The Humble D-Bit

By
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Novice model engineers frequently delay making their own tooling, thinking that this is for "experts" only and so would be better tackled after they've gained some experience. This need not be so. With a little knowledge and very basic equipment, even a complete beginner can make useful, highly accurate tooling. And in special circumstances, such as reamers with strange tapers, it may be impossible to locate the tool you need, regardless of the size of your check book. That's when the humble "D-Bit" comes into the picture.

In this article, we'll examine what is required to produce 'D' bit tooling in the home shop, and how to use it. While the item in question is frequently called a "reamer", it is in fact a single point drill. And despite its apparent simplicity, a correctly made 'D' bit is capable of drilling very deep holes that are straighter and closer to size than you'll get from any twist drill! We will see why this is so later.

Reference [1] tells us that 'D' bit drills were once made commercially in England. These had channels ground into them to carry coolant to the tip and generally had a Morse tapered shank for direct insertion to the lathe tailstock (thus removing a drill chuck of dubious quality from the equation when attempting to drill an accurately sized hole).

Figure 1 shows the general form for a parallel D-bit. Mine are all made from water-hardening drill rod. This material is called "silver steel" in England and some of her ex-colonies because of its bright appearance—there is no actual silver in the steel itself. It has a high carbon content to facilitate heat treatment, but is supplied "soft". The material is available in all the usual Imperial and metric drill sizes. It is quite precise in size and regularity, so I believe "drill rod" is a far more descriptive term. The common water-hardening variety (W-1) requires the least effort to machine and heat treat, although oil and air-hardening material may also be used. We'll examine the relative merits after we deal with the basics.

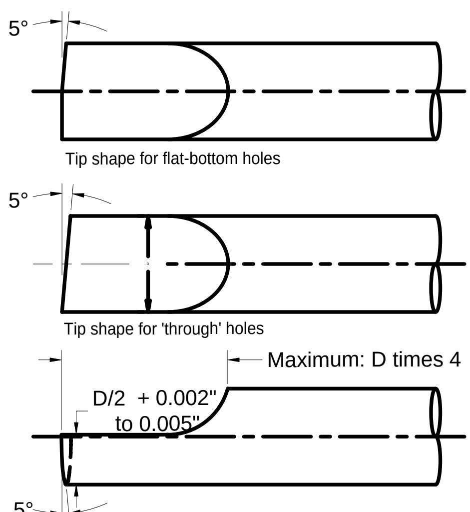

Figure 1, D-Bit forms

The name of the tool obviously derives from the general shape when viewed end-on. There is some debate over how much material needs to be removed, both longitudinally, and from the diameter. Easy questions first: how long for the relieved section? The rule of thumb is three to four diameters. Factors governing the decision are swarf retention and diameter. With no axial flutes, swarf cannot get away, so it accumulates in the open space of the D. The larger this cavity, the further you can drill before having to withdraw to clear the chips. However, the quenching process can induce warps if the D section is long and thin, so it's a trade off. Some of my very small D-bits, say from 1/8" down, have a flat of one diameter or less. Some large tapered bits go five diameters, or even greate .

Now, the big controversy: remove exactly half the diameter, or some amount slightly less? In reference [3], George H Thomas eloquently explains that in order to drill precisely to size, a drill must not cut on its sides. Making the size across the 'D' slightly greater than the diameter achieves this [1][3][6]. The amount required is small: usually between 0.002" and 0.005" above the axis, up to a maximum of 0.010" for bits above 1/2" in diameter. As well as preventing the sides from cutting, this config - ration provides guidance as the slight shoulders keep the round portion firmly pressed into hole, while a bit with the D on the axis may wander. And be warned: a 'D' below the axis will wander. A side benefit is that not only does it provide the required guidance, it will also allow you to re-sharpen the tool a few times. This would not be possible with a cutter having an edge formed exactly on the axis.

The flat may be formed by milling, grinding, or even filing (providing you use a filing rest). Milling is best as it allows more precise results.

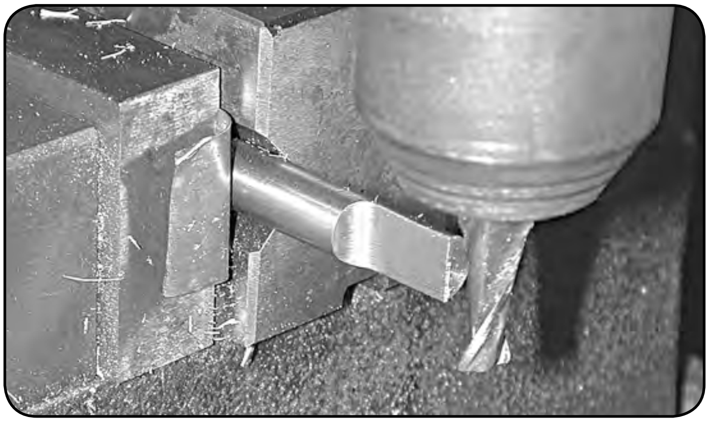

Photo 1, Cutting a simple D-Bit

Photo 1 shows a 'D' formed against the side of a two-flute cutter. The radius this produces behind the flat is a benefit as it helps prevent warping during quenching, and does not introduce a stress point as a sharp transition would. Which is not to say that a sharp transition must be avoided.

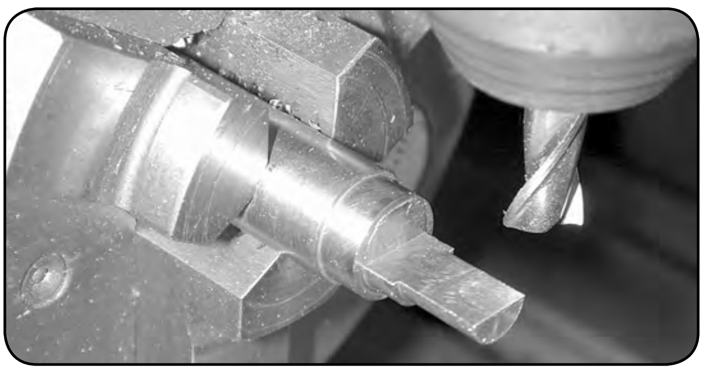

Photo 2, Two-step bit

Some cutters, like the two step cutters in Photo 2 require a flat as a precise depth stop—although there are obviously other ways of providing such a stop. Just avoid it if you can.

I should mention that lack of a mill is no impediment to machining the 'D' this way. You can grip the cutter in the lathe chuck and mount the blank horizontally in your tool post so that the cutter will remove 20 to 30 thou as you wind the cross slide out. After the cut is made, the 'D' is measured and the work is raised slightly until the final dimension is reached. In any case, avoid climb-milling, and leave at least 0.001" extra for stoning or grinding after hardening and tempering.

Tapered 'D' bits require a slightly different approach. They will be used to form a precisely tapered hole, generally for things like prop drive washers. They will be made to some included angle and, unless made for a one-off job, will be used to reproduce this angle in pre-drilled holes of various diameters. Because of this, the length of the 'D' will need to be relatively long to provide the range, up to the maximum of the shank size. Form the 'D' over the entire length of the taper. That is, until the flat reaches the parallel shank. Avoid trying to make the tool cover too wide a range. A long pointy one will certainly warp during heat treatment. Better to have two or three stubby ones of the same taper, but with varying minimum and maximum diameters.

There is a problem making them however: how do you arrive at one half, plus a few thousandths, on a tapered shank? You can't just apply the callipers to the taper at any point and measure with the required precision.

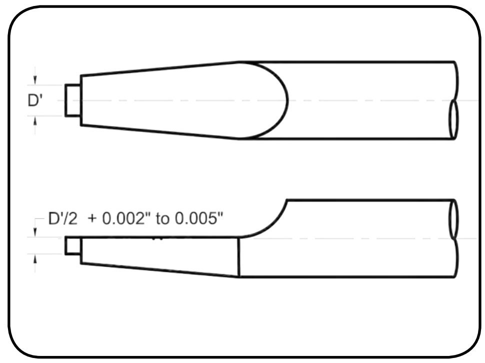

Figure 2, The stub trick

Fortunately, there's a simple trick we can use, as shown in Figure 2. Turn a short parallel stub on the end that will be smaller than tip at the minimum taper. Turn it to a nice even number, so you can measure the stub and know when you've shaved just under half of it away. This allows you to ignore the tapered section, which will be right when the tip is right (see Photo 3).

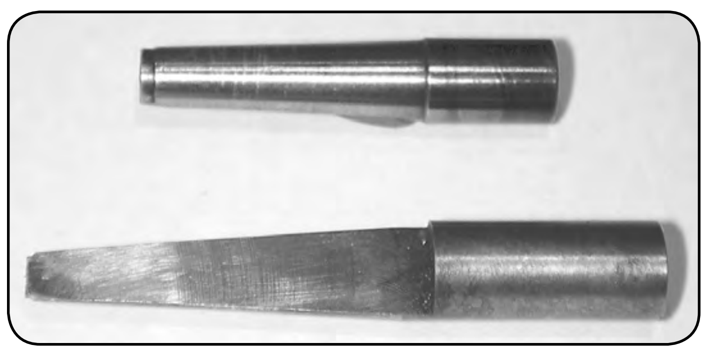

Photo 3, The stub trick

Incidentally, a tapered 'D' bit is not actually "cutting on the sides" as the sides are, in effect, the tip! So you still form it to be one half the diameter, plus a bit. And try to remember to stamp the taper angle on the end of the bit before hardening it and tempering.

The tip of a parallel D bit needs some clearance and rake ground in. Between 5 and 10 degrees is sufficient. But remember that the sharper the point, the more quickly it will blunt, and the more fragile it will be. I like to rough this in while the tool is still soft, then just touch it up on the stone, or grinder later (Photo 4).

Photo 4, Touching up the point

When the 'D' has been formed and any burrs removed with a light touch from a fine, Swiss pattern file, we are ready for the heat treatment stage.

A propane torch is best for this (see Photo 5).

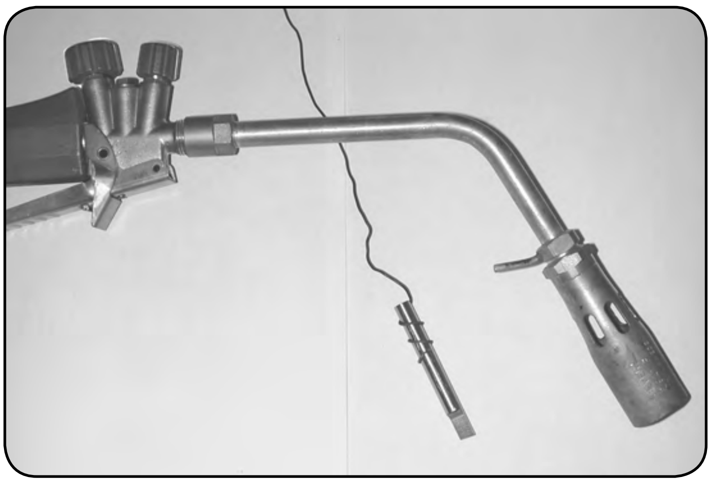

Photo 5, Propane torch and wire hanger

Oxy-acetylene is an option, but the danger of damage to the bit is greater. We are going to heat the 'D' section, and a short length behind it, to cherry red, then quench it in cold water. This is (surprise) called "hardening". But as it leaves the edges glass hard, they are too brittle to use, so we must then "temper" the tool.

One problem that may be encountered during hardening is the formation of "scale" on the tool as the steel passes through the critical temperature. Some advocate coating the steel in liquid soap, or acrylic paint (typewriter corrector fluid) before heat treatment. The theory is that it will burn off, but will remain long enough to keep the oxygen out until we are past the scale forming temperature. I've tried it with variable success. There are also commercial borax-based preparations for this purpose. Generally, I don't bother.

There's no need to "soak" the steel at the cherry stage. Just getting the shank behind the 'D' to cherry red will heat the thinner 'D' section plenty. We are now ready to quench. For this, you'll need a container of cold (room temperature) water, preferable deep, but not necessarily of a large diameter. The volume of water should be such that it can absorb all the heat from the tool without growing appreciably warm itself. Experience will show you how much, or little is required.

Here's the important part in this whole process. From the torch flame, quickly plunge the bit vertically into the water, and don't stir it about! Warping is caused mostly by differential cooling—that is, one side cools first, contracts, and the bit warps. By going in vertical, we minimise the chance of this. The reason for not stirring is that for a short period, the hot steel will be vaporizing the water in contact with it. If you stir, the fluid flow may allow steam bubbles to accumulate behind the round tool bit. This prevents water from coming into contact with it. We are then in danger of getting differential cooling and may induce a warp [4]. Just plunge it in and drop it. Good things will happen.

Notice the piece of soft iron wire coiled around the bit in Photo 5? This allows you to apply heat and get a clean entry to the quench tank while your hand remains comfortably far away from the dangerous activity. Of course for these procedures, you will take suitable care and wear protective gear appropriate to the risk, as you assess it. That is for you to decide personally, and to take the full responsibility for the outcome.

The bit after quenching is seen in Photo 6.

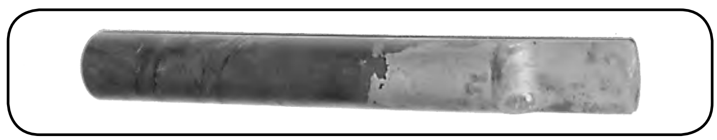

Photo 6, Quenched D-Bit

Before we temper the tool, it must be polished back to bright and shiny over the curved sections (you can ignore the flat and tip as these will be stoned or ground after tempering). So out with the 600 grit wet-and-dry paper. Apply a spot of oil, and polish away until the original bright finish is restored. It's at this stage you'll discover if your anti-scale precautions, or lack thereof, have paid dividends. Scale—as opposed to simple oxide 'blueing'—is very difficult, or impossible to remove!

When steel is heated, a colored oxide forms which is a very reliable temperature indicator. This will begin as a light yellow color, appropriately termed "straw". As temperature increases, it darkens, going to purple, and finally blue with hue graduations along the way, light to dark [5]. For a bit that will only ever work in aluminium, light straw is acceptable. This would be too brittle for steel though, where dark straw is best.

Blue is a bit soft, leading to quick blunting and possible scoring of the tool. To temper, apply the heat to a point a few diameters below the start of the 'D'. It does not matter if this part goes blue. As the heat builds up the straw color will 'grow' up the polished tool. As soon as the straw yellow on the end starts to deepen, plunge vertically back into the water. Heat treatment is now complete.

The cutting edges on the flat and the tip can now be ground, and/or stoned to a sharp edge. I'm assuming no description of this process is required. Just be careful to keep the tool flat while carrying this out. We're now ready to put our 'D' bit to work.

'D' bits are generally used in one of two ways: either to open out a hole to final size and finish—perhaps correcting for a slightly wandered hole left by a twist drill in the process, or to fully drill a hole without pre-drilling. Tapered 'D' bit "reamers" are always used in a variation of the first manner, and as the flat will emerge from the entry hole, chip clearance is less of a problem. I recommend that you rotate the chuck by hand when using a tapered 'D' bit reamer. It requires surprisingly little force, and the slow speed gives an outstanding finish

It's best to orient the flat uppermost so chips can accumulate on the shelf (to a degree). Allowing them to fall into the rotating work can cause scoring of the hole—especially if you don't clear them out frequently and thoroughly.

For longer holes, you can use the 'D' bit like a reamer, remembering that a reamer likes to cut. Drill through somewhere between 1/32 to 3/32" undersize. The 'D' bit will, unlike a twist drill entered into a wandered hole, correct the path rather than follow it. And, unlike a hand reamer, there's no need to "float" the reamer into the hole [2]. Slow speed and feed is the order of the day, with a lubricant appropriate to the material being worked. It is important to withdraw frequently to brush away the chips that pack up in top of the 'D'. Surprisingly, a hole pecked away a sixteenth of an inch at a time will not show evidence of this.

It's worth mentioning that for deep holes, gun makers have determined that if you have the option, it's better to hold the cutter stationary and rotate the work as this tends to push the drill back onto its axis. Even twist drills will perform better this way [7].

You can even choose to drill the entire hole with the 'D' bit—well, almost anyway. There is no doubt: this will produce the truest hole to remarkable depths. But in this case, it's vital to provide a short, bored start for the 'D' bit, exactly to size and preferably deep enough to allow the full diameter shank to enter the pilot hole. You will have to peck away with very frequent withdrawals, but the results are outstanding and astonishing. I've drilled very deeply through cast iron like this with perfect precision. Just be careful of chip extraction, and heat build-up. It's possible the weld steel together this way (just don't ask; I don't want to talk about it!)

A last word about air and oil hardening drill rod (you thought I'd forgotten, didn't you?) There is no great advantage in using oil hardening stock. The slower quench rate may help reduce any tendency to warp thin reamers, but I doubt it. The other choice is a new alloy: "A1" as in "A" for air hardening. Sounds like black magic to me, but one respected modeler I know swears by the stuff. The advantage is the part can be wrapped in a stainless steel foil envelope (very hardy stuff), and both brought to cherry red. The foil keeps the air out, preventing scale formation. You can even squirt some argon into the pouch from your MIG welder set-up to provide further insurance (we all have one of those, right?). Quenching takes place at room temperature by placing the wrapped part on a large lump of cast iron (like a drill press table) to help draw the heat out. Definitely magic territory. I've not tried this, and heaven forbid I should try and buy the stuff here in Australia, but as I said, I respect the source, so pass this mention along for what it's worth.

So there you have the humble 'D' bit; a simple, easily made tool that will provide outstanding results for a very modest investment. For instance, the rear shaft journal of the Morton M1 is 8mm. It needs to be finely finished by reaming. Compare the cost of an 8mm. hand reamer that you'll use once with a couple of inches of 8mm. drill rod. The end results will be identical in both cases. Which one are you going to choose?

References:

[1] Bradley I: *Novices' Workshop: The 'D' Bit, Model Engineer*, Model and Allied Publications Ltd, Herts, England, Volume 136, Issue 3387, Feb. 20, 1970, p171.

[2] Chernich R. A.: *Mills 1.3*, Model Engine Builder, Elmwood Publishing, CA, Volume 1, Number 1, p8.

[3] Thomas G. H.: *The Model Engineers Workshop Manual*, TEE Publishing, England, 1992, ISBN 1-85761-000-8.

[4] "Cain, Tubal": *Hardening Tempering & Heat Treating (Workshop Practice Series No 1)*, Argus Books Ltd, Great Britain, 1984, ISBN 0-85242-837-5, p39.

[5] ibid. p 36.

[6] Bradley I: *The Amateur's Workshop*, Nexus Special Interests Ltd, England, 1995, p86.

[7] Colvin F. H., Stanley FA: *Drilling & Surfacing Practice*, (reprinted) Lindsay Publications, IL, 1996, ISBN 1-55918-172-9, p41.

Editor's Note: These can be used in current, past and future build projects like the Wobbler, the Mortons and many upcoming projects. Go make one! Or two!