FEBRUARY 2006 / VOLUME 58 / NUMBER 2

➤BY TED HENDERER, Ph.D., KENNAMETAL INC.

solid synchronicity

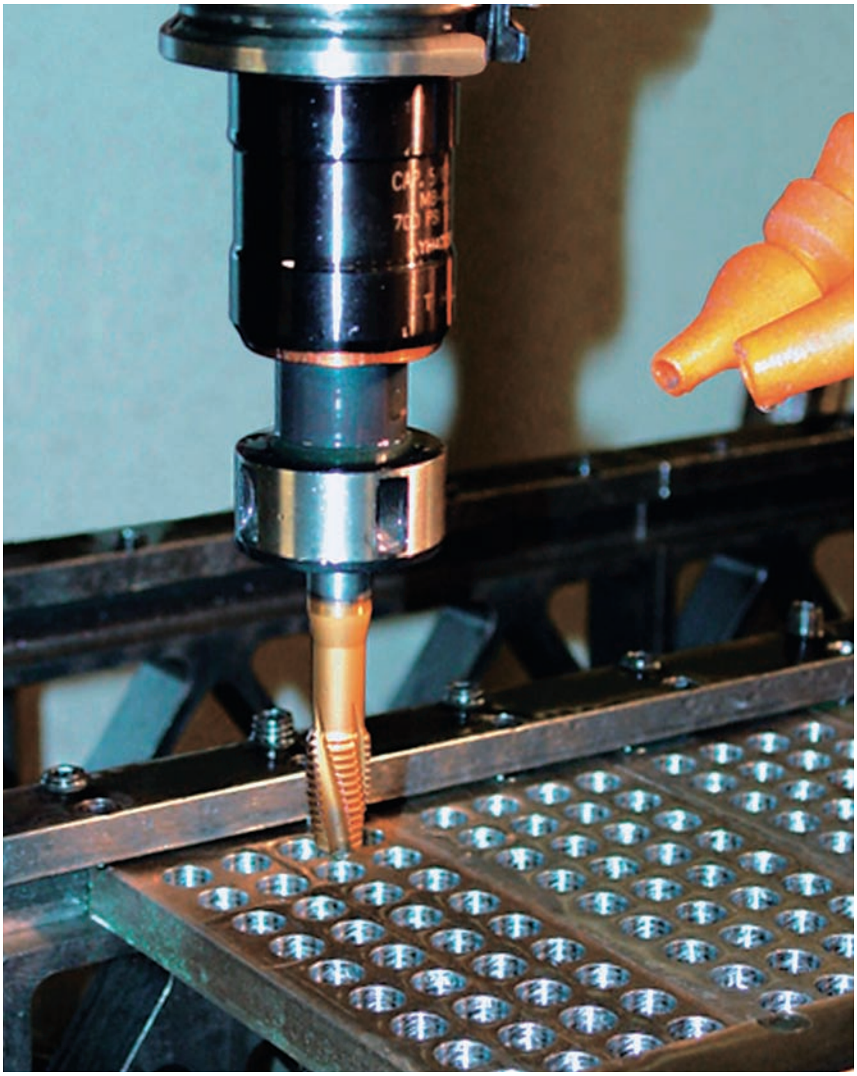
Realizing true high-speed synchronous tapping with solid-carbide tools.

Heat is a cutting tool's worst enemy. Unfortunately, though, it's exposed to temperatures at the tool/workpiece interface high enough to shorten its life and limit its performance. A variety of tool materials have been developed to combat this problem. The most popular are HSS and cemented tungsten carbide.

HSS tools have excellent strength and toughness, but cemented tungsten carbide is preferred over HSS because of its higher hardness and ability to retain that hardness at high cutting temperatures—its hot hardness. Typically, solid-carbide cutting tools can be run at least four times faster than HSS tools, and they last longer. However, carbide has lower fracture toughness than HSS, limiting its application in some machining operations, especially tapping.

Unlike most cutting tools for turning, milling and drilling, taps inherently have weak cutting edges and low overall strength. A carbide tap's cutting edges can chip or fracture easily, rendering the tool useless, even in relatively easy-to-machine materials such as steel. When tapping mild steel, long, continuous chips can bind in a tap's flutes, limiting carbide taps to threading materials even easier to tap than steel, such as aluminum and cast iron.

Steel and other ferrous materials, though, are the most common materials for assemblies requiring screw threads. As a result, toolmakers strive to develop taps that resist cutting-edge chipping and breaking. Much of their efforts center on developing carbide taps, given the material's inherent advantages vs. HSS.



All images: Kennametal

All in the Head

The dimensional accuracy of the internal screw thread defines the precision and fit of a screw-thread assembly. When threading holes, taps typically have been driven by drill presses or nonsynchronous machine tools equipped with flexible tapping heads that allow the tap to rotate and feed at a rate approximating the desired lead of the internal screw thread.

These older-generation machine tools do not accurately coordinate feed and rotation during tapping, which are necessary conditions for producing a screw thread. Consequently, flexible tapping heads have to be used to make allowances for the errors. A flexible tapping head allows the tap to run out radially during tapping, which limits screw-thread accuracy. These conditions result in low rigidity and nonuniform tap loading.

Successful application of carbide taps depends on how rigidly the tool is held and how well the feed is controlled. For most machining operations, these conditions are taken for granted, but they are just becoming a reality for tapping.

Recently, machine tool controls have improved to the point that spindle rotation and feed can be synchronized, which eliminates the need for flexible tapping heads.

Also, shrink-fit and hydraulic toolholders hold the tool with greater rigidity and dramatically reduced radial runout than flexible tapping heads. When rotated, these holders' concentricity is within 3µm.

Although not as desirable as shrink-fit and hydraulic holders, precision collet-type, tremendous-grip, high-precision (TGHP) holders also are effective.

Not all CNC machines termed "synchronous" or "rigid" feed the tap perfectly on lead as the spindle rotates. For this reason, shrink-fit, hydraulic and collet-type TGHP tapholders have been modified to allow a slight amount of axial movement to compensate for the small errors inherent with synchronous tapping machines.

The industry-standard tap shank tolerance is loose, typically +0.0000"/-0.0015". Because available taps can be used with flexible tap heads, the dimensions that control runout need not have restrictive tolerances. For example, runout of the shank and thread diameter of a ½" HSS tap may be up to 0.0016", per industry standards. And there is no requirement that directly controls concentricity of thread diameter and chamfered cutting edges to the tap's shank, which allows runout and uneven loading. Instead, these dimensions are measured to the centers in which the tap is held during manufacturing.

Recommended speed ranges when applying carbide taps

Workpiece material group	Examples	Hardness	Speed* (sfm)
Low-carbon steel (<0.25% C)	1018	<220 HB	300 to 400
Free-machining steel	12L14	<275 HB	250 to 350
Medium and high plain-carbon alloy and tool steels	1040, 4340, H-13, D-2	<32 HRC	200 to 300
Ferritic, martensitic and PH stainless steels	430, 410, 17-4 PH	<32 HRC	150 to 210
Ductile and malleable cast iron	A-47, A-536	<300 HB	250 to 400
Gray cast iron	Class 20-50	<300 HB	250 to 400

*Speeds shown are for through-hole tapping less than 3 diameters deep.

New Beginning

To gain the full benefit of carbide, Kennametal has a new tap design that takes advantage of rigid machine tools and precision toolholders. Like high-performance carbide drills and endmills, the carbide tap has a fully cylindrical shank, which ensures concentricity and an effective grip. (Most taps have a cylindrical shank with a square end.)

Also, the shank diameters are the same size as other tools. For example, the shank diameter for the ¼-20 carbide tap is 0.2500", the same as the shank size of the 0.201"-dia. carbide drill commonly used to create a hole for a ¼-20 thread.

To take full advantage of shrink-fit, hydraulic or precision collet-type TGHP holders, the shank diameter of the carbide tap is held to H6 of DIN standard 7160. So, the shank of a ½" tap has a diameter tolerance of +0.0000"/-0.0004" and roundness is held to within 0.00012". Square ends are not required because these holders have sufficient gripping force for tapping when the tap shank diameter is held within this tolerance. Furthermore, the tap's threaded body and cutting chamfer is concentric to the shank within 10µm, which promotes a uniform load on the tap.

When the tap is used with a precision toolholder, a fully rigid tooling system with reduced tap runout is created. This satisfies the two conditions required for successful application of carbide taps: rigidity and uniform loading.

Faster tapping

Some application data has been collected for Kennametal's new carbide taps. In one test with M12x1.75 taps, through-holes were tapped in 4340 steel with a hardness of 32 HRC. TiN-coated HSS taps normally produced 1,500 holes at a conventional tapping speed of 50 sfm. At 300 sfm, the HSS taps lasted 158 holes. The carbide taps showed little wear when the test was concluded, at 1,700 holes. In another test in 4340 steel, in which HSS taps failed at 1,300 holes when run at 50 sfm, M6x1 carbide taps produced more than 6,000 holes when run at 300 sfm.

An automotive component supplier machining A-536 ductile cast iron found it could increase the tapping speed from 110 to 400 sfm with the new taps, thereby reducing tapping cycle time by 65 percent. Because tap life increased to 40,000 holes, or four times the life of P/M HSS taps, total tapping cost was reduced 66 percent when both the machining and tooling costs were considered.

Another manufacturer discovered the carbide taps could be run at 300 sfm when tapping A-36 steel parts, thereby reducing the time to tap four 3/8-16 holes by 30 seconds. Furthermore, one carbide tap completed a typical job that normally required three or four HSS taps.

Feed Up

When solid-carbide drills were introduced, users had to reduce the feed per revolution, compared to HSS drills, to reduce the load on the cutting edges and prevent chipping. However, carbide drills could be run at faster cutting speeds. Advances in carbide drill grades and design greatly reduced the tendency for chipping, thereby enabling practical feed rates to be raised.

For taps, just the thread pitch, number of flutes and chamfer length control chip load; tapping conditions cannot further reduce the load on a tap's cutting edges. However, improvements to the design of solid-carbide drills that allow higher feed rates also apply to solid-carbide taps in order to avoid chipping. These improvements include a new KC7542 grade that combines a high-strength, cemented carbide substrate developed for taps with a newly developed, nanolayer TiAlN coating used for carbide drills.

Kennametal's KC7542-grade solid-carbide tap provides cutting-edge strength and wear resistance when performing high-speed synchronous tapping.

Fast and Furious

Improvements in machine tools, controls, toolholders, carbide grades and tap design have extended the range of materials that can be effectively tapped to include not only short-chipping materials, like aluminum and cast iron, but also, for the first time, long-chipping materials like carbon and alloy steels (see Table).

In addition, when held in a shrink-fit, hydraulic or precision collet-type TGHP holder on a CNC machine capable of synchronous tapping, recently introduced carbide taps can machine steels up to five times faster than HSS taps. The result is significantly higher productivity when tapping. △

Don't be blindsided

A word of caution when tapping blind-holes: not all CNC machines are equally capable of synchronous tapping. Because the tap and spindle must decelerate at the bottom of the hole, lead errors can occur during reversal, which causes thrust on the tap and oversized thread gaging. And because the tap is still engaged with the workpiece during deceleration, tap reversal and reacceleration, the tapping speed should be reduced by about 40 percent when tapping blind holes from the speeds recommended for tapping through-holes.

—T. Henderer

About the Author

Ted Henderer, Ph.D., is a research engineer for Kennametal Inc., Latrobe, Pa. For more information about the company's cutting tools, call (800) 446-7738 or visit www.kennametal.com.