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A Turn for the Better

Machining operations can be optimized with input from spindle manufacturers.

Spindle manufacturers are more open than ever to collaborating with machine tool builders to ensure that the best spindle for an end user's needs is specified.

For example, a decision on whether to select a belt-drive or motorized spindle may hinge upon concerns over future repair/rebuild expectations. Repairing a belt-driven unit costs about one-third the price of fixing a motorized spindle. And, usually, a belt-driven model takes less time to repair. On the other hand, motorized spindles tend to have lower intrinsic vibration and are typically smaller than their belt-driven counterparts.

The point: Don't choose a spindle without adequate input from the experts.

Take the case of Milltronics Mfg. Co., Waconia, Minn. The machine tool builder recently debuted a line of 40-taper, 15,000-rpm machine tools.

"Three years ago, users preferred our larger, 50-taper machines, and spindle speeds of 6,000 to 8,000 rpm were adequate," explained Milltronics Sales Manager Andy Hockert. "Now, 15,000 rpm is typical, and users prefer carbide tooling and 40-taper machine tools with linear rail construction that allows faster cutting of aluminum and specialized plastics."

Recognizing that users must be prepared to take on a variety of jobs quickly, Milltronics works with spindle supplier Setco Sales Co., Cincinnati, to equip machines with custom-built spindles that suit machine tool users' needs.

Setco Sales

Critical part-print tolerances of spindle surfaces are being measured to ensure vibration-free operation.

"Flexibility in machine tools is paramount," said Hockert. "Eighty-five percent of our customers are standard job shops that have to be ready to do any kind of job."

Bob Hodge, Setco's vice president of engineering, told CUTTING TOOL ENGINEERING that the repair/rebuild issue, along with ease of use and ready access to motors, has spurred an increase in the use of belt-driven spindles for milling and boring operations.

Bill Heintz, president of Automation Engineering Co., a Torrington, Conn.-based machine tool components distributor that sells Setco spindles, emphasized the importance of close consultation with spindle experts to learn about the various options possible when specifying a spindle. "Servo-type units are best for larger applications and precision holemaking. For example, we are selling servo units to a European maker of automotive steering parts. Meanwhile, smaller shops are using electric, pneumatic and hydraulic spindles, employing them in manufacturing cells with CNC machines that combine with other workstations for holemaking and other operations."

He added, "For high-volume work, the equipment must be designed for longevity, use proven control electronics and high-quality bearing systems, and be sealed so that it is essentially maintenance-free."

Speed vs. Quality

In the past, many machining operations were routinely performed with deep cuts at slow speeds. Now, of course, it's become common to take more passes at shallower DOCs and much higher spindle speeds. Multiple high-speed passes avoid overheating the material and distorting the final part dimensions.

"Maximum material-removal rates are being achieved at around 20,000 rpm with multiple passes," said Hodge. "Higher speeds [than that] are normally not an advantage. The trade-offs in spindle design to enable a 30,000- to 50,000-rpm operation adversely affects reliability. The old saying is true: Speed kills when spindles run too fast to last."

Hodge said his company has found that ceramic rolling elements and high-nitrogen-steel raceways with improved seal technology, such as Setco's Air-Shield, offer substantial benefits in terms of reliability and durability, and high-speed lubricating greases have significant advantages over air/oil and oil mist.

"The typical automotive powertrain plant has as many as 2,000 spindles. It could save about $5 million annually with just a nominal increase in spindle reliability and durability," Hodge claimed.

Eliminating vibration at higher speeds, particularly from 7,500 to 10,000 rpm, is a major spindle-design challenge. Spindle unbalance must be minimal to prevent damage to the bearings and ensure good machining characteristics.

Vibration control is usually built into the unit. Many high-production shops utilize advanced sensor options, such as those for measuring internal temperature and bearing vibration, to predict when spindle maintenance is needed. Sensors built into the spindle also enable the user to set up a maintenance schedule that is compatible with production.

Collaborative work among the spindle supplier, the machine tool builder and the user can pinpoint adjustments that can be made to the spindle *and* toolholder to minimize or eliminate vibration.

"What is needed to do precision work is paying more attention to stiffness in the overall toolholding and spindle system," Hodge said.

Mike Engster, president of Centerline Inc., Ponca City, Okla., added, "HSK or ISO toolholding requirements include accuracy to 0.0001" and balance to Quality Grade 0.4. The latest spindles need to be balanced to this degree as well."

Vibration modal analysis is particularly effective in determining the source of instability, especially where the tool meets the part dynamically. Specific vibration modes can reveal the "weak link" in the cutting process. The weak link might be damaged spindle bearings, an improper toolholder, improper workholding or changes to the machine tool that occur over time.

Manufacturing Laboratories Inc. (MLI) specializes in vibration and balance analysis and control. The Las Vegas-based company's history includes participating in the development of the first 36,000-rpm, 36kW spindle for the U.S. Air Force.

MLI's vice president, Tom Delio, said: "A vibration monitor on the machine tool informs the operator when established limits are exceeded. This provides adequate warning to avoid tool breakage and wear and maintains a high level of productivity while reducing the production of substandard parts. The philosophy in doing so is to base speed and feed changes on a machine sensor and analysis intended to optimize productivity.

"Implementing a proactive approach," he continued, "creates an overall system that produces consistently good parts and fewer rejects."

Bearing Down

Spindle bearing technology has increasingly turned to angular-contact designs and hybrid ceramic bearings. This has enabled spindles to operate at higher power levels, up to 50kW, for example, when used for high-speed milling.

Bearing materials, such as high-nitrogen steels, and hybrid ceramics have contributed to increased operating life and enabled higher speeds, said Setco's Hodge.

Chris Curtis, sales engineer for NSK America Corp., Schaumburg, Ill., added, "Higher-cost ceramic and air bearings, as well as tapered roller and hydrostatic bearings, are being used at higher power levels to [prolong spindle] life. In lower-power, lower-speed spindles, angular-contact stainless steel bearings are still used because of lower cost—even though this means a shorter life and more maintenance."

Typically, lower-power spindles are air-cooled, while higher-power spindles are cooled by refrigerated oil. However, users are increasingly trying other spindle lubricants, such as air/oil systems and greases, for high-speed applications.

Cliff Behm, applications engineer at Russell T. Gilman Inc., Grafton, Wis., said, "More hybrid ceramic bearings are being used that feature high-speed greases instead of oil mist, eliminating local airborne pollution."

Hodge said, "Angular-contact bearing technology has kept pace with grease developments. We have determined that greases have increased service life threefold because spindles run at a lower temperature with thicker lubricating systems."

The following companies contributed to this report:

Automation Engineering Inc.
(860) 482-9131
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Milltronics Mfg. Co.
(952) 442-1410
www.milltronics.net

NSK America Corp.
(847) 843-7664
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Russell T. Gilman Inc.
(800) 445-6267
www.rtgilman.com

Setco Sales Co.
(800) 543-0470
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However, he added, use of greases has been catching on fairly slowly in machining. "If spindle life is 2 years, a grease with a life of 3 to 5 years does not have a large impact. If the spindle has a life of more than 8 years, however, grease life becomes more of a factor.

"We have determined that the No. 1 cause of bearing failure—in 52 percent of the cases—is contamination by materials, such as metal chips and coolant," Hodge said. "Although air/oil systems have a tendency to wash out these contaminants, better seals are still the most effective way of improving this situation. Over the past 5 years, our field data has shown life improvements of more than twofold because of improved seal technology. Seals also have enabled us to use high-speed grease systems that are packed for life for applications that used air/oil lubrication in the past. This improves reliability by having no lube lines or reservoirs to service."

Spindle reliability and the role the spindle supplier has in maintaining that is well represented on the shop floor of camping equipment manufacturer The Coleman Co. Monthly, it machines a few million components for 400 different parts.

"These are generally standard parts that have had a stable design for a long time," said Coleman's Gene Larson, who oversees drilling and tapping operations. "Once production is set up, it rarely changes."

These operations have to run, he said, problem-free for 2 years or more in an oily, chip-laden environment. Obviously, this can take a toll on a machine tool's spindle.

In a harsh environment like that, the key to success is to tune into spindle performance and stay in touch with the spindle's supplier.

About the Author

Larry Olson is a freelance writer who has written extensively about manufacturing-related topics.