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When the Chips are Down

A hole's depth-to-diameter ratio plays a key role in selecting the appropriate drill.

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When a machinist chooses a drill for a specific application, he or she must know the depth of the hole being drilled. The deeper the hole, the more chips there are to remove.

If chips are not removed efficiently, they can clog the flutes of the drill, causing production delays and, ultimately, negatively impact hole quality. Therefore, effective chip removal is key to successfully drilling any material.

Depth-to-Diameter Ratio

Machinists should calculate the depth-to-diameter ratio when selecting the most appropriate application-specific drill style. This ratio takes two measurements into consideration: the drill's diameter and the depth of the hole being drilled. For example, if the drill is ½" in diameter, and the required hole depth is 1½", the depth-to-diameter ratio is 3:1.

The flutes in most standard twist, or jobber, drills are capable of handling the chips produced by the tool's cutting lips, as long as the depth-to-diameter ratio is about 4:1 or less. All holemaking applications exceeding that ratio are completed most effectively with tools designed for deep-hole drilling.

Once a hole specification reaches a depth-to-diameter ratio greater than 4:1, a standard twist drill is incapable of lifting the chips out of the cut and away from the drill. The drill's flutes quickly will be congested with chips, and it becomes necessary to stop drilling, remove the drill from the hole, allow the chips to clear from the flutes and then continue drilling. This method, commonly known as pecking, has to be repeated until the necessary drill depth is achieved.

Pecking shortens tool life, reduces productivity and can diminish hole quality. Each time the drill comes out of the hole so chips can clear the flutes, there is the chance that when it is reinserted, it won't line up correctly. This can cause the hole to be larger than the tolerance specified.

Drill manufacturers have developed two designs in the last few years to successfully handle the challenges of deep-hole drilling.

True Parabolic Drills

The parabolic-flute style was specifically engineered to drill holes with depths of up to 15 times the drill diameter—without pecking—in materials no harder than 25 or 26 HRC. These materials include low-carbon steels and various aluminum and copper alloys. For example, a ½"-dia., parabolic-style drill can successfully drill a hole up to 7½" deep.

With its wider flute space, the "true"

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Flute and point geometries of jobber, parabolic and wide-land parabolic drills.

Recommended Starting-Point Speeds and Feeds for Wide-Land Parabolic Drills

CUTTING SPEEDS (SFM)

	HARDNESS	STRAW	TIN	TICN	TIALN
FERROUS					
Low-Carbon Steel	85-125 HB	90	125	135	-
Medium-Carbon Steel	125-175 HB	90	125	135	-
High-Carbon Steel	175-225 HB	90	125	135	-
Alloyed Steel	200-300 HB	60	80	90	-
Heat-Treatable Steel and Forgings	370-420 HB	40	50	60	70
Tool Steels	24 HRC	60	80	90	110
Tool Steels	>24-30 HRC	30	40	45	55
High-Speed Steels	14-30 HRC	35	50	55	60
Gray Cast Iron	240 HB	115	160	175	-
Gray Cast Iron	>240-300 HB	90	125	135	-
Malleable Cast Iron	<300 HB	70	95	105	-
Chilled Cast Iron	<350 HB	25	35	40	-
300 Series Stainless Steel (Austenetic)	120-200 HB	60	80	90	100
400 Series Stainless Steel (Martensitic)	200-300 HB	40	50	60	80
Stainless Steel—Sulphurized	>25 HRC	45	65	70	80
Spring Steel	400 HB	25	35	40	45
NONFERROUS					
Aluminum Alloys	40-100 HB	180	-	-	-
Aluminum, Cast <10 percent Si	200 HB	200	275	-	-
Aluminum, Cast >10 percent Si	200 HB	180	225	-	250
Brass—Long-Chipping	190-210 HB	150	-	-	-
Bronze—Long-Chipping	150-200 HB	90	115	-	130
Copper—Low-Alloy	65-100 HB	120	145	-	-
Plastics—Duraplastics	Not applicable	55	75	80	-

FEED RATES (IPR)

for Straw, TiN and TiAlN;
for TiCN increase by 25 percent

		1/8" 3.17mm	1/4" 6.35mm	3/8" 9.52mm	1/2" 12.70mm
FERROUS					
Low-Carbon Steel	85-125 HB	0.0040	0.0065	0.0080	0.0100
Medium-Carbon Steel	125-175 HB	0.0004	0.0065	0.0080	0.0100
High-Carbon Steel	175-225 HB	0.0030	0.0050	0.0065	0.0080
Alloyed Steel	200-300 HB	0.0025	0.0040	0.0050	0.0065
Heat-Treatable Steel and Forgings	370-420 HB	0.0025	0.0040	0.0050	0.0065
Tool Steels	<24 HRC	0.0030	0.0500	0.0065	0.0080
Tool Steels	>24-30 HRC	0.0025	0.0040	0.0050	0.0065
High-Speed Steels	14-30 HRC	0.0025	0.0040	0.0050	0.0065
Grey Cast Iron	240 HB	0.0050	0.0080	0.0100	0.0125
Grey Cast Iron	<300 HB	0.0050	0.0080	0.0100	0.0125
Mallable Cast Iron	<300 HB	0.0050	0.0080	0.0100	0.0125
Chilled Cast Iron	<350 HB	0.0025	0.0040	0.0050	0.0065
300 Series Stainless Steel (Austenetic)	120-200 HB	0.0025	0.0040	0.0050	0.0065
400 Series Stainless Steel (Martensitic)	200-300 HB	0.0025	0.0040	0.0050	0.0065
Stainless Steel—Sulphurized	>25 HRC	0.0025	0.0040	0.0050	0.0065
Spring Steel	400 HB	0.0020	0.0030	0.0040	0.0050
NONFERROUS					
Aluminum Alloys	40-100 HB	0.0050	0.0080	0.0100	0.0125
Aluminum, Cast <10 percent Si	200 HB	0.0050	0.0080	0.0100	0.0125
Aluminum, Cast >10 percent Si	200 HB	0.0040	0.0065	0.0080	0.0100
Brass—Long-Chipping	190-210 HB	0.0040	0.0065	0.0080	0.0100
Bronze—Long-Chipping	150-200 HB	0.0030	0.0050	0.0065	0.0080
Copper—Low-Alloy	65-100 HB	0.0040	0.0065	0.0080	0.0100
Plastics—Duraplastics	Not applicable	0.0030	0.0050	0.0065	0.0080

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parabolic design gets chips away from the cutting edges more rapidly while allowing an increased volume of coolant flow. This significantly reduces cutting friction and the potential for chip welding and galling, and lowers power consumption, torque load and thrust.

The helix angle of a parabolic drill is from 36° to 38°. This is higher than a standard twist drill's helix, which is from 28° to 30°. The helix is the degree, or amount, of "twist" in the drill. Up to a point, the higher the helix, the faster the chips are evacuated from the hole.

Another feature that makes the true parabolic style perform well in deep holes is its heavier core. (The drill's core is its spine, or the material in the middle that has not been ground away to form the flutes.) A standard twist drill's core comprises about 20 percent of the finished tool. In a parabolic, the core is approximately 40 percent of the finished drill.

The heavier core adds rigidity and increases stability when drilling deep holes. The point of a parabolic drill is notched, or split, to allow for the larger core diameter and has the added benefit of preventing any drill walking that might occur when holemaking begins.

Parabolic drills are made of HSS and come with or without performance-enhancing surface treatments.

Wide-Land Parabolic Drills

A few cutting tool manufacturers also offer wide-land parabolic drills to combat the challenges of deep-hole drilling difficult-to-machine materials, which are commonly known as work-hardening materials.

Wide-land parabolic drills share many of the same features as true parabolic ones. They have a 36° to 38° helix, for quick, efficient chip removal, and a heavier core diameter, for added rigidity and increased stability in deep holes.

However, the wide-land parabolic drill has different flute and land shapes than the true parabolic. In the wide-land drill, the land smoothly transitions into the flute, which provides strength and rigidity to the land and still allows chips to flow through the flute.

Rubbing and friction generated during drilling can slightly soften or temper a drill's cutting lips, causing them to wear faster.

"Red hardness" is the ability of these cutting lips to maintain hardness while drilling.

Wide-land parabolic drills are made of both HSS and cobalt-HSS. The cobalt version has a higher red hardness, so cobalt-HSS tools traditionally last longer and are more resistant to abrasion.

Coating Coverage

Here are the properties of some of the most popular coatings for the true and wide-land parabolic drills described:

■ Titanium nitride significantly improves wear life and hole finish, often enabling higher drilling speeds than uncoated tools in a broad range of materials, especially ferrous steels.

■ Titanium carbonitride is harder, tougher and more wear-resistant than TiN under moderate cutting temperatures. Like TiN, TiCN-coated drills may be applied at higher cutting speeds in a broad range of materials, especially ferrous steels. TiCN-coated tools should be used with caution when machining nonferrous materials because of the coating's tendency to gall.

■ Titanium aluminum nitride offers improved wear life, especially in conditions where high temperatures are generated. TiAlN-coated drills should also be applied with caution when machining nonferrous materials because of their tendency to gall.

To maximize performance when deep-hole drilling, speeds and feeds must be adjusted for specific depth-to-diameter ratios. When drilling at a depth-to-diameter ratio of 4:1, the speed should be reduced by 20 percent and the feed should be cut by 10 percent. Reduce the drilling speed by 30 percent and the feed rate by 20 percent when the hole is 5 diameters deep. And, when the depth-to-diameter ratio is 6:1 to 8:1, reduce speeds by 40 percent. In addition, feeds should be reduced by 20 percent when the depth-to-diameter ratio is from 5:1 to 8:1.

Although standard HSS twist drills can be suitable when the desired hole is no more than 4 diameters deep, a machinist should apply a parabolic or wide-land parabolic drill for deeper holes. The cost for this type of tool can be double or triple the initial cost of a jobber drill, but the lower cost per hole justifies the expense.

About the Author

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