Drilling Difficult Materials

High-temp alloys, hardened metals, and composites pose special challenges

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Drilling a hole to required specification in production drilling can be challenging when the workpiece material is especially difficult-to-machine. Trends in manufacturing from the largest titanium or composite parts for aerospace to Inconel for the smallest medical devices require versatility in handling the principal enemies of successful drilling: heat, abrasiveness, and hardness, or, in the case of materials like austenitic stainless, gummy softness. Each poses difficulties that must be overcome through a combination of drill-point geometry and edge prep, substrate, coatings, and coolant delivery.
Forming Nice Tight Chips

“End users are always looking for higher penetration rates, longer tool life, and straighter holes, if they are required,” says Joseph Nuzzi, director of research and development, Allied Machine & Engineering Corp. (Dover, OH). “Every year, when we bring end users and our distributors to our technical education seminar, the first thing we tell them is that in any high-production drilling application, you first have to form a chip small enough so that it can be readily evacuated out of the hole. Proper drill cutting geometry is required, and once chip formation is right, the chip flow has to be removed from the hole by providing enough kinetic energy behind a fluid media. A coolant system, comprising coolant through the tool, and possibly high-pressure coolant, is the required means to achieving such chip evacuation, since proper coolant systems pull more heat away from the tool.”

Allied Machine introduced its GEN3SYS XT high-penetration, replaceable-tip drill with geometry, edge strength, grades, and coating developed specifically for stainless, high-temp alloys, and nickel-based alloys like Hastelloy, Monel, and Waspaloy. “The difficult stainless is the austenitic stainless, typically the 304, 316, 350, 321 series, materials that are designed for the food and pressure-vessel industry applications. These materials have an extremely high deformation ratio, the ratio of chip thickness to feed per tooth, which translates into extremely thick chips when you’re trying to machine or drill austenitic stainless. In that situation, you need a good geometry, edge prep, and a real good coating to make sure drills stay together and withstand the heat generated.

“The GEN3SYS XT (‘SS’ geometry) forms a nice chip in austenitic stainless, and remember, if you can’t form the chip, you can’t be successful in high-production drilling. You have to form nice tight cones, or nice tight 6s and Cs in order to make sure you can evacuate the chip out of the hole, and the deeper you go, the harder it becomes to get chips out,” Nuzzi points out.

“When you talk about composites, metal-matrix composites, phenolics, and carbon-fiber composites, these are all materials that have very little tensile strength, but are extremely abrasive. It’s like taking a drill down the hole and rubbing it up against sand paper. What it does is wear away the flank. We drill composites with our TA and our GEN3SYS lines of drills with either diamond film coatings or PCDs, and have developed a vacuum drill for our TA line of drills for removing the dust that is generated, “ says Nuzzi.

Predictable Tool Wear

According to John Dotday, drilling product and industry specialist, Sandvik Coromant (Fair Lawn, NJ), when it comes to machining hardened materials or composites, end users are looking for predictable tool wear. “Difficult-to-machine materials present special problems, but once we identify the right tool to use and the right cutting parameters, if we tell our customers that they can drill 100 holes today, they want to be able to drill 100 holes every day. The trend today is drilling materials in a harder state. In the past, you had a piece of material, you drilled in a soft state, hardened it, and finished with a reaming operation, or redrilled if necessary. Now, end users want to drill in the hardened state, making subsequent processes unnecessary.” In March, Sandvik Coromant will introduce its new solid-carbide CoroDrill 860 PM 4234 with TiAlN coating in 3–20-mm diameter sizes with geometries that are being tested for stainless, plate, automotive components, and wear plates in steels ranging from 1018 up to tool steel.

Composites offer a special application area, one for which Sandvik Coromant has introduced CVD-coated CoroDrill 854 and 856 drills. “Both drills are designed for composites; 854 for fiber-rich composites where fiber content is above 50% and 856 for resin-rich materials with resin content above 50%. For hand-held applications, which are quite common in the aircraft industry, we’ve introduced a family of uncoated 452 drills, which are designed to drill without splintering and delaminating composite parts.”

Kennametal Inc. (Latrobe, PA) offers complete lines of application-specific drilling solutions in solid-carbide, indexable, and modular tools, as well as hole finishing and tapping
tools. Recent developments in the Kennametal solid-carbide drill portfolio include solutions for high-temperature alloys and exotic materials. “The most recent introduction is the line of Beyond solid-carbide drills. The drills feature new Beyond grades that are applied in both OEM and factory-regrind manufacturing centers, ensuring performance throughout the complete life of the tool. Beyond is a proprietary surface technology that lowers stress and torque in drilling holes and improves chip flow and drilling performance,” explains Frank Martin, Kennametal global product manager, solid-carbide drills. “The result is that Beyond technology improves both overall tool life and consistency at the same time.”

Kennametal’s application-specific drill portfolio also features Y-TECH, developed for exotic materials. The Kennametal Y-TECH drill’s unique design makes the violent motion of drilling less random which overcomes the tendency of the drill to walk and enables the production of straighter, more cylindrical, and more parallel holes. Martin explains: “With all drills, whether HSS, carbide, or indexable, when you enter the part, the material makes the drill deflect. Once it deflects, it begins a triangular motion, bouncing around and boring the hole out. It creates the basic need for a reamer. The Y-TECH features an unequal grind and margin design that is engineered to counter balance and produce a more predictable motion, resulting in the best-in-class possible hole quality from a drill.

SumoCham exchangeable-tip drills from Iscar Metals Inc. (Arlington, TX) work very well in titaniums, Inconels, Waspaloy, Hastelloy, and stainless steels with the “M” geometry. Ben Davis, national drilling product manager explains: “The SumoCham features coolant delivery with two small holes that come down through each flute, delivering more coolant to the bottom of the hole to flush chips out than a single hole down the center of the tool. The holes in the flute also allow for a deeper flute for better chip evacuation.” The DR Twist line of drills features this same coolant delivery method.
"Normally when you're cutting materials, you rely on some of the heat that is produced to go away with the chip. High-temperature materials restrict that absorption of heat so you have to reduce the amount of heat at the cutting edge by using the proper geometry, coating, and coolant," says Davis. "That's why I recommend running at slower sfm when drilling these materials as compared to materials such as alloy steel. Slowing drilling down generates less heat in the cut and prevents the chance of work hardening."

**Drilling Straight Holes**

For drilling tool steels and hardened materials, Mitsubishi Materials USA Corp. (Mountain Valley, CA) offers the MHS WSTAR drill series, which features webs 6–8% thicker than a conventional drill. In addition, a double margin ensures that the drill runs straight and doesn’t wander and break off easily. Nika Alex, product specialist drilling, explains: "The helix angle is a little smaller than our regular drills, making the drill stronger, and the primary and secondary relief angles on the point angle are bigger. All of these variables are done so the drill doesn’t break when increasing cutting forces." Mitsubishi Materials offers eight sizes in its MCS drills for drilling CFRP materials. The MCS drill features a newly developed PVD diamond-coated grade with a back clearance near the margins down from the top of the point angle and a larger back clearance for better chip evacuation.

Phoenix drills from BIG Kaiser Precision Tooling Inc. (Hoffman Estates, IL) feature a unique point geometry that lessens cutting forces on the drill for longer tool life when drilling hardened and stainless steels. A newer subset of this line is the Power-Phoenix for deep-hole drilling up to 30XD. According to Mike Bojanowski, the Power-Phoenix was designed to be effective even in applications where you have lower coolant pressure available. Drill flutes are polished as well as coated to facilitate chip removal. Applications include small stainless and titanium parts used for implants in the medical industry, as
well as stainless, titanium, and high-nickel alloys used in the aerospace industry.

Diamond-Coating for Composites

According to Mark Blosser of Komet of America Inc. (Schaumburg, IL), nano-crystalline diamond coatings represent an important breakthrough in producing tools that are extremely sharp with hard cutting edges for drilling or milling composites, aluminum and aluminum alloys, and graphite. “The ultra-fine, high-purity diamond layers can be applied to tools of all sizes, even large and complex-shaped surfaces. As a result, there is significant improvement in both the adhesion and stability of the layer, as well as its mechanical properties and controlling the surface roughness of the coating,” Blosser explains. “Applications in the aerospace, mold and die, and energy markets are already benefiting from nano-crystalline coated tools. End user examples include doubling feed in cutting carbon-fiber composites and increasing tool life by a factor of eight in drilling carbon-fiber/aluminum/titanium composites.”

Seco Tools Inc. (Troy, MI) has launched new drills for composite materials for drilling CFRP materials. “Basically, we have two different geometries,” says Thomas Sandrud, product manager, drilling: “C1 has an optimized drill point for carbon fiber and in stacked titanium/carbon fiber or aluminum/carbon fiber when exit is in the carbon fiber.” The diamond-coated drill has a double chamfer and two different angles for exiting on the carbon fiber without splintering and delamination. C2 geometry is used for stacks entered on carbon fiber and exited on titanium or aluminum, controlling chips so that the metal chips don’t roughen the carbon-fiber surface. C1 and C2 drills are coated with a CVD Dura coating.

Three drills series, the MDW GS series, the SMD replaceable-head drill, and diamond-coated drills for CFRP machining, are available from Sumitomo Electric Carbide Inc. (Mount Prospect, IL) for difficult-to-machine materials. The MDW GS drill series features two variations: the GS noncoolant through drill and the HGS which is through-coolant with double margin. Coatings include TiSi and TiAlCrN combination super-lattice PVD coating. The high hardness of chromium helps with the high-temperature alloys like Inconel and titanium in drilling with 12, 20, 25 30XD drills. “With the coatings, we recommend running at elevated feeds compared to previous drills or previous coatings,” says Rich Maton, assistant engineering manager.

“We can apply our Walter Titex X-treme drills in all stainless steel, cast iron, nonferrous, titanium alloys, and hardened materials in low or high-volume drilling,” says Patrick Nehls, Walter USA (Waukesha, WI). “When considering the number of holes, it’s important to maximize your return in cost per part. With the additional features of the Walter Titex X-treme, we’re seeing better tool life. Since the line came out at the end of 2009, we’ve been involved in testing and switching end users over from the Alpha 4 to the X-treme drill with improved productivity results. We’re going to end up selling them fewer tools, but because of the performance of the tools, they’re opening us up to more opportunities with the customer that we didn’t have before.”