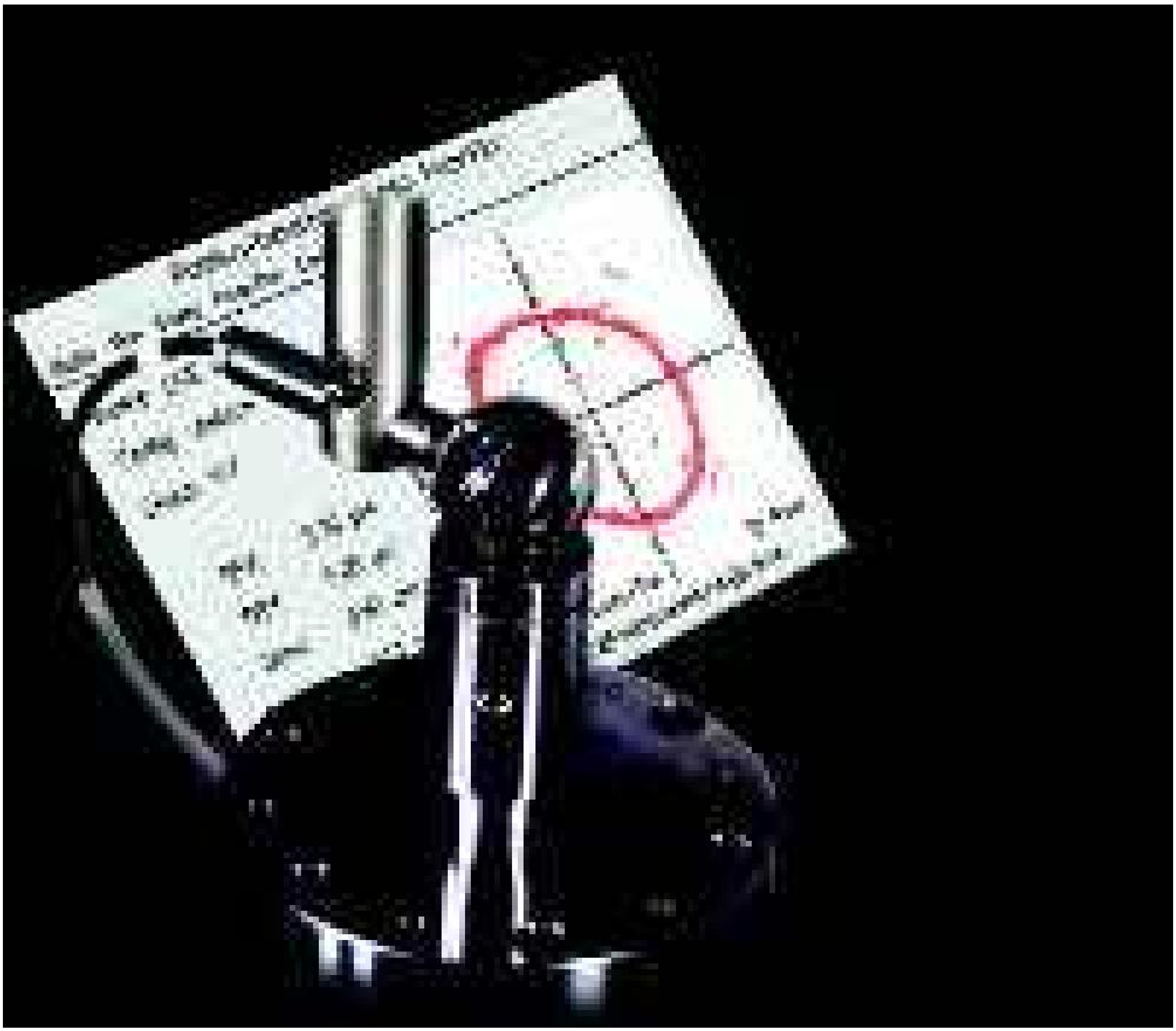

MACHINING / CUTTING

Sensors Spawn Spindle Standard

Measuring axis rotation benefits from today's technology.

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Dr. George Tlusty, a pioneer in machine tool measurement and professor of mechanical engineering at the University of Florida once said "a person can't talk about accuracy if they don't have a way to measure it." The statement definitely holds true for a committee set to release a new standard on spindle measuring that would enable shops and OEMs to differentiate between spindle accuracies at the micro-inch level.

Current spindle-measuring standard, ANSI/ASME B89.3.4, for testing and specifying axes of rotation is precomputer-era and based on what most believe are antiquated instrumentation such as displacement dial indicators and oscilloscopes with mounted Polaroid cameras. The new standard, which is intended to guide OEMs and end users toward updated methods of testing and describing spindles, reflects advancements in measuring and sensing technologies, a key one being noncontact, capacitive, sensing probes.

These probes measure a spindle's thermal growth and its synchronous and asynchronous error motions under operating conditions. Measuring rotating-spindle errors (displacement at the point of machining) lets OEMs and shops characterize machine tools and their abilities, test for optimum spindle speeds, determine warm-up time for repeatable results, and check for damage after a crash. "But more importantly, with these abilities, users can predict and control part quality," says Don Martin, president of Lion Precision in St. Paul, a company whose Spindle Error Analyzer system uses capacitive sensors.

Technological advancements such as noncontact, capacitive sensors are changing the standard for spindle measuring.

A Spindle Error Analyzer system from Lion Precision includes probes, mounting nest, master ball targets, and more.

Lion Precision's noncontact, capacitive, sensing systems measure spindles under operating conditions for turning centers, VMCs, and HMCs.

"Thermal growth," he says, "is the largest single error source in machine tools." As machines heat up, grow, and bend, they cause changes in tool position and tilt, feature location, hole depth, and surface finish and flatness. Accurately measuring temperature qualities with capacitive sensors reveals how long a shop should wait for a machine to warm up and stabilize before cutting parts.

Synchronous error motion is the out-of-roundness of a spindle's rotation, while asynchronous error motion involves nonrepeating changes in a spindle's position on successive rotations. Measuring synchronous error motion predicts a machine's ability to cut a round hole and lets shops categorize their spindles for determining which ones to use on critical jobs. It also works for testing a spindle's ability to make good parts after a crash. Asynchronous error motion, according to Martin, is directly associated with part surface finishes and appears as fuzziness in a polar plot.

For its system, Lion mounts a master-ball "target" in the spindle to be measured and positions the ball in front of stationary capacitive sensing probes arranged in a nest setup. These probes use electrical fields to measure changes in the air gap between them and the master ball as it rotates in the spindle's center path.

Within the nest, a bottom probe measures *Z*-axis movement, a pair of probes at right angles handles *X* and *Y*-axis movement, and another pair of *X* and *Y* probes measures a second master ball above the main one. The company's software collects probe readings as they happen, analyzes the results, and displays them onscreen with polar and linear plots and discreet measurement values.

Lion's Spindle Error Analyzer detects radial, linear, and angular errors. Radial errors are those occurring around a radius. With a perfectly rotating spindle, sensor output remains constant with no indicated movement in either *X* or *Y* directions.

Linear, or axial, movement errors happen in the *Z* direction and often involve thermal drift, a condition that causes the spindle to grow or stretch. Angular error (tilt) is the spindle "kicking" out. This angular displacement is more pronounced farther from the spindle's face surface.

Lion In The Lab

Lion Precision's noncontact, capacitive, sensing probes play a key role in the machine dynamics research lab at Penn State University at University Park, Pa. With the sensors and its own research-version software, the lab focuses not only on spindle measurement but also on embedding capacitive sensors into spindles for realtime process monitoring.

The lab measures spindles as accurately as possible to understand their characteristics and how their performances influence part quality. Currently, the lab gets single measurements to repeat to within an angstrom (1/10 of a nanometer), an accomplishment attributed to its improved techniques, hardware, and software.

"We can distinguish between the best, high-quality air-bearing spindles," comments Eric Marsh, associate professor of mechanical engineering at Penn State, "which is a challenge because they are small and have less air to measure."

In its process-monitoring research, the lab embeds Lion's sensors into grinding spindles and measures forces on grinding wheels. Such force measurements are advantageous for optimizing process conditions, improving process control, and producing high-quality parts.

"In precision applications where aerostatic spindles and shallow depths of cut are common," says Marsh, "detecting small forces with conventional force sensors requires compliant elements in a machine's force loop, which reduces its stiffness and degrades accuracy." While, on the other hand, he points out that measuring rotor motion with noncontact capacitivedisplacement sensors does not degrade machine stiffness.

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