➤ BY ALAN RICHTER, EDITOR

Speed Pass

A look at single-pass bore finishing with multiple-spindle honing machines.

There's more than one way to hone a bore. One method is with a powered honing tool, or stone, that rotates and reciprocates while the abrasive portion continuously expands and contracts along the tool's axis during each cycle. This process is generally known as conventional honing and involves multiple strokes of a single tool to remove the required amount of material and impart the specified surface finish.

Another method is single-pass bore finishing using a multiple-spindle honing machine. For this process, a series of diamond-plated, barrel-shaped tools that have preset diameters are passed through a bore with a single in-and-out-stroke movement while the tool, part or both are rotating, according to Robert Marvin, product manager for Engis Corp., Wheeling, Ill., a manufacturer of single-pass bore finishing systems. A single layer of diamonds is permanently plated onto the tool and about 50 percent of each diamond particle protrudes from the bond. Tool life is from tens of thousands of parts to a million or more.

Single-pass bore finishing follows the existing bore centerline while removing a relatively small amount of material per pass.

The number of tools applied varies depending on the workpiece material, the amount of material that needs to be removed, the specified surface finish and the geometrical requirements, but four or six tools is common.

As the part is transferred from one tool station to the next, Marvin noted that each tool's diameter is set progressively larger, in ever-reducing increments, while the size of the diamond grits is reduced to achieve maximum efficiency. In a four-tool arrangement, for example, the first tool's diameter might be 19.000mm and be plated with 60/80 diamond grit, followed by a 19.020mm tool with 100/120 diamond, then a 19.030mm tool with 200/230 diamond and, finally, a 19.035mm tool with 325/400 diamond.

Engis

Let's Go Floating

Single-pass bore finishing follows the existing bore centerline while removing a relatively small amount of material per pass. This is achieved by allowing the tool, part or both to float rather than be rigidly held.

"We've found that floating the part in the fixture and allowing only the tool to rotate, not float, gives us good

results in most cases," said Gerry Schnitzler, senior product manager for machines at Sunnen Products Co., St. Louis, a builder of conventional honing and single-pass bore-finishing machines. With this approach, the tool is rigid in the spindle.

"We have had instances where we floated both the part and the tool because that gave us the tightest tolerance," Schnitzler said. "But most of the time that just adds complexity and cost."

Of course, sometimes a part weighing more than a couple pounds is too heavy to float. Then, the floating mechanism is built into the tool and, for example, the tool runs through a universal joint.

In many cases, Marvin said, the most precise geometries are obtained by using bearing-mounted, floating fixtures. In applications where it is impractical to float the fixture, toolholders with some form of float movement are often used. And when the process is performed correctly, "bore geometry better than 0.000020" is possible," he said.

Single-pass bore finishing can achieve a high level of bore precision and a low overall cost per part, but applications exist where other processes are better suited.

Machine Matters

Although single-pass bore finishing can be performed in a machining center, dedicated machine tools are preferable. "On a machining center, you'd probably only have one spindle and normally that's used for one final pass," Schnitzler said. "If you're looking at a production situation where you're removing more than 0.0005" of material, let's say, then you'd probably want to use multiple spindles."

Even when the volume and stock-removal requirements are appropriate, it's usually not practical to perform single-pass bore finishing in the machining center that produced the part. "Usually machining centers are horizontal and you lose a bit of your free-floating ability because of gravity," Marvin said. He added that the way the part is fixtured in a HMC may not provide sufficient clearance behind the hole for tool travel.

Also, the coolant used in an HMC is more for flushing than lubricating. But lubrication is important for single-pass tools to prevent material from embedding between the crystals. "If it's bad enough, it could destroy a tool," Marvin noted.

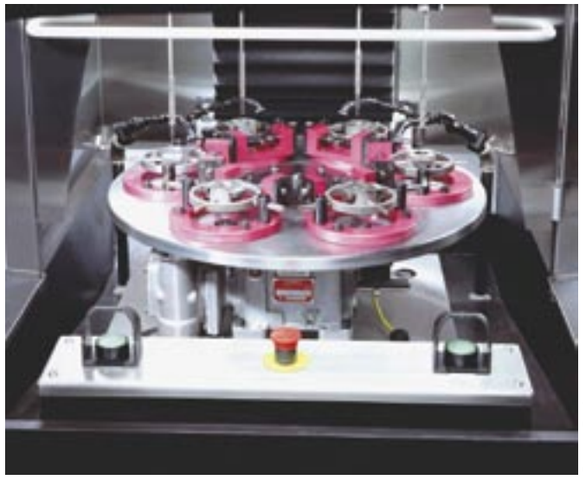
Even the chips remaining in an HMC from previous operations could cause a problem. "If one of those chips got onto a fine-grit tool," Marvin said, "it could tear the tool off."

In addition, because most single-pass bore-finishing applications require at least a couple of honing tools, productivity would suffer when bore finishing on an HMC, which is set up to apply one tool at a time. Marvin indicated that an HMC is appropriate for less than 5 percent of single-pass bore-finishing applications.

Transfer Ahead

Most single-pass bore-finishing machines have rotary tables to transfer a part from one tool station to the next. The machine functions similarly to a rotary transfer machine, where a part's cycle time is determined by the longest individual operation. When single-pass bore finishing, the cycle time is the time it takes for the tool to pass through the bore and remove the material and be pulled back. "The tool is probably removing less than a hundred-millionths of material—if anything—when it's pulled back through," Schnitzler noted.

However, there are times when a linear arrangement makes more sense. Al Wennerstrom, manufacturing manager at Belden Machine Corp., a Broadview, Ill.-based builder of multiple-spindle honing machines, described one scenario. "We couldn't put the part on a rotary table because it was such an odd-sized part," he said. "We were running nine clamping cylinders at 6,000 lbs. of pressure and we had so many hydraulic lines and hoses that we couldn't get the part through a rotary coupling so we had to do a linear arrangement."



Sunnen Products

Inside a six-spindle single-pass bore-finishing machine.

Being a multiple-spindle machine doesn't mean that each spindle's tool has to be applied for every part. A four-spindle machine might have two roughing tools and two finishing tools. "Sometimes we double it up and load two pieces," Wennerstrom said. "The first and third tools would be the roughers and the second and fourth tools would be the finishers, and each bore would get just two passes."

And like taking a finishing pass on an HMC, one spindle might do the job. "If someone bores a hole within two- or three-tenths of the size tolerance, it could be a single tool then," Wennerstrom said.

Single-Pass Limitations

Single-pass bore finishing can achieve a high level of bore precision and a low overall cost per bore. (Marvin said the perishable tool cost is as low as a penny per bore.) But applications exist where other processes are better suited.

One is finishing blind-bores, because the basic single-pass-tool design calls for a tapered lead. This prevents up to a third of the bore from being properly sized with the single-pass process. "The worst thing about the single-pass tools is that they're [usually] prevented from going into blind-bores," said Wennerstrom.

He noted that single-pass bore finishing of blind-bores isn't impossible, though. It can be done if certain conditions are met relating to workpiece material, amount of material to be removed and surface-finish specification. But, significant changes would need to be made to the tools. "All the tools are specials," Wennerstrom said of the single-pass tools from Sidley Diamond Tool Co. that Belden outfits its machines with, "but the ones for blind-bores would be more special. They'd need more engineering."

Ultimately, Wennerstrom feels honing isn't the way to go when finishing blind-bores. "It's hard to hone a blind-bore, put it that way. It might need an ID grinding operation."

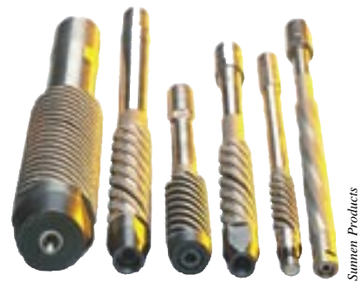
Schnitzler concurred that it's not common for single-pass tools to be applied when finishing blind-bores, noting that a stub-length special would be needed. "The single-stroke process isn't as well-suited to blind-bores as conventional honing is," he said.

Another factor is that some materials aren't suited for the single-pass process. Only the hardest plastics achieve the desired results and certain grades of stainless steel and aluminum are problematic. According to Schnitzler, the gummier grades tend to load up the tools, but they can be successfully honed by using an oil-based coolant specifically developed for a specific grade. He added that usually a water-based coolant is applied for the single-pass process because it more effectively removes heat from the part.

Part geometry plays a role, as well, in determining whether the single-pass process is appropriate. "On a thin-wall part, sometimes you put a tool into the part and it will expand and the tool won't cut as well," Wennerstrom said.

Other Factors

In addition, the bore's length-to-diameter ratio and number and type of bore interruptions are factors. There's no definitive length-to-diameter ratio at which the single-pass process becomes inappropriate, but it's more suitable when the ratio is relatively low. However, the bore's length needs to be balanced with the number of bore interruptions, such as cross-holes, which, when present in the part design, provide an exit for the coolant and the chips created. This minimizes surface galling and tool loading.



Sunnen Products

A selection of high-production helix single-pass honing tools from Sunnen Products.

"If it's a solid bore with a 2:1 length-to-diameter ratio, that might not be a good situation for single-stroke," Schnitzler said. "If the length-to-diameter ratio is two or greater, but 50 percent of the bore has cross-hole interruptions, that probably is a good candidate for single-stroke."

An additional consideration is whether the bore surface requires a texture to enhance lubricity retention in the surface texture that's generated. This usually means a crosshatch pattern, which is more the domain of conventional honing. Of course, a single-pass tool can be programmed to take multiple passes, but cycle time increases and the depth of the resulting pattern is limited.

"Most of the stock removal is done on the first pass, so any scratches you're able to generate in the bore after that first pass are pretty superficial and don't provide the kind of crosshatch pattern and depth of texture that conventional honing does," Schnitzler said.

An option is to have a reciprocating spindle for the final spindle on a multiple-spindle bore-finishing machine. Instead of the tool taking a single pass, it expands and contracts two or three times to generate the crosshatch, Wennerstrom explained.

Part volume is another consideration. Wennerstrom noted that Belden only builds multiple-spindle honing machines for high-volume applications and indicated a minimum run would be in the low thousands.

However, with quick-change tooling and modular fixturing, Schnitzler said a smaller run is feasible, depending on the application. "Even if you only have 100 or 200 parts, it would be attractive to do the parts this way because of the quick cycle time," he said. "If the setup only involves changing tools and fixture nests, you could probably do that in under 15 minutes on an eight-station table and even less on a six-station."

Marvin concurred. "If you're just running 20 or 25 parts, single-pass bore finishing wouldn't be worth it. But if you're doing batches of 100 or 200 parts that would repeat throughout the year, it would make sense."

Schnitzler added, "There are many factors that determine whether a part is a good candidate for single-stroke bore finishing. Not all parts are and that's why we offer other options." △

The following companies contributed to this report:

Belden Machine Corp.
(708) 344-4600
www.beldenmachine.com

Engis Corp.
(800) 99-ENGIS
www.engis.com

Sunnen Products Co.
(314) 781-2100
www.sunnen.com