The WHIRLING PROCESS for Internal Threads

By Ralph Wehmann

With the advent of “internal whirling,” Leistritz has introduced an innovative new way to machine internal threads, thereby increasing efficiency, productivity, and quality.
As an industry leader in the field of whirling technology, Leistritz has developed an innovative solution to machining difficult internal threads. The process, which is called “internal whirling,” can be performed in both soft material using carbide tooling and in steel as hard as 65 hrc with CBN. In each case the process is performed dry, without coolants.

The process was developed in response to pressure from the ball screw industry, where the process of choice has been grinding with internal thread grinding machines, which has always been the slowest and most troublesome operation in producing a ball nut. Internal whirling eliminates thread grinding and eases the manufacture of all types of internal threads.

Grinding has several inherent disadvantages. It requires very high cutting speeds, and with the small-diameter grinding wheel that’s needed for internal grinding, this translates into spindle speeds in excess of 30,000 rpm.

Another problem when grinding involves coolant and the difficulties associated with distributing it to the exact interface between the grinding wheel and the workpiece. Very often, sophisticated coolant filtration and auxiliary pumping systems are required.

The third drawback to grinding is the thread profile or form. Because the grinding wheel cannot be angled to the helix angle, it must be dressed with a compensated or narrowed contour to generate an acceptable thread profile; in many cases with less than ideal results. The wheel is grinding askew to the thread profile, and a larger than necessary contact with the workpiece can cause high heat and burn the work, creating micro cracks.

Also, the grinding wheel quill must be as long as the internal thread that needs to be ground. In the case of long threads—and especially those with small diameters—the wheel can be a long distance from the spindle bearings. Subsequent deflection from the grinding forces requires using very conservative grinding parameters and, as a result, very long cycle times.
Internal whirling has none of these disadvantages. The spindle speed is normally under 2,000 rpm. Fast enough for CBN tooling, but still manageable and safe. Internal whirling is normally done dry. The ideal cutting conditions, combined with the optimal cutting edge preparation on the insert, create an environment in which nearly all of the heat is carried away by the chips. An air blast through the whirling spindle maintains a temperature of both the tool and the work below 150°F.

The tool oscillates axially in and out so that the insert profile is very nearly the same as the desired thread form. The Leistritz Internal Tool System uses a supporting mandrel with a bearing right up close to the cut, enabling very large length-to-diameter ratios. This system also produces very accurate threads and excellent surface finishes, comparable to grinding.

In most cases this internal whirling process eliminates a rough threading operation. Leistritz has developed its CBN technology to a state that the system can reliably and economically remove the full-hardened steel to reveal a precision, finished thread in one pass. This is unheard of with grinding, which normally requires minimal stock removal to reduce the cycle time. Internal whirling...
is always performed in a single pass, and the cycle time is the same if removing full material or just simply finishing, so most manufacturers choose to take full benefit of this technology by eliminating the roughing operation. This, however, requires that the nut blank be hardened to a depth at least as great as the profile so that a sufficient hardness of the material at the finished profile remains.

ACME, rope, ball, gothic, multiple start, or standard V threads are all ideal for this process. Interrupted cuts—where a thread needs to be machined through a groove, channel, or holes—are no problem and have no negative effect on the tooling. Although internal whirling produces a thread in a single pass, it never removes more than the calculated chip thickness, which is normally between 0.001-0.004".

Leistritz’s Innovation 200 machine is an inverted vertical machine with the chuck on top. The “Z” axis longitudinal travel moves the chuck and its rotary “C” axis up and down. The internal whirling head remains stationary below. This concept isolates any vibration caused by the oscillating masses directly into the massive “minerlit” machine bed. Minerlit is an epoxy based polymer granite offering maximum thermal stability and superior vibration damping characteristics compared to cast iron. It is mixed as a viscous solution and then poured into a mold and cured. Locating surfaces and mounting holes are then machined for assembly. Hydrostatic guideways for all axes guarantees the highest precision and accuracies, and having the chuck on top also prevents any chip buildup inside the workpiece bore.

The machine has been designed for a maximum thread length of 200mm (8"), but longer lengths are possible. The total internal whirling system is capable of producing square pitch threads. This means that a screw with a bore diameter of Ø25mm and a pitch of 25mm is possible. The production time savings can be huge. In many cases internal whirling will produce a thread 10 times faster than grinding, and with comparable quality. In some extreme cases the savings is even greater. For example, a Ø32mm thread with a 5mm pitch 80mm long needs only three minutes to whirl in full, hardened steel. Another example of a Ø1.0” minor diameter with a .3125” pitch, 2” long can be whirled in about 60 seconds.

Yet another advantage to this system is the ease in integrating automatic loading. Since the chuck remains above the work, and the combined “X” and “Z” axes have expanded travels, the chuck can be used as its own gripper system to go to a known position and pick up a blank workpiece. By adding a parts conveyor that travels through the machine base, a simple “pick and place” loading system using the machine axes is provided (please see accompanying photo). A sliding automatic door separates the loading and cutting areas.

To increase the machine utilization and guarantee the best possible concentricity to critical diameters, Leistritz has added turning, milling, and probing capabilities to the Innovation 200. The probe can be used to find the true position of existing
timing holes or surfaces, so the thread can be precisely timed for the start point, etc. Hard turning of the bore prior to whirling is suggested to improve the overall thread quality. Even the slightest amount of run-out can negatively effect the finished thread. Of course, facing and OD turning is available and provided for. The Innovation 200 is a fully capable, 75HP, CNC lathe. Using a block tool holder system, fixed tools are mounted directly to the machine bed; thus a turret is eliminated, so chip-to-chip times are reduced while increasing rigidity for hard turning applications. The standard hydraulic, 10” chuck is mounted to a DIN 5026 spindle capable of 4,000 rpm. Additionally, a high speed, 12,000 rpm, 20HP milling spindle with HSK 63 spindle adapter is available for auxiliary operations such as finishing of the ball return holes for the crossover mechanisms of ball nuts, etc.

As the tool rotates at cutting speed (approx. 540 sfm), it also oscillates axially. The amount of oscillation is calculated from the thread parameters and tooling circle diameter. The tool circle diameter is approximately 75 percent of the bore diameter of the workpiece. This means that, if the tool was exactly on center, it wouldn’t cut at all. So the “X” axis is used to control the cutting depth and to compensate for taper control. Higher lead threads require larger oscillation amounts. The oscillation continually maintains the cutting insert “normal” to the helix angle. This

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Cutting action maintains the most true profile and ideal cutting characteristics. When the tool rotates far enough so that it’s no longer in the cut, it oscillates back to the beginning while continuing to rotate. While this continues for each spindle rotation, the workpiece (“C” axis) is slowly rotated in the same direction as the tool and the “Z” axis of the machine is advanced at lead until the desired thread length is achieved. The rotational rate at which the work turns determines the chip thickness removed by each pass of the insert. At this point the spindle is stopped, the “X” axis is retracted, and the entire tool is withdrawn. Normally a completed thread is achieved in a single whirling pass.

Changeovers are very fast, simply selecting a program in the CNC, if the profile remains the same and the diameter is similar. The oscillation amount is programmed directly into the CNC part program as a “W” axis value. In the accompanying diagram, the support mandrel does not rotate. It has a supporting bearing very near the cutting forces. The whirling shaft is driven from inside the main internal whirling head (not shown) and rotates at a maximum speed of 2,285 rpm. This whirling shaft also oscillates axially with each revolution. There are air blast lines integrated into the support mandrel to blow chips away and cool the tool, and the insert is rigidly held in place with a clamping plate. These components can be quickly and easily changed from one workpiece to another. The workpiece and application determine which, if any, components need to be changed.

The entire concept has recently premiered, but it has already proven itself in Europe with several ball screw manufacturers. In another installation an Innovation 200 is producing an automotive component with a six-start thread used in the suspension of an SUV to control automatic vehicle leveling. This tier 1 supplier is using the machine to do both hard turning and hard internal whirling to produce a finished nut that is assembled with the mating screw—though hard whirled in a different machine—to deliver more than 200,000 units annually.

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