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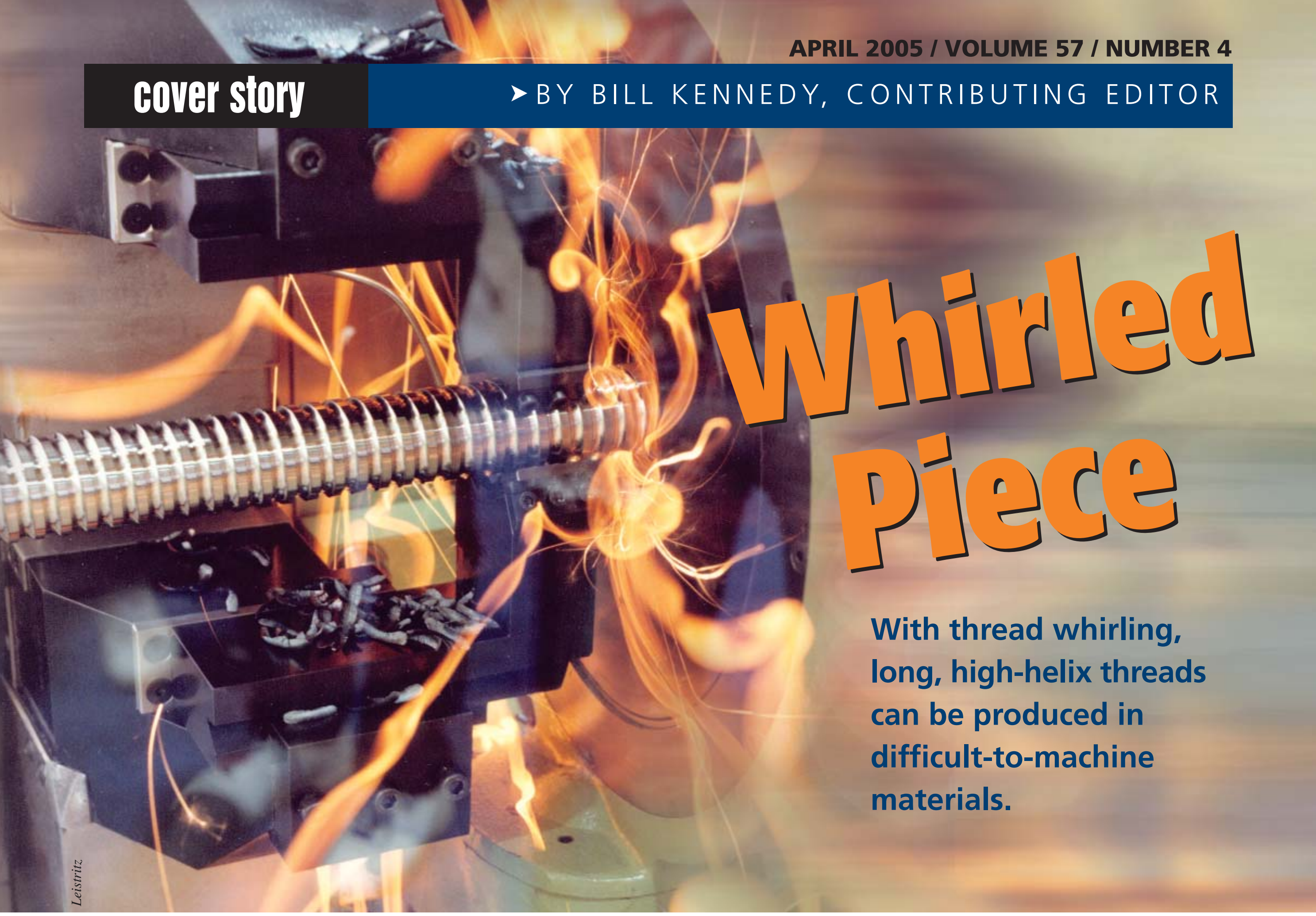
cover story

BY BILL KENNEDY, CONTRIBUTING EDITOR

Whirled Piece

With thread whirling, long, high-helix threads can be produced in difficult-to-machine materials.



Leistritz

Introductory physics books list the six simple "machines" that are the building blocks for more sophisticated devices. Of the six, arguably, the screw offers the most elegant combination of form and function, as the thread seamlessly transforms rotary motion to linear motion … and vice versa.

Throughout the mechanical world, screws provide precise positioning and motion control. Heavy machinery, for example, makes wide use of ballscrews, worms and feedscrews. The external threads of such heavy-duty screws can be produced by a variety of methods, including single-point threading, thread chasing, threadmilling, hobbing and thread rolling.

One efficient way to quickly make a large, precise OD thread is thread whirling. (Small and internal threads are thread-whirling candidates too; see sidebars.)

With thread whirling, a cylindrical workpiece rotates slowly while a ring with cutting edges located on its ID whirls around the part and cuts the thread. The ring is set off-center in relation to the workpiece axis and is tilted to create the thread's helix angle (Figure 1).

The first thread-whirling machines, developed more than 50 years ago, were lathes fitted with supplemental whirling rings. Today, specialized machines are available that maximize the benefits of the process.

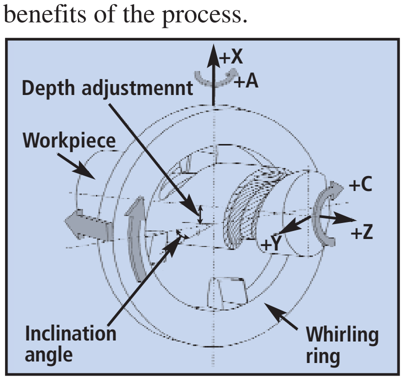


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Figure 1: Thread whirling involves the action of an off-center whirling ring, with cutting edges located on its ID, around a rotating workpiece.

"Converting a lathe was state-of-the-art 50 years ago, but we don't do that anymore," said Ralph Wehmann, sales manager for thread-whirling machine builder Leistritz Corp., Allendale, N.J. "Although it looks like a lathe, you need to have certain things, mostly in the precision and rigidity areas, that allow you to capitalize on the advantages of whirling, including better cycle times, better surface finish and so on."

The smooth, tangential cutting action of thread whirling minimizes cutting forces and permits a high metal-removal rate, making the process ideal for generating long, high-helix threads in difficult-to-machine materials. Wehmann said thread whirling doesn't really compete against single-point threading on a CNC lathe. "Whirling comes in for bigger, tougher stuff, which you can't do with a single point," he said.

The traditional way to make a long ballscrew is to rough-grind the thread's helix into an unhardened workpiece, heat-treat the part, then finish-grind it to final dimensions. With thread whirling, a shop can eliminate the rough grinding by thread whirling an unhardened shaft, induction hardening it, then finish grinding it. Furthermore, modern thread-whirling machines can be fitted with PCBN cutting tools to machine an already hardened part. Because the surface finishes produced when thread whirling are acceptable for many applications, in some cases final grinding can be eliminated altogether. Although grinding imparts excellent finishes, it can be time-consuming. For an equivalent finish, thread whirling can be three or more times faster than grinding. "The advantage is speed," Wehmann said.

Jim Keagy, manager of manufacturing engineering at R.H. Sheppard Co. Inc., Hanover, Pa., offered an example of thread whirling's speed. Sheppard machines worms on steering shafts for heavy trucks. A typical shaft, made from 2¼"-dia. 8620 steel, has 4" of single-lead, 1"-pitch-dia. worm thread contoured to accommodate a 5⁄16"-dia. ball. Previously, the shop rough ground the worm from a solid, hardened the shaft and performed a finish grind. Then, thread whirling replaced the initial rough grinding. "We previously ground the worms at a rate of 30 or 31 an hour, and now we can whirl up to 70 to 80 an hour," Keagy said.

For the steering parts, he added, a final grinding operation remains necessary. "An excellent [ground] finish is imperative. This is a steering worm and you can feel everything in the steering wheel," Keagy said.

Ring Around the Whirler

In a whirling ring, as in a milling cutter, the inserts follow each other through the cut and share the workload. The more inserts, the faster the ring can cut. A whirling ring might be designed to hold eight inserts.

However, according to Wehmann, "you could take seven of those inserts out and still make a good part, but it would take you longer. You'd have to slow the feed rate down because you'd only be cutting with one tool."

Wehmann compared the situation to a choice between a 2- or 4-flute endmill. "You can do the same job with a 2-flute endmill as with a 4-flute endmill, with

A small whirl

To make the precision screws used in items such as surgical implants, medical parts makers generally produce them on Swiss turning machines that enable the parts to be completed in one operation.

Mark Saalmuller, sales manager for Swiss machine tool builder Tornos Technologies U.S. Corp., Brookfield, Conn., said, "With medical screws, you tend to have a lot of very nasty-shaped threads in titanium and stainless steels, and to try to chase those threads is a real horror."

Saalmuller said Tornos has been offering thread-whirling capability on its machines for more than a decade. Although the tools and parts are small, he said the cutting method is similar to the big machines "where you have a number of cutters in a head, and they are going to just nibble away at the threads." Tornos whirling heads are fitted with circular form cutters that are regrindable.

Tornos Technologies

Thread-whirling capabilities on Swiss turning machines permit creation of acute thread profiles in difficult-to-machine materials without the need for secondary operations.

As is the case when producing large threads, thread whirling on a Swiss machine is employed where single-point threading would be difficult or impossible, especially where the length-to-diameter ratios are large. In the Swiss machining method, the workpiece is fed through the spindle's guide bushing and after the material is turned down, it can't be drawn back for repeat passes. To make a thread significantly smaller than the workpiece diameter, it might be necessary to preturn the smaller diameter, then turn the thread on another machine. In that case, Saalmuller said, "you're doing two operations, two setups, [which requires] more capital equipment."

With thread whirling, he said, "it's all built into the cutter. So if you have a ¼"-dia. screw, and the thread size is 3⁄16", you just go right in with your whirling ring, without preturning. It's a big advantage, in many cases, to make a complete part without secondary operations."

Revealing one of the "tricks of the trade" in small-parts manufacturing, Saalmuller said that a thread-whirling ring can effectively provide a deburring action that will further save secondary operation time. For example, after the thread-whirling ring machines a small distance on the tip of the screw, a side-working tool mills flutes, then the thread-whirling ring returns to complete the screw's full length, deburring the flutes as it goes.

Saalmuller said development work is proceeding on thread-whirling options for Swiss machines that will enable production of the "big"—over ½" diameter—threads needed for larger medical devices.

—B. Kennedy

The following companies contributed to this report:

Danaher Motion
(866) 993-2624
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Leistritz Corp.
(201) 934-8262
www.leistritzcorp.com

R.H. Sheppard Co. Inc.
(717) 637-3751
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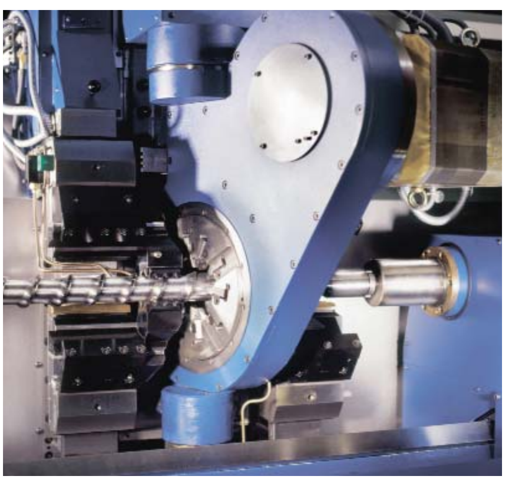
Tornos Technologies U.S. Corp.
(800) 243-5027
www.tornos.ch

the same chip thickness, but it's going to take you twice as long," he said.

Some shops choose to strike a compromise between speed and overall productivity by tooling the whirling ring with more than one type of insert. For example, a ballscrew maker may tool a 6-insert ring with three inserts that produce the ball profile and three inserts that create the chamfer. This permits machining ballscrews for a specific ball size while altering the shape of the screw's chamfer by changing to the three chamfer inserts. Manufacturers, Wehmann said, "can adjust the depth of the chamfering tool to get the exact chamfer size that they need. They are reducing the effective number of teeth in the ring, so it's taking longer to cut that screw, but whirling is so fast that they are still very pleased."



Leistritz

The whirling ring is bolted into a housing and driven by a high-torque-drives, toothed belt.

The whirling ring is bolted into a housing and driven by a high-torque-drive, toothed belt, or in the largest machines, a gear set. The mounting method provides a quick-change capability that reduces noncutting time when tools must be replaced. Keagy said the whirling rings his facility uses have four inserts and are preset off the machine. "We've got multiple rings that are preset at the ready. We've done tool testing and predetermined that the most economical point to pull those tools is 600 parts. At 600 parts, the machine stops, we pull the ring out, put a new ring in and go back to whirling."

The Whirling Way

Thread whirling requires coordinated movement of the workpiece and the whirling ring, and a unique selection of cutting parameters. Chucked in the machine spindle, the workpiece rotates at a relatively slow speed that is determined by its diameter and lead of the thread being made.

Wehmann said rotation speed for a small (0.25"-dia.) workpiece might be 80 rpm, while a large (8"-dia.) screw with a deep profile might rotate at only 1 rpm. The workpiece rotation speeds have a minor impact on removal rates.

The mrr is set, however, by the cutting speed of the whirling ring, as well as the rate at which it is fed into the workpiece. The ring's rotation speed depends on its diameter and the surface speed recommended for the material being threaded. Based on the cutting circle of the whirling ring, which is the diameter of the cutting edges inside the ring, Wehmann said, "for soft steel, we typically use 450 to 750 sfm to calculate the rpm of the whirling spindle. Hard steel is performed over a narrower range, typically 525 to 600 sfm."

Chris Walther, manufacturing engineer at Danaher Motion, Saginaw, Mich., which manufactures Thomson-brand ballscrews, said his shop thread-whirls parts of different configurations and materials, and varies speeds and feeds accordingly. He estimated that 60 to 70 percent of the screws made at the facility are whirled hard with PCBN inserts, with the rest hardened after whirling. Expressing the cutting speeds in rpm, he said much of the hard whirling takes place at the thread-whirling machine's 2,100-rpm maximum speed, while the unhardened pieces are machined in the neighborhood of 600 to 1,000 rpm.

The shop has a database of applications it uses as a guide. "We keep logbooks that we can look back in and get a good idea where to start," he said, "and then tweak it in from there."

The feed rate of the whirling ring determines the thickness of the chip it generates, which, in turn, determines the surface finish of the part. "The bigger the chip, the faster the cycle time, but the rougher the finish," said Wehmann.

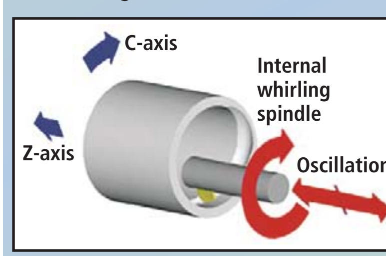
Walther added that "on a hard whirl, you probably go between 0.002" and 0.003" chip thickness, and on a soft

Get an ID on that

Obviously, the teeth inside a thread whirling ring can't cut an ID thread. However, within the last year, Leistritz Corp. has introduced a machine that mimics the intermittent cutting action of whirling to produce internal threads in both hardened and unhardened large parts.

The Innovation 2000 machine features an inverted vertical spindle, which remains stationary while the chuck moves above it in the X and Z axes. The thread-whirling tool looks like a boring bar, but it rotates and oscillates as the workpiece also rotates.

Ralph Wehmann, sales manager for Leistritz, said, "as the tool is in the cut, it's cutting at the helix angle, oscillating at the exact amount as the helix angle, and when it's not cutting, it's coming back."

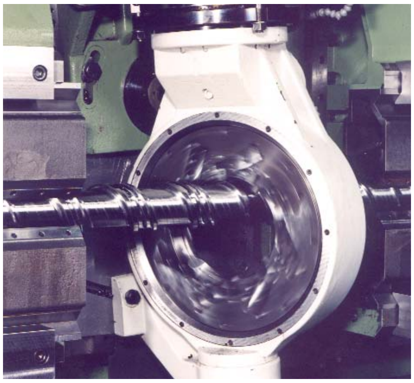


Leistritz

In internal thread whirling, the tool turns and simultaneously oscillates at the helix angle of the thread.

Grinding large internal threads usually requires a high speed, multiple passes, specially dressed grinding wheels to form the thread helix and long machining times. The new machine operates at relatively low cutting speeds, and it can produce a thread in one pass. Coolant is not required. It also features hydrostatic guideways and a massive bed with rigid construction to damp the forces of the tool oscillation.

—B. Kennedy



Thread whirling of a feedscrew.

whirl, from 0.003" to 0.006", depending on your desired finish."

During thread whirling, the workpiece and whirling ring rotate in the same direction. The cutting conditions are much like climb milling; maximum chip thickness occurs as the cutting tool enters the work. If the workpiece and ring rotated in opposite directions, chip thickness would be at its minimal at the point of entry, and the insert would rub rather than cut, generating heat and degrading surface finish.

As opposed to the thin, long chip produced by single-point threading, the thick, short chip generated in thread whirling is easier to control and carries away heat. This usually eliminates the need for coolant. Sheppard's Keagy said the dry machining aspect of thread whirling is an advantage for a number of reasons.

"Grinding under coolant," he said, "is a messy operation. The coolant is hard on the machine, and you have to get rid of it. With dry whirling, you eliminate that coolant. You don't have the cost of recycling or anything else."

Another factor in cycle time is the helix angle of the thread being whirled. A tight, high-helix thread generally takes longer to whirl than a low-helix thread form. The lead, or pitch, of a thread plays a part in determining cycle time. When a screw's lead becomes larger, the helix angle also increases. At the bottom end of the range, a 0º lead produces a 0º helix angle or inclination of the whirling head; the face of the whirling ring would be perpendicular to the workpiece centerline. It follows that a workpiece with a high lead has a high-helix angle, and the whirling ring moves along the shaft at a comparatively fast rate and, thus, a short cycle time.

Leistritz refers to a thread's "unwrapped length"—the cut length of the thread if it was unwound from the shaft. For a defined screw length, a screw with a smaller lead has a longer unwrapped length (more windings around the shaft). Helix angles in the range of 0º to 8º are considered low-helix angles, while helix angles above 20º are considered high. Wehmann added that screws with helix angles above 33º are not good candidates for whirling because the large cutting circles they require negate many of the benefits of whirling. For these screws, milling or hobbing is recommended.

Walther said he chooses thread whirling on a case-by-case basis. The shop still employs all the processes it had before it acquired the thread-whirling capability, "but we've moved some things around because of the quickness of the thread-whirling machine."

Depending on the tolerances specified by the customers, "we look at each product individually and decide which would be best-suited for each machine." △