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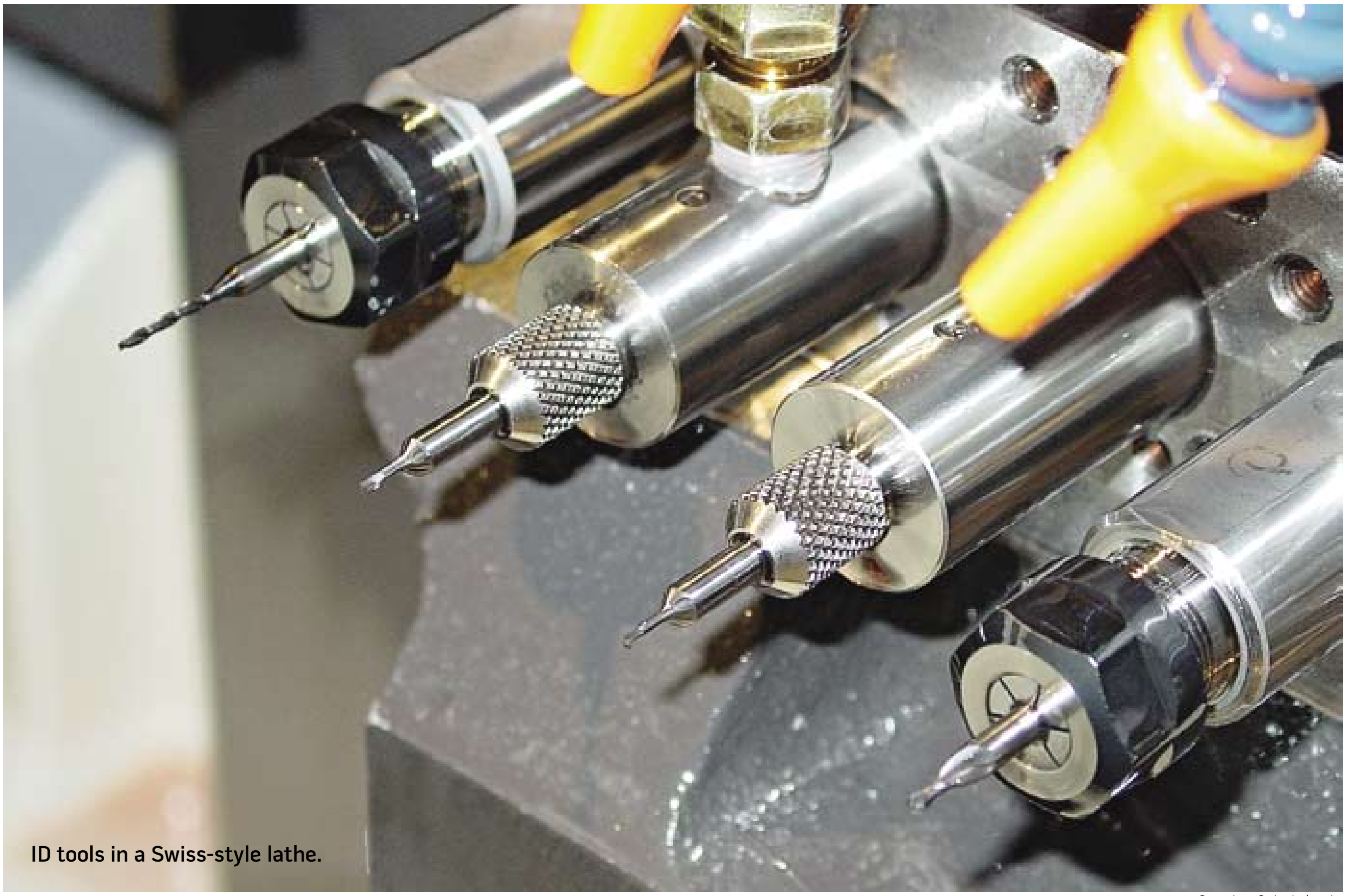

ID tools in a Swiss-style lathe.

Genevieve Swiss Industries

Small Bars, Big Results

By Dave Nelson, Productivity Inc.

Knowing the features and ways of applying mini and micro boring bars in Swiss-style machines can increase productivity.

Boring bars have big jobs to do on Swiss-style lathes. Both mini and micro boring bars are typically used on these machines. Successful use requires understanding their unique challenges.

Mini boring bars are defined as inserted bars that are typically under ½" in shank diameter. Carbide micro boring bars range from about 0.016" to 0.25" in diameter and are typically too small to accept screw-on inserts. Micro boring bars fit into sleeves to adapt them to a machine's tool stations. The bars in effect become inserts.

Swiss-style lathes make small, precise, complex parts for many industries. They excel at making these parts largely due to their stable setups—the guide bushing in most Swiss-style lathes supports the material as it passes through and moves past a tool's cutting edge.

However, the guide bushing only serves to minimize part deflection. While turning tools are typically kept short in Swiss machines to minimize tool deflection, boring bars are not. A boring bar may have excessive overhang (more than 3:1 length-to-diameter ratio) due to the operations it performs.

Swiss Challenges

Smaller parts, complex geometries and difficult-to-cut materials present unique challenges for Swiss-style machines. Because tool sizes are so small, placement is critical. As diameters shrink, error in tool placement has a proportionately greater effect on the way the tool cuts and a larger ratio of error to size occurs.

How close the cutting edge is to the centerline is more exacting with micro boring bars than with larger tools. The allowable error when boring a 6" diameter is far different than when boring a

0.1" hole. An error of 0.001" on a 0.1" bore, which may not seem like much, equates to an error of 0.06" on a 6" bore.

Error in tool alignment center height may be caused by errors or defects in the tooling, such as toolholders having too large a bore, burrs, blemishes or dirt on the boring bar shank. There can also be error in the machine tool itself, such as an alignment issue. It is, of course, best to have the machine properly aligned and the tooling in good condition.

Even with a properly aligned machine, some shops make the mistake of correcting center height error by rotating the boring bar to place the cutting edge on center. This adjustment might work for larger diameter bars, but in smaller sizes there are compromises with tool geometries. For example, if the tool is above centerline, it can be rotated down to place the edge on center. This method works in principle, but the effective radial rake of the bar becomes more negative. A negative rake increases the cutting force and directs chips back towards the part, causing surface finish problems due to the chips rubbing on the machined surface.

A tool that is below centerline may be rotated up to compensate. While the tool's rake is still positive, its clearance angle is compromised. Even a very small adjustment in this direction can create too little clearance. This can easily cause a tool to rub, bounce and break, especially when the tool is a micro boring bar.

Clamping Methods

A variety of clamping methods are used by toolmakers, the most common being setscrews. Two setscrews in a holder typically locate on a bar's flat. This maintains a relationship between the holder's flat and the bar's flat.

Clamping from the side pushes the screws into the bar and pushes back on the holder's thin wall. "Over time, the hole is elongated," said Jim Gosselin, president of tooling supplier Genevieve Swiss Industries Inc., Westfield, Mass. "The holder is no longer any good."

Collets or split rings offer a better clamping method, as they grip the bar with more surface area, producing a more rigid setup. They are also more likely to place the tool shank on centerline. Finding the correct orientation, however, requires the skill of an experienced operator. The setup takes longer

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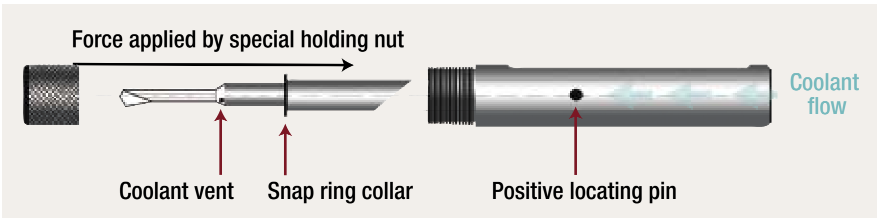
and must be done at every tool change.

To assure repeatability in length, stops are used on the micro boring bar. With a modification of a 45° taper on the back of the shank, centerline orientation can be achieved as well. The taper locates on a pin inside the mating sleeve, providing accurate placement in both length and orientation.

The Microbore line of boring bars manufactured by Utilis and distributed in the U.S. by Genevieve Swiss uses a variation of the taper back method. This tooling line eliminates the need for a setscrew and instead uses a knurled nut that pushes against a built-in ring on every bar. Only axial pressure is used to push the bar into the holder.

"All the nut is doing is pushing back," Gosselin said. "It is a superior clamping method to the setscrew." This technique, along with tight tolerances on both the shank of the bars and the bore size of the holders, provides exact placement and ease of use, according to Gosselin.

No tool is required, allowing the tool change to be done entirely by hand. With tool slippage eliminated, chances of breaking an adjacent tool and of operator injury are reduced and the possibility of overtightening is significantly reduced. Without a tool, it is difficult for the operator to overtighten the nut.

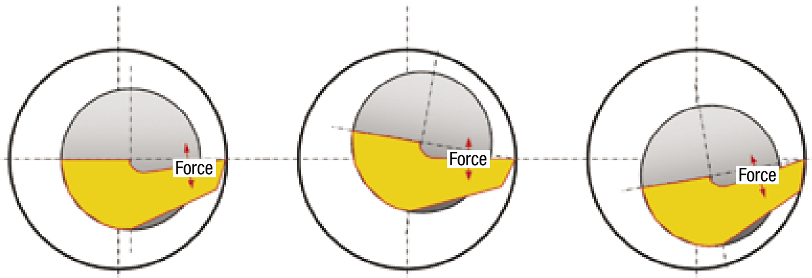


A simple design for a micro boring bar system.

Spindle Limitations

Another issue with cutting small parts involves the limits of current spindle technologies. Machine tools typically cannot spin the material fast enough to reach the surface footages required by carbide tools. A 0.1"-dia. workpiece would have to run at 22,920 rpm to reach 600 sfm.

"In mini and micro hole machining, where the diameters are ⅜" or less, carbide requires a surface footage that is normally not achievable on many machines," said Larry Myers, vice president of Denitool Inc., Murfreesboro, Tenn. "This is why, with the help of a metallurgy firm in Europe, we developed a tool material called Denalloy that can run at lower surface footages without the fear of edge chipping. With Denalloy, we are outperforming carbide with a tool that costs 10 percent



Positive rake boring bar set on centerline provides the most efficient cutting results. The positive chip rake reduces cutting force and heat. Chips are pulled from the inner wall for enhanced evacuation.

Positive rake boring bar set above centerline and rotated down to achieve centerline. The effective chip rake is neutral, requiring more cutting force. Chips are moderately controlled but could have evacuation trouble. Tool life is slightly reduced due to some increased heat.

Positive rake boring bar set below centerline and rotated up to achieve centerline. The effective positive rake would improve chip flow, except clearance is sacrificed, causing the tool to rub and bounce. The result causes excessive chatter, heat and premature tool failure.

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to 15 percent less." Denalloy tools cut smoother and last longer as a result of optimized surface finishes, according to the company.

This material creates a tough tool that resists chipping and breaking and can handle the necessary slower rpm. Geometries can be ground into the tool that allow for freer flow of chips. This is particularly important when boring titanium as it is a material that has memory—it bounces back behind the cut. Cutting tools also need larger clearance angles when cutting titanium. Clearance angles in most materials are from 5° to 7°. For titanium, clearance angles are 11° to 15°.

Titanium and nickel-base alloys are typical materials for medical and aerospace parts, among others, made on Swiss-style machines. These materials are difficult to machine because of their relatively poor heat conductivity. Heat from the cut goes into the tool, not the part or the chip.

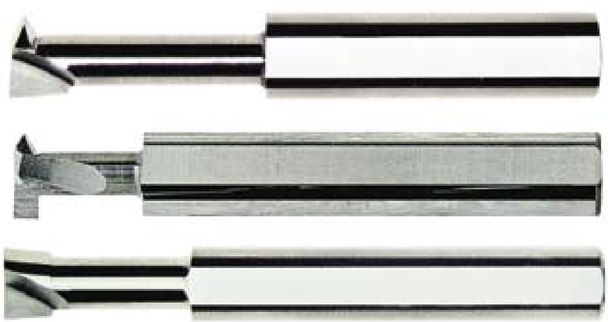
To reduce this heat, manufacturers use sharp tools, typically with a hone of 0.001" or less. This hone is placed on the tool to strengthen the edge for longer life. However, when boring many exotic materials, it is often better to not have a hone. Instead, a tool with a very small nose radius or even no nose radius is applied. These tool features allow a freer cut and improve tool life. This may seem counterintuitive, as the hone is designed to extend tool life when cutting low-carbon steels, for example. But a sharp tool increases tool life when machining titanium and nickel-base alloys because the amount of heat being generated is decreased.

A hone is an edge preparation that

strengthens the edge by distributing the cutting forces over a broader zone. The problem is that it creates a condition where more energy is needed to make a cut in the first place. "A rounder edge means the tool must be pushed harder," said Gosselin. That energy is converted into heat, the greatest enemy of tool life.

Positive tool rake geometries help create freer cutting conditions. A positive radial rake directs chips away from

Denitool



Internal Tool

Above: A system of boring bar tools for boring, grooving and threading.

Right: Examples of combination tooling: boring and threading (top); threading and grooving (middle); and flat-bottom drilling and double boring.

the part surface and a positive axial rake directs them out of the bore.

While rake angles direct chip flow, properly directing coolant is also important. For example, all Utilis and Denitool micro boring bars include through-coolant holes that deliver the coolant along the neck of the bar for enhanced chip evacuation.

Reducing Tool Pressure

The combination of these geometries creates the possibility of a weaker tool edge, but the combination of a sharp edge and small or no nose radius significantly reduces tool pressures.

These geometries require a high-quality deburring process after grinding. The Utilis tools are deburred using a proprietary process that removes burrs yet leaves the tool sharp. "For improved tool life, you need a tool that is very sharp, very clean and free of burrs," Gosselin said.

Cutting exotic materials creates hard chips that can washout part of the toolholder near the pocket of inserted tooling. This washout diminishes the integrity of the holder. Maintaining the fit between insert and toolholder helps prevent premature insert failure. Thus, toolholders should be made of high-grade materials, something Denitool has been doing for years.

"Instead of using standard 4000 series steel hardened to 38 to 43 HRC, our indexable toolholders are made with a special type of die steel that can be hardened to 52 HRC," said Denitool's Myers. "This offers pocket integrity over a longer period of time, and the tool surfaces adjacent to the insert are less likely to deteriorate and inhibit chip flow."

Countering Chatter

Sharp tools also help reduce chatter—an issue with any size part on any machine. For Swiss machines, setups are very rigid; the material is held not only by a collet but by the guide bushing, resulting in far less bar whip. Less bar whip reduces the chance of introducing external vibration into the cut. In addition, OD turning tools can be kept short, reducing the chance of tool deflection. Sharp edges on the cutting tool help reduce chatter by reducing the forces on the tool that might develop into a harmonic vibration.

Utilis micro boring bars have another line of defense against chatter. Because cylindrical bars create an ideal environment for harmonics to develop, Utilis grinds irregularly placed facets on the neck of the tool to break up harmonics before they can develop into chatter. Bars can extend 5 to 7 times the tool diameter when needed.

Limited Tool Positions

Another issue when using mini and micro boring bars in Swiss machines is that due to the limited travel of the machine tool, the number of ID tools is also limited. Some machines have only three ID tool positions. Boring bars often serve multiple purposes to compensate for the limited number of toolholders.

Multiple diameters in a hole or bore may appear to mean multiple drills, and while using step drills in Swiss machines can help reduce the number of tools needed to create part features, they present an added expense. Micro boring bars are far more versatile than step drills. Rather than using step drills, a combination of one drill and one boring bar can be used. First, the drill opens up a hole so that the boring bar can hog out the remaining material to create multiple diameters.

If a part has complex internal features, it may be useful to apply hybrid tooling—special bars that can machine multiple features—thus reducing the need for multiple tools.

One form of hybrid tool is simply a 2-flute endmill with one cutting edge ground back. This modification creates a tool that can be used as a flat bottoming drill and also as a boring bar by shifting the tool off center. Many tool manufacturers make 1-flute inserted drills that can act as a drill, a boring tool and a turning tool. This hybrid tool adds functionality without taking up more tooling stations.

Internal Tool Inc., La Verne, Calif., a maker of special solid-carbide tooling, builds bars for Swiss-style machines that combine boring with threading or grooving. These are single bars with two edges, allowing the tool to first bore to size then follow with a single-point threading tool or an internal grooving tool. Internal Tool also makes a tool that combines grooving and threading.

In addition to hybrid boring bars, there are other toolholder options. It may be convenient to use an OD tool station as an ID station. To do this, a square shank holder is built with one or two holes to accept the round shank of a spot drill or a boring bar. This can be done if there are OD tool stations open and if hole depth is less than 0.5".

For cutting small internal features in difficult-to-machine materials on Swiss-style lathes, mini and micro boring bars are used. Using these tools requires careful examination of tool geometries, tool grades and clamping methods as well as special toolholders and hybrid tools. All these characteristics combine to produce a solid cutting system. CTE

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Very small internal groove tools (1mm minimum hole diameter) are available down to 0.4mm.