Striving for Perfection

The production of 'perfect holes' takes patience and careful planning.

KPT/Kaiser Precision Tooling

► BY BILL KENNEDY, CONTRIBUTING EDITOR

How do you make a perfect hole? Drills can wander, especially if the hole is deep. It's also difficult, if not impossible, to cast a hole that is perfectly straight and exactly positioned. Producing a precisely positioned, sized and finished hole usually requires a boring operation.

The same factors that affect most other machining operations govern the accuracy achievable when boring. However, boring has its own unique demands as well. Prominent among them is the need to control the deflection that results from tool overhang, which is dictated by hole depth.

In general, careful production planning, solid fixturing and rigid tooling form the foundation of accurate, productive boring. That was borne out in discussions with the managers of three shops about their quest for boring perfection.

Productivity Via Creativity

Creative application of tools and fixtures can help a shop handle challenging boring operations. InnovaTech Ltd., Philadelphia, focuses on developing and applying innovative machining processes, tooling systems, fixturing and material handling to serve its customers in a variety of industries: power tool, telecommunications, electronics, aerospace/defense, medical and appliance.

A good example is InnovaTech's machining of die-cast aluminum housings for a major power tool manufacturer. Part volume can exceed 50,000 pieces annually. To meet the customer's just-in-time demands, machining processes must be as efficient as possible.

In any machining operation, the workpiece must be accurately located and securely held. To ensure that each housing is identically positioned when clamped in the fixture, InnovaTech first turns the back face of the casting flat with a PCD tool. High-speed turning with PCD tools eliminates breakout that can occur due to interruptions in the housing face.

Fixturing is another key consideration, and it took InnovaTech time to develop its unique fixture. "We went through three or four iterations of clamping when we first started" producing the parts, said company general manager Tony Dagrosa.

InnovaTech clamps five castings simultaneously in a slab-sided fixture, which was designed in-house and that provides access to both the front and back ends of the castings (Figure 1). The fixture is bolted to a mechanically actuated Kawata Touchdex indexer. InnovaTech has two of the fixture/indexer setups mounted on the rotary pallet changer of the SuperMax vertical

machining center it uses for the job. The arrangement allows one group of parts to be changed out while another is being machined.

First, the outside of the casting's front is finished with an endmill. Then, after qualifying the main bore with a drill, the machinist rough-bores two different diameters in the main bore with Command Tooling System's Urma VersaMax double-cutter boring heads. The larger bore has an as-cast diameter of about 1.050", and rough boring removes about 0.0020" per side. Finally, a carbide tool from Horn USA cuts a snap-ring groove.

When the front of the casting is done, the VMC's spindle moves to a location above the indexer's actuation shaft and, with a bracket attached to the side of the spindle housing, pumps the shaft twice. The fixture rotates 180°, exposing the backside of the castings.

Two closed-end bores are roughed and finished inside the casting with endmills and small boring bars. Then a boring head, designed by Command, descends through the main bore in an offset position, shifts to center and performs a back-boring operation, working from the bottom of the bore up (Figure 2). After back boring, the tool returns to the offset position and withdraws. Final size is held within ±0.0004".

InnovaTech's toolmaker/application engineer, Steve Wren, said he wrote a special macro for the part program that provides a true "square" move-back to the offset position. It ensures that the tool doesn't score the bore as it exits the part.

Dagrosa said, "The roughing cuts leave 0.003" to 0.005" in the bore to finish up with, and we come in with a very accurate boring head."

To ensure smooth operation of the final assembled product, the housing's main bore and the two internal bores must be located and finished within 0.0002" of each other. The back-boring operation results in all the bores being finished in one setup. This helps ensure that tolerances are met. All dimensions are verified by air gaging.

InnovaTech performs another interesting process on the housing: A turning operation, performed on the VMC, that Dagrosa refers to as "an OD boring operation." Small journals inside the casting that have an as-cast diameter of about ¼" are rough-machined to 0.003" or 0.004" oversize with an endmill. They are finished to ±0.0004" with a special tool held in a precision boring head.

"We're boring a knob, so to speak," Dagrosa explained. "We use a boring bar to finish the outside diameter of the journal and the side of the journal."

A special tool was designed for the tenths-adjustable boring head used in the operation. To save weight, InnovaTech chose a non-balanceable head that it hard-balanced.

Nearly all the machining on the housings is done near the VMC's maximum speed of 15,000 rpm. One exception is the back-boring tool, whose eccentric insert holder must be held to 5,000 rpm.

Even at these constant high speeds, the PCD-tipped inserts used in the boring heads provide excellent tool life, according to InnovaTech utility man/operator Mike Luckangelo. The boring heads are balanceable (except for the one that bores the journal) and are designed to run at high spindle speeds.

"The high-speed tooling really makes the job for us," Dagrosa said. "We can machine hundreds of castings a day and make very few adjustments to the tools because they are balanced and can run at a high rpm. That gives us excellent process control."

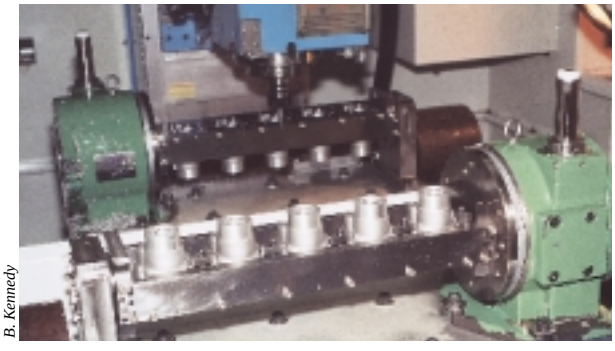

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Figure 1: InnovaTech uses two combination fixture/indexers in conjunction with a rotary pallet changer. This arrangement enables operators to load one set of castings offline while another set is being machined.

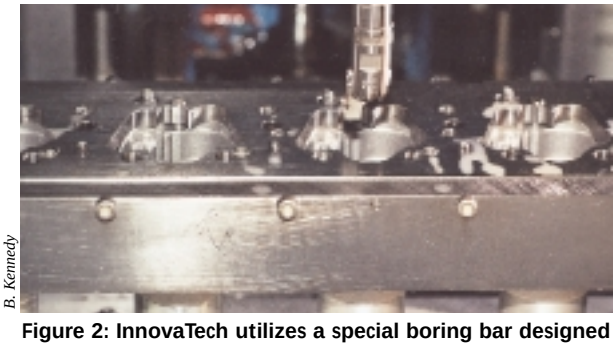

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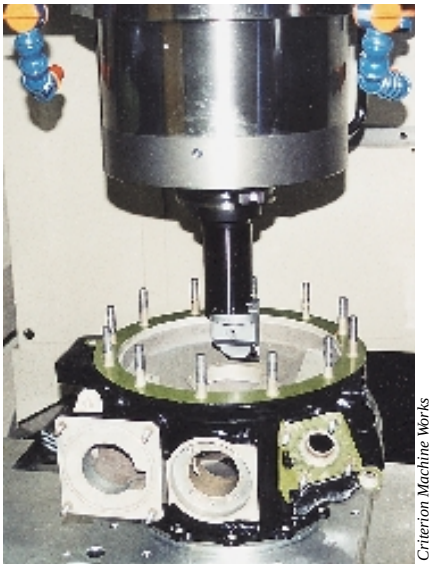
Figure 2: InnovaTech utilizes a special boring bar designed for back boring the castings it machines.



Criterion Machine Works

Figure 3: A component for an auxiliary power unit is machined at Ohlinger Industries with a Criterion Machine boring head.

Rigidity Required

Ohlinger Industries Inc., located in a 35,000-sq.-ft. shop in Phoenix, repairs and overhauls components used in the gas-turbine, auxiliary power units found on commercial aircraft (Figure 3).

While many of the gear boxes and pumps the shop overhauls are made of magnesium or aluminum, it bores a lot of replacement bearing liners made of

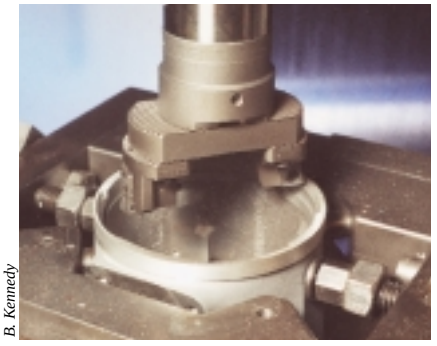


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Figure 4: For the stator housing, Marc applies a two-cutter boring head that roughs and finishes in one pass.

4130 or 4340 steel. Ohlinger cuts the old bearing liner out of the component, presses in a new one, then rough- and finish-bores it to final size.

Company vice president Randy Ohlinger said that sometimes machinists rough with a 0.001"-increment boring head and finish with a 0.0001"-increment head. Getting material out is quicker with a roughing tool, but, he cautioned, "you don't want to take too much."

The steel bores generally have a 0.020" stock allowance; after roughing, about 0.005" remains for finish boring. Bore diameters range from ½" to about 3", and a typical final tolerance is ±0.0002".

Ohlinger said holding size is the biggest challenge when boring the replacement sleeves. "You have to make sure you have a rigid tool. If the tool flexes, you can blow the bore oversize." A deep hole (in this case, 5" to 6") may require a heavier, more rigid bar. And the shop's boring operations often include more than one pass per bore.

Sometimes, shop personnel line-bore parts. They do this when boring same-size holes in the carrier on top and the gear box below. "We have to line-bore them so they're aligned properly," said Ohlinger.

The bar passes through air when it exits the top hole and before it enters the bottom hole. Shop personnel machine the bores with tenths-adjustable boring heads from Criterion Machine Works. To minimize deflection, Ohlinger said, the shop uses heavier steel or carbide boring bars.

Criterion says the density of bars made of solid carbide or heavy metal—a machinable tungsten alloy—helps them resist deflection. Criterion also recommends applying the largest-diameter boring bar that will fit the bore and still permit chips to be evacuated.

Ohlinger's production varies from machining a single unit to semiproduction runs. The nature of the repair business sometimes dictates processing a single part, but when different customers submit similar parts, the shop tries to run them simultaneously.

For semiproduction runs and repeat jobs, the shop builds fixtures. "Using fixtures is quicker and provides more rigidity," Ohlinger said. Longer production runs are processed on CNC machining centers, and runs involving fewer than 10 parts are performed on highly accurate, manual American SIP jig-boring machines. Order turnaround time is 30 days or less.

Keep the Motor Running

Marc Electric Inc. was founded 30 years ago in Yeadon, Pa., as an electric-motor repair shop. Today, the company distributes, repairs and services pumps, motors, gear boxes and drives.

Until a year ago, Marc Electric's in-house machine division performed its work on manual machines. Then the

Tips for repeatable boring

The goal of precision boring is repeatability. But achieving it takes more than simply adjusting the cutting edges, said Jack Burley, vice president of engineering at KPT/Kaiser Precision Tooling Inc., Elk Grove Village, Ill.

Accurate toolholding is fundamental. The taper of the toolholder shank that fits into the spindle must be precisely ground. Burley said the industry standard for a steep-taper shank is AT4. The smaller the AT number, the more precise the taper is, the more contact you get on the spindle. That, in turn, "gives you that much better repeatability and location," said Burley.

Then there's machine hygiene. "One of the first things we check if a customer is having poor repeatability is cleanliness," Burley said. A piece of matter measuring 0.0001" that rests on the tool taper makes 0.0002" difference on diameter at the gage line. But at the end of 10"-long tool, the difference can be 0.001".

Not surprisingly, he recommends keeping machine spindle pockets clean. And, he added, the tool carousels of some older machines are located in the machining area. In many cases, especially when machining aluminum, a chip will land on one of the precision boring tools, work its way into the spindle and "wreak havoc." When precision boring, it's best if the toolchanger and magazine are isolated from the machining area.

Insufficient retention-knob force is another cause of poor repeatability. It can result from slipping in the spindle or, simply, a diminishing of the retention force over time. Whatever the source, repeatability suffers and, if left unchecked, can lead to chatter.

In high-speed boring, Burley said, the No. 1 cause of out-of-round bores is poor tool balance. A boring tool with 100 gm.mm unbalance that's run at 2,000 rpm might produce a bore 0.0001" to 0.0002" out of round. (The magnitude of error also depends on other factors, including the size and tightness of the spindle and the rigidity and symmetry of the part fixturing.) The same tool run at 6,000 rpm could produce a bore out of round by 0.0005".

Poor fixturing is another cause of out-of-round bores. "It's not that the fixturing doesn't hold the part well," he said, "it's the unequal squeezing of the part." This often arises with weak parts, such as aluminum die castings. "If you're not careful how you clamp the thing, it's going to move all over the place."

Lastly, Burley said precision boring is such a demanding operation that it's a good process for testing machine tool accuracy. "If you ever do a geometry check on a new machine, a precision boring operation will allow you to assess the machine's accuracy.

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For more information on KPT/Kaiser Precision Tooling Inc., call (888) 866-5776 or visit www.kptkaiser.com.

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Marc Electric Inc.
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Alfred W. Maser Tool Co.
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Ohlinger Industries Inc.
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company won a manufacturing contract to build small motors that drive the contacts together in the high-voltage circuit breakers used in power plants.

Each motor is about 4" in diameter, 10" long and has a horsepower rating of approximately 1.5. Marc machines the housing, gear case and gear case cover from 319-T aluminum castings. Volume is around 500 annually, which is "a lot for us because we're a small shop," said Marc Vice President Joseph T. Morinelli.

The contract's production and tolerance requirements prompted Marc to purchase its first pieces of CNC equipment: a Haas VMC and a Miyano lathe. The total volume of the contract is not large. But because Marc machines so many different components for the motors and its CNC machining capacity is limited, the shop constantly seeks ways to minimize cycle times so it can meet production schedules.

One timesaving candidate was a boring operation on a stator housing (Figure 4). The as-cast bore is 3.015" in diameter and 3" deep, and includes four interruptions about ¼" wide, spaced at 90° intervals. Final size is 3.191", ±0.001", putting the total material removed at 0.107".

"We bore straight down through the interruptions," Morinelli said. "It's not a steady cut. The pressure on the boring bar isn't even, like it would be if you were machining a solid piece."

Marc sought tooling recommendations from distributor Alfred W. Maser Tool Co., Southhampton, Pa. Maser suggested applying Command Tooling's twin-cutter Urma IntraMax system to balance the cutting forces through the interruptions. The system features a rough/finish-process configuration, wherein the insert on the lead cutter makes a roughing cut while the following, smaller insert finishes the bore. Roughing and finishing in the same pass reduces both cutting and tool-change time.

"We thought in the beginning we would need two operations and two heads to finish the bore, but that didn't prove to be the case," Morinelli said.

Gregg Van Waes, product manager for Command's Urma boring systems, said: "If the hole's not in true position or if there's major out of roundness, the rough/finish process may not be the best solution. But it's really ideal for production runs, where you're trying to squeeze every second out of the cycle time. This allows you to save on the cost of buying an additional tool, and it also eliminates an operation and a tool change."

When Marc won the contract to manufacture the stator, it inherited a complex, but solid, fixture from a shop that had done the job since the 1950s on a Borematic horizontal machine. Morinelli adapted the fixture for use on his VMC.

"It's a nice fixture," he said. "It's got little fingers that come out of the top and grip with tension, so you don't have a lot of vibration."

He said vibration is the main problem when boring a relatively thin-walled casting. To counter the problem, Marc runs the part at 1,200 rpm, a 7.0-ipm feed and applies positive-rake inserts.

Marc Electric and the two other machine shops profiled understand that precision boring makes unique demands and success is an outgrowth of careful planning. And, like any company that successfully bores parts, the management at all three shops know that boring perfection requires patience and a certain amount of trial and error.