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Tapping the Hard Stuff

Specially designed taps can be very effective for threading hard materials, as can thread mills.

Walter

In life, some people think that it's hard when you reach 40. In materials, though, "hard" starts when you hit 36. That HRC number is viewed as dividing soft from hard.

Justin Verburg, a national application specialist for tapmaker Titex+Prototyp NA, Waukesha, Wis., said hard starts at 36 HRC because at that point, a material usually elongates less than 10 percent. Generally, such materials can't be threaded with a cold-form, or roll-form, tap. (See sidebar on page 67.) Consequently, holes in hard materials tend to be threaded via cut taps or thread mills.

However, a general limit isn't an absolute limit. Some taps can cold-form threads in materials up to 44 HRC.

Naturally, cut taps can manufacture threaded holes in both soft and hard materials. Tapping harder materials, though, requires a number of changes to a tap's design.

Manufacturers tap harder materials when making a variety of products, including aerospace parts and medical devices. For example, Computer Integrated Machining Inc., Santee, Calif., taps materials in the range of 32 to 39 HRC for medical parts, such as guides for bone saws. CIM also taps 48 to 52 HRC materials, including stainless steel laser components used in the photonics industry.

However, CIM is foremost a manufacturer of turbines for pumping gas and oil from land-based sites. The turbine parts are often made of nickel-base alloys, such as Stellite 31, and reach 48 to 52 HRC after heat treatment.

Manufacturers also tap harder materials when producing molds and dies. These products are often made of tool steels, such as H-13 and P-20. H-13 can reach 48 to 52 HRC, while P-13 can reach 50 to 55. Such hard materials include heat-treatable alloys and cobalt-base alloys.

Manufacturers can thread materials with hardnesses up to 55 HRC with HSS-E taps, but the companies should apply carbide taps beyond that point, said Alan Shepherd, technical director for tapmaker Emuge Corp., West Boylston, Mass. (In HSS-E, the E stands for "extra" and indicates cobalt enrichment.)

Consequently, carbide taps would be applied to martensitic stainless steels. "They get really hard—the high 50s, low 60s—in the 400 series," Verburg said about the stainless steels. Those steels have 11.5 to 18 percent chromium as their major alloying element.

Tapping may also be performed on harder materials used in process-control components. Nickel-base superalloys, for example, are applied for measuring flow rates of chemicals, including acids. "The materials have to be resistant to those things," said Bill Roberts, a senior process engineer with Roberts Automatic Products Inc., a Chanhassen, Minn., machine shop.

Roberts Automatic Products

Taps can thread holes in a variety of materials, from aluminum to stainless steels (shown here) to materials with a hardness in the low 60s of the HRC range.

Tap Design

Naturally, taps for harder materials need harder coatings than those for softer materials. Harder coatings include TiN and TiCN, for example. The taps for harder materials also include a number of other differences, too.

One difference is the number of flutes. "For harder materials, you want a high number of flutes," Verburg said.

For example, a 2-flute tap is appropriate for aluminum. Taps applied to the hardest materials may have five or six flutes. "More flutes provide more cutting edges to distribute the extreme cutting forces and wear," Shepherd said.

Another difference is the amount of relief in the tools. Taps have less relief when they're designed for tapping softer materials because reduced relief improves stability in those materials.

Taps intended for harder materials have more relief. A material's hardness may require a tap to have so much relief that the tool has a negative, or radial, cutting face. Taps for soft materials feature positive cutting faces, which resemble sharp eagle claws. These claws would be chewed up in harder materials, though, so cutting faces are made with more relief.

Also, greater relief can be achieved via chamfer relief of the tap's lead, or cutting, edge; eccentric relief, which influences the tapping thread's pitch and minor diameters; and profile relief, which affects the major, pitch and minor diameters.

"The increase in relief results in less drag on the tap, which would be good for harder materials," Verburg said. Harder materials have little give, so taps with too much drag would break.

Also, reduced drag increases the tap's free-cutting ability and decreases the torque needed to tap a hole. Decreased torque, however, shouldn't be confused with little torque. Tapping hard materials requires significant power. "You're putting a lot of forces on the cutting edge," Verburg said.

Besides increased relief, taps for harder materials need larger rake angles.

According to Verburg, a tap's rake angle affects the cutting edge's stability more than the relief angle does. Reducing the rake angle increases the stability of the cutting edge's motion and usually results in better chip formation. But, reducing the angle—which is necessary for harder materials—increases the cutting forces and torque, Verburg added.

Also, when tapping harder materials, manufacturers should expect the taps to have short lives, even when they're designed for harder materials. Providing an example, Mike Brown, CIM's president, said a long life for a tap would be about 100 holes in a harder material. Tool life for a particular tap depends on a hole's depth and a material's specific hardness.

Manufacturers should also expect taps for harder materials to be more expensive than their counterparts for softer materials. For example, manufacturers would normally need carbide taps when working with extremely hard materials.

Tapping Harder Materials Bit by Bit

Besides tap design, manufacturers should also be aware of tapping technique when threading harder materials.

Technique is a concern because the harder the material, the greater the chance of tap breakage. Manufacturers can reduce that chance by applying their cut taps via pecking, which takes several incremental passes to achieve the desired feature. Cutting threads a little at a time reduces the load on a tap.

Bob Ghamandi, owner of HighVac Co., an Inglis, Fla., machine shop, peck taps with high-performance cut taps. He peck taps to thread holes in nickel-base alloys, such as Hastelloy as well as Inconel 625 and 718. These

The following companies contributed to this report:

Balax Inc.
(262) 966-2355
www.balax.com

Computer Integrated Machining Inc.
(619) 596-9246
www.cimsd.com

Emuge Corp.
(800) 323-3013
www.emuge.com

HighVac Co.
(352) 447-7033
www.highvac.net

Roberts Automatic Products Inc.
(800) 879-9873
www.robertsautomatic.com

Titex+Prototyp NA
(800) 945-5554
www.walter-tools.com

materials can have hardnesses from 45 to 50 HRC before heat treatment. HighVac taps such harder materials to manufacture flanges for the semiconductor industry.

To thread Hastelloy and Inconel, HighVac applies a cut tap at a fraction of the depth of the thread to be created per peck. "I'll do synchronized tapping in steps," Ghamandi said. "You go around and take a few pecks at it."

For example, HighVac would engage a cut tap at a depth of 0.1" if it were cutting a thread with a whole depth of 0.5". "I'll go around that five times," Ghamandi said. After the fifth pass, the thread is fully created.

However, manufacturers must have a machine tool capable of peck tapping. "It's all in the machine," Ghamandi said. Moreover, peck tapping is slower than regular cut tapping. Nonetheless, it can be useful at reducing the number of broken taps and of nearly completed parts that have to be scrapped.

Compared with Thread Milling

Threading holes in harder materials can also be accomplished with thread mills.

Emuge

Although generally suitable for softer materials, some cold-form taps can tap materials with hardnesses up to 44 HRC.

"Carbide thread milling cutters generally do not have a problem machining the higher hardness materials," Shepherd said. He added that thread milling permits better control of the tool's feed rate.

Moreover, thread milling is often the safest way to manufacture a threaded hole in harder materials. Specifically, a workpiece can be more easily salvaged if a thread mill breaks in a hole. If a cut tap breaks, removing the tool from the hole and salvaging the often costly workpiece is more difficult and

Cold-form tapping of softer materials

Cold-form tapping has many advantages compared with cut tapping when threading holes in softer materials, generally those with hardnesses of 35 HRC and lower.

Cold-form tapping doesn't create chips, since material is extruded rather than cut. Cold-formed threads have higher surface tensile, yield and shear strength than cut threads. The greater strength results from swaging. This process forms threads by causing workpieces to deform plastically and permanently.

Cold-form taps usually outlast cut taps because a cold-form tap has no sharp cutting edges to wear down quickly. Also, cold-form taps are capable of making threads with a greater length-to-diameter ratio than cut taps.

Moreover, thread sizes are often more consistent when they're made with a cold-form tap rather than a cutting tap because the cold-form tap extrudes material and forms its own lead as it threads a hole.

"With a tension/compression toolholder, the tap isn't going to be affected by lead error in the machine tool," said David Lammi, national sales manager for tapmaker Balax Inc., North Lake, Wis. "[The tool] doesn't need a lead screw to tap."

However, the size consistency comes at a price. Manufacturers need to be more precise when cold-form tapping, starting with making the core hole.

The success of cold-form tapping depends on the core-hole diameter. That tolerance is commonly tighter than it would be if the threads were created via cut tapping. A one-unit variation in hole size can result in a four-unit variation in a formed thread, said Dave Sibinski, a senior process engineer with Roberts Automatic Products Inc. Consequently, a core hole may need to be reamed before forming its threads.

If the core hole is too large, there won't be enough material for the cold-form tap to create threads of the correct size. If the hole is too small, the cold-form tap will have to move more material to create the threads. "Too small of a hole will give you premature wear," said Justin Verburg, a national application specialist for tapmaker Titex+Prototyp NA.

Also, when creating coarser-pitch threads, cold-form taps must move more material to form each thread. The more material moved, the greater the chance of workhardening. Stainless steels, titaniums and nickel-base alloys all workharden. Consequently, they can shorten a tap's life or break the tap.

—J. Hazelton

sometimes impossible.

Consequently, thread milling is often a preferred way of making threaded holes in the mold and die industry and the aerospace industry.

Also, manufacturers can more easily control thread size when thread milling. Thread mills create threads via helical interpolation, which involves the simultaneous movement of the X, Y and Z axes of a CNC machine tool. As the thread mill wears, the machine tool can be programmed so its helical interpolation compensates to continuously produce the hole size specified, said Roberts of Roberts Automatic.

However, thread mills can be more expensive than taps, and cost is something that must always be kept in mind.

Thus, threading of hard materials can be accomplished by thread milling, in some cases by cold-form taps, and by specially designed taps. As for choosing the best tool for a threading application, sometimes it's not just the material that's hard. △