DECEMBER 2004 / VOLUME 56 / NUMBER 12

cover story

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Hole Strategies

Companies that produce high quantities of holes.

For shops that drill hundreds, thousands or hundreds of thousands of holes every day, holemaking productivity is a make-or-break issue. Different shops approach production holemaking in different ways, but they all face common challenges, including balancing reliability and productivity over long runs, tailoring holemaking processes to the material at hand and maximizing flexibility through careful tool selection and machine tool programming. Here's a look at three companies and the challenges they face in their high-volume holemaking processes.

F&S Tool

A machinist gages a rough-drilled, high-cavitation mold plate at F&S Tool.

More Cavities

F&S Tool Inc., Erie, Pa., makes injection molds ranging from single-cavity prototypes to 128-cavity production molds. F&S specializes in high-cavitation molds designed to produce small plastic components and closures, such as pill bottles, spice containers and caps for bottled water—parts made in the millions.

To maximize profitability of such high-volume, low-cost parts, the molds are engineered with as many cavities as possible. The cavities typically range from about ⅝" to 4" in diameter, and the molds are usually made of stainless steel.

F&S chooses drill styles according to the hole diameter. Toolmaker Andy Bartlett said holes from 0.118" to 0.400" in diameter are made with solid-carbide twist drills; drills with indexable carbide heads (ChamDrill from Iscar Metals Inc.) handle 0.400" to 0.880" diameters; and inserted drills produce holes with diameters 0.880" and larger. F&S drills the holes on OKK USA and Mori Seiki vertical machining centers.

A key drill selection criterion is maximum tool life in interrupted cuts. Before cavity drilling, each workpiece is gundrilled perpendicular to the cavity face with waterline holes that average $\frac{3}{8}$" in diameter and 50" deep. When the cavity drill passes through the waterline holes, the result is an interrupted cut. F&S seeks drills that resist wear but aren't so rigid that they fail when subjected to the shock of passing into and out of a cut. The ChamDrill, for example, has a hard carbide indexable cutting tip mated to a forgiving steel drill body that can withstand the rigors of interrupted cuts.

Reliable drill performance is required to permit drilling without close operator attention. Scott Faulkner, vice president of manufacturing and part of a four-brother team that runs F&S, said, "If we've got 128 holes to drill, I don't want to have the guy standing in front of that machine for an hour. I'd rather have him set the drill up, make the first hole, let it go and be programming the next plate."

The following companies contributed to this report:

F&S Tool Inc.
(814) 838-7991
www.fs-tool.com

GKN Sinter Metals
(248) 371-0800
www.gknsintermetals.com

Marmetal Industries Inc.
(888) 276-1242
www.marmetal.com
www.b2bdesigndevelopment.com/mi/index.htm

F&S Tool

A stainless steel stripper-plate mold component at F&S Tool.

In the area of programming, hole-making reliability depends on the selection of optimal cutting parameters, Faulkner said. Choices are based on many factors, including diameter of the holes, chipload and the chipbreaking capabilities of the drill. Regarding cutting speeds and feeds, Faulkner said F&S "starts on the high end, then works its way back and finds a balance." In most cases, the high end consists of the most aggressive machining parameters recommended by the tool supplier.

Bartlett said "it's fun to see how hard you can actually push. You have to run carbide hard. It's almost a recipe. You give it the proper speed and feed, and you're going to get the best tool life and machine hours out of it."

Productive drilling of the cavities also depends heavily on efficient evacuation of chips. To lift the chips up and out of the holes, F&S uses a ChipBlaster high-pressure coolant system that provides coolant flow at 1,000 psi and 13 gpm.

Bartlett said: "You've got to have not only the pressure but also the volume. When you get into bigger inserted drills, without [adequate] coolant pressure and volume you can't get the chips out. Even a shop with a CAT 50 machine and 80 hp can't run like we can because they can't get the chips out of there."

Bartlett cited the example of a job that required the production of 11 identical molds. The first molds, completed on a medium-duty machine without high-pressure coolant, each required 200 hours to complete. Later, after F&S added a 30-hp machine with the ChipBlaster system and high-performance carbide drills, the last few molds took only 100 hours each, "because we could push so much harder," he said.

Bartlett stressed the importance of using high-quality, consistent workpiece materials. "If you start with junk material, you're going to fight [the material] with chips. You're going to fight it with machinability," he said. "It might vary from plate to plate; one plate you can push on, another you have to back way off."

F&S tested a number of stainless steel alloys, and settled on RoyAlloy, from Edro Specialty Steels, Walnut, Calif., a prehardened (34 HRC), free-machining, 400-series martensitic stainless steel developed specifically for making molds for plastic parts.

Bartlett said the consistency and free-machining nature of the alloy enabled F&S to raise its feeds 30 percent. "I can program every inserted drill with the same speeds and feeds, as long as it's a standard application," he said. Bartlett pointed out that roughing operations offer the best opportunity for cycle time savings. "Everybody finishes at the same speeds. The faster you can get that material roughed out, the quicker you're going to get done," he said.

Jim Dinger, vice president of marketing and sales at F&S, said that during the mold industry's recent tough times "it's been a challenge for many moldmakers to maintain their level of production." F&S has done it through continually improving its processes. Dinger said continual improvement has given F&S a competitive edge over the years. But, he noted, the edge is for a shorter period of time than in the past. "It used to be a year and half. Now, we've got a competitive edge for 8 to 12 months. We've had to do a lot of things differently," he said.

Faulkner feels that shops that claim they don't have the time to test new technology are falling behind. "We always have time to test, and our guys want to test." He said suppliers typically are willing to absorb the cost of tools and/or materials used in tests conducted at local facilities.


Marmetal Industries

Marmetal Industries often drills copper-nickel alloy tube sheets unattended on vertical machining centers.

Holey Sheets

Marmetal Industries Inc., Horsham, Pa., makes parts for shell and tube heat exchangers. The company specializes in machining copper alloys for military, high-pressure and marine equipment that requires high resistance to corrosion. A typical exchanger consists of an outer cylindrical shell surrounding hundreds of longitudinal tubes whose ends are pressed or welded into heavily perforated plates called "tube sheets."

Marmetal machinist Mike Cardamone said some 24"-dia. tube sheets feature 800 holes or more. "All they are is holes!" he exclaimed.

The copper-nickel alloys from which the tube sheets are machined are abrasive and gummy. While HSS-cobalt drills are sufficient to cut the material—"It doesn't necessarily require carbide," Cardamone said—the alloys clog the flutes of conventional reamers.

So, to finish the holes, Cardamone applies modified HSS endmills. "I doctor them up and we use them to bring the hole to size." The endmills produce a spiral pattern in the holes. "Sometimes there are surface finish requirements, but other times our customers like them a little rough because the tubes actually adhere to the tube sheet better," he said.

Cardamone also uses modified endmills to produce larger (about 1¼"-dia.) holes, following a drill with an endmill whose relieved flutes make it resemble a keyway cutter.

Cardamone pointed out that Marmetal must balance tool life and productivity against the expense of the workpiece material. "The material, copper nickel, is not cheap," he said. Breaking a drill could force scrapping of an expensive tube sheet, so Cardamone runs each job as fast as possible without taking the chance of wrecking a part. "You have to weigh it out. I don't want to start costing my employer more money than I make them!"

Experience determines optimal cutting parameters, Cardamone said, and enables him to know when to sharpen a drill and how many holes it will produce. For example, simply the sound of a drill at work can indicate excessive wear. "It starts thumping," he said.

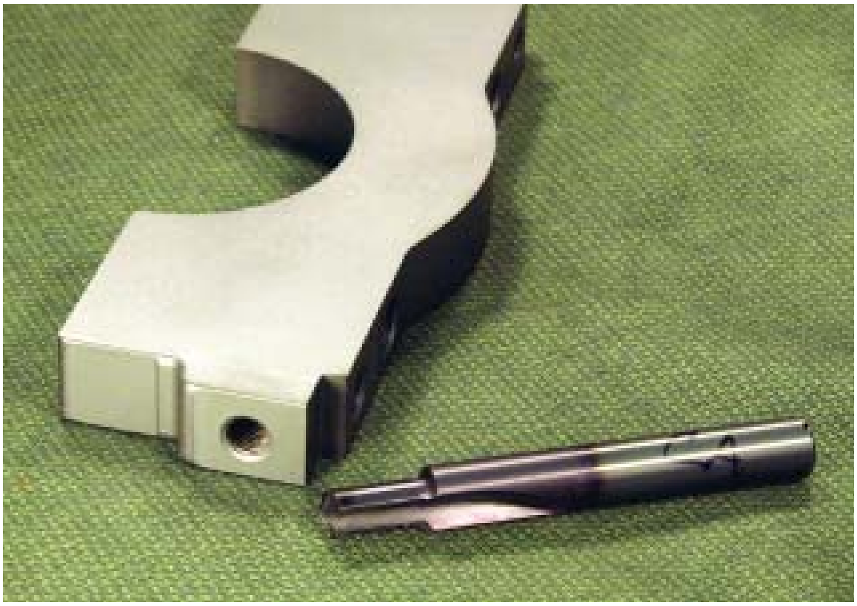
Chip appearance can also indicate problems. A chip coming off just one flute of the drill, Cardamone said, indicates improper sharpening, specifically, too much angle on one side.

Production volume affects how the holes are drilled. Cardamone described an order for two tube sheets that are new products for Marmetal. "Kind of tricky. They have a O-ring slot inside the hole," he said, "so on that job, I'll start out a little slower because we're only making two of them."

Variations in the alloys themselves also affect drilling. "From manufacturer to manufacturer, the copper nickel changes a little bit," Cardamone said. "It may have a little more iron in it. That makes it a lot harder and the drill won't last as long."

Marmetal owner Jerry Lynd said the shop drills the tube sheets on Haas VF5 and VF4 vertical machining centers, often running unattended. "If we are drilling tube sheets that take 6 hours, we program the machine and go home and let it run. It changes tools all through the night. When we're doing thousands of holes, the machine switches out the tool every couple of hundred of tools. I think we probably switch it out before we have to, to make sure," he said.

Trends toward small lot sizes and just-in-time delivery have changed the face of the heat-exchanger industry. Cardamone said: "A lot of these heat-exchanger shops haven't kept up with the technology. They have machines from the '60s, like Pratt & Whitney multiple-drill machines with 100 drills to do a certain tube sheet. They were, and are, good machines, but you have to dedicate one machine to one tube


GKN Sinter Metals

Each day, GKN Sinter Metals uses coated-carbide drills to make about 200,000 side-bolt holes in main bearing caps made of copper-phosphorus P/M steel.

sheet or you're always changing it. You may need to have 10 machines where you could have one CNC machine."

Cardamone uses FeatureMILL from FeatureCAM to program parts. Changeovers are fast. "One of this, two of that. If I didn't have a CAM system I'd be in trouble," he said.

Wholly Machinable

The machining characteristics of workpiece materials are a major consideration at GKN Sinter Metals, an Auburn Hills, Mich., producer of P/M parts. The company's focus is on automotive parts, but it also makes P/M parts for small engines, white goods and other industrial applications.

GKN's Wisconsin operations produce a range of ferrous P/M parts, including main engine bearing caps, clutch plates, gears and axle components. The company makes about 100,000 main bearing caps a day, representing over 90 percent of the world's production of P/M caps. The parts are formed from a proprietary GKN copper-phosphorus P/M steel developed specifically for the application. P/M Machining Technical Center Manager Denis Christopherson said transient liquid-phase sintering enables the material to deliver superior strength, ductility and machinability.

Because P/M is a near-net-shape process, it eliminates the need for most machining operations. On the main bearing caps, machining is limited to finishing cuts in the tight-tolerance areas (50µm for the cap-to-block press fit) and drilling of 7mm- to 9mm-dia. side-bolt holes perpendicular to the compacting direction of the part. GKN drills the bolt holes on transfer lines or CNC cells, depending on the specific part or production capacity requirements. Coated carbide drills are applied at relatively high feed rates, in excess of 25 ipm.

With the vast number of holes made in the bearing caps (200,000 per day!), Christopherson said high throughput is crucial to cover the capital costs of the equipment. Tool wear and drill life are important, but secondary to total output. "Therefore," he said, "optimizing the process is a business decision, and some portion of drill life is sacrificed for overall productivity."

Regarding the drilling itself, P/M materials have an undeserved reputation for being difficult to machine, Christopherson said. One reason is that shops often apply the same machining tactics as they do for cast irons. That's a mistake.

"Conventional P/M steels are short-chipping in nature, and typically produce higher cutting loads than cast irons, so specific edge preparation and tool design play an important role in maximizing drill performance," Christopherson said.

Rigid toolholding and workholding are required to compensate for the higher cutting loads, and to limit side loading. Christopherson said that increased side loading increases heat generation, and the porosity of the P/M material also lowers the "heat sink" effect of the workpiece, resulting in higher temperatures at the tool/workpiece interface.

"It is crucial to flush the chips from the tool tip and keep them from binding and breaking the drill," he said, adding that the drill tip and flute designs should be optimized and through-coolant applied to effectively remove the chips and allow heavy feed rates.

"All these factors can be addressed through proper machining [practices] and tool design," he said.