How to turn on a lathe without one

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Some parts of the RepRap project (http://reprap.org), particularly while prototyping some of the parts we can't automatically fabricate yet, require the use of a lathe. If you've not got a lathe, do not despair. It is possible to make one from other tools in a non-destructive way.


You will need:

- Walnut-sized blob of Polymorph (strong, low MP plastic). I have big walnuts.
- Electric drill – really should be mains-powered.
- Drill bench clamp, of the sort used to turn drills into bench grinders.
- Drill chuck on a stalk of some kind.
- 2 G-clamps
- 75mm (3 inch) bench vice anchored to wooden block.
- Meccano axle or known straight rod
- Handy chisels or actual lathing tools.

Notes:

Eye protection is essential. Arrange drill rotation so that swarf and broken tools fly into the bench, not your face.

Do make sure you are familiar with basic workshop safety. Ask Mummy or Daddy before playing with chainsaws first, don't run with scissors etc. Wear eye protection.

Use the right thickness of wooden block so that when your drill is in the clamp on your bench, the centre of the movable section of the vice is roughly level with the drill chuck, as per the photos. I used coach bolts to anchor the vice. My block is

360mm long, 50mm high and the vice is mounted 60mm from the left-hand edge of it.

Drill chucks can be salvaged from cheap hand drills, dead electric drills, or use one of those chucks that plugs into a hex socket. Did I mention eye protection?

Directions

Boil some water to soften the Polymorph. You could use epoxy instead, but Polymorph is easier to make fine corrections to. Put the drill in the holder and clamp it down – don't plug it in yet. I'm right-handed so I'd clamp it on the left edge of my workbench. You can turn soft materials like PTFE and PVC like this, using a wood block to prop your chisel up, or run a file over the part to shape it while it is rotating.

Illustration 1Setting up lathe with both chucks gripping the smooth rod.

Illustration 2First attempt, showing Polymorph far too close to the spare chuck.

Put a piece of something round and smooth, like a Meccano axle or known straight rod, into the chuck of the drill. Fasten the spare chuck on the other end of the rod as per Illustration 1. Both chucks have now aligned themselves on the same straight rod.

Arrange the vice, half open, so that the end of the sliding block coming out of it is alongside the shaft coming out of the spare chuck. You'll be clamping that shaft to the sliding block shortly.

G-clamp the vice's wooden block firmly to the bench. Push Polymorph carefully firmly around the chuck shaft, and G-clamp it to the sliding block without moving the chuck much. Push the Polymorph so that it keys into features on the sliding block and the face of the G-clamp. Make sure the Polymorph does not foul the spare chuck as shown in Illustration 2, or you will be unable to change bits.

Before the Polymorph solidifies completely, check the alignment by undoing the electric drill's chuck and cranking the vice in and out. The piece of straight rod should be central to the chuck all the way. If not, slacken off the G-clamp, heat things up with a hair-dryer to soften them, and re-align until you get it right. This is the technique you will use each time you set it up, but hopefully the hair dryer won't be needed next time.

Now all that is necessary is to put the workpiece in the drill, and hold the drill bit in the spare chuck. Crank the vice back and forth, and the drill moves in and out.

You can use Polymorph and a G-clamp to hold any other lathing tools you might have to hand to the vice; with enough Polymorph you can hold the tool at any angle! But be sensible and strengthen with jigs or wooden blocks where needed. Angle the vice to cut or turn conical sections. Tools held in Polymorph will fly off if you work them too hard. **DO NOT** let the tools warm up that much.

If all you want to do is drill a hole in a bolt, say for the RepRap extrusion head, just put the bolt in a block of wood, tighten the nut, and clamp the block level to the vice as per the Polymorph blob above.

Why an 'Afghan Lathe'? Because I first saw this kind of technique being used by Afghan gunsmiths to produce counterfeit firearms with remarkable precision.

Illustration 3Cutting off the head of the bolt.

Illustration 4Smoothing the cut end.

Making a RepRap Nozzle

So, our first victim. The RepRap extruder. This is an M6 brass bolt – good conductivity, no corrosion, works in this simple lathe easily. Stick it in the drill chuck and chop of its head with a hacksaw. Start the drill and file the end flat, as seen in Illustration 4. Smooth it, and stop the drill.

See all those circular scratches on the end? The centre of that is where we want to bore a 3mm hole. Put the 3mm bit in the chuck. Now, line up the end of the drill bit with the centre of the bolt. You want to make sure these are perfectly aligned. Encourage the wooden block that holds the vice into alignment with a Fine Adjuster or large mallet before fully tightening the G clamp.

Illustration 5Applying lubricant to the centre drilling process

Once you're happy with the lineup, remove the bolt from the drill, and slide the drill bit into the chuck on the drill. Tighten the chuck, this should centre the bit nicely. Once you are absolutely sure that the drill bit is centred as close as you can get it, place the bolt back in the drill. We're ready to start lathing.

Grab some lubricant of some sort, I used WD40 at first, then oil. Some form of shielding to catch flung lubricant before it hits the workshop wall is in order. Drip or spray the lubricant onto the end of your bit as per Illustration 5. You don't want too much on there, just a tiny amount will do. Start up the drill, and slowly turn the handle on your vice. This sends the drill into your bolt – note the placement of a piece of board to facilitate the easy removal of swarf and to save the desktop from oil stains. Drill it in stages. Do a small amount, pull out the bit, clean off the swarf and dust (preferably with a brush of some kind), add more lubricant, and let it cool. Repeat this until you break through the other end.

Illustration 6The machined components for a nozzle.

Illustration 7The completed removable nozzle.

Be careful with the finished bolt, it will be very hot. Use pliers to remove it from the chuck, and dunk it in some water. This will cool it down to a more easy to handle temperature.

Now we make the actual nozzle part as a removable component – this makes fixing jams and changing the width of the deposited plastic much easier. What we're aiming for is something like the left-hand part in Illustration 6. Chop off a section of M6 brass bolt about 7mm long and drill a 3mm hole most of the way through it using the same method as above. Then turn it around and carefully drill a 1mm hole through so the holes connect. Be gentle or you'll break the 1mm drill. When you do, buy a couple for spares...

Screw the 3mm hole end of the section into the nut a turn or so, and solder it in place so it looks like the part in Illustration 7. Lead-free solder has a higher melting point and is preferable, but the flux on ours wasn't very good. We ended up tinning the parts with standard solder and then finishing the job with lead-free.

Illustration 8Aligning nichrome with the 1mm hole

Now the fine hole in the end can be made, again from solder. The illustrations on how to do this show an early non-interchangeable nozzle, but the principle is exactly the same.

Take a piece of solid nichrome or stainless steel wire that is the same size as the hole you intend to make – in this case 0.32mm – and put it in some kind of holder that can be easily clamped – melting it into a glue-stick or Polymorph is good. Then clamp it so that the wire goes through the centre of the hole in the section of bolt as per Illustration 8.

Without moving the wire around too much, apply solder all around the wire so that it is fixed in place. You need only use enough solder to ensure the wire is completely surrounded – do not fill the entire section of bolt or the wire will be hard to remove. Allow to cool.

Illustration 9Wire fixed in nozzle

Illustration 10Testing the nozzle with water.

You should now end up with something looking like Illustration 9. If not, re-melt and try again.

Hold the wire very firmly in pliers or artery forceps, and pull the wire steadily out in a direct line. If the wire breaks, pull the bit hanging out the other end. If that breaks, see previous step.

Smooth off the excess solder with a fine file and/or fine sandpaper, pausing to clear the minute hole and file teeth frequently.

The nozzle should now be ready. Fasten it onto the hollow bolt with the aid of some PTFE plumbers' tape to prevent leaks. Keen students my wish to test the nozzle by putting a syringe full of water through it. The water should come out in a nice, straight stream.

The nozzle is now ready for the heating element and temperature sensor, which was developed by Dr. Adrian Bowyer and originally covered here at http://reprap.blogspot.com and has been hacked around by yours truly below. The lathing system described here is also handy for constructing the PTFE rod holder for the nozzle, and probably a few other parts of RepRap as well as general prototyping. I hope you like it.

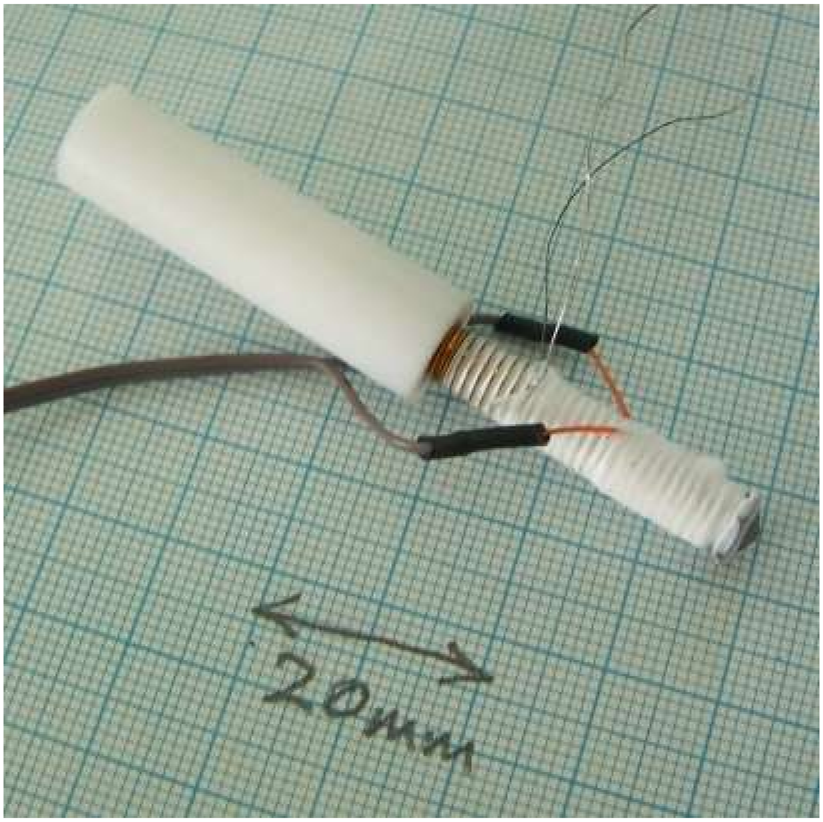
Illustration 11The author posing by his completed lathe. Safety glasses are in the right hand...

Take the bored-out M6 brass bolt, and wrap some PTFE thread-sealing tape around the thread...

...and wind a 300 mm length of 0.2mm diameter nichrome wire into the PTFE-insulated valleys of the thread as a heater. The PTFE needs to be thin to allow heat conduction, but thick to prevent shorting with the brass. About two or three thicknesses seemed to work well. Then put a thermistor (RS 484-0149; cut and paste that part number into the box top-left on the RS main page) against the thread at the nozzle end and wind yet more PTFE tape round it to keep it warm.

Using the lathe, put a 3mm hole down a 40mm length of 10mm diameter PTFE rod, then drill out and tapped M6 the last 5mm or so:

If you mess up the tap – PTFE is quite soft in this regard – wedge the rod in with some PTFE tape and apply a small hose clamp around the outside to hold the whole thing tightly together. Otherwise, screw the whole assembly together:



The thermistor is the bump at the right hand end; this was positioned past the end of the heater windings to get temperature readings from the brass, not the nichrome heater wire; before putting the thermistor on, clear a patch of PTFE away using a wall file or small wire brush to expose the brass, so the thermistor is resting right on the metal. Wrap a little PTFE tape or heatproof insulation around the thermistor leads to stop them shorting. The heater wires are the ones heading off top right.

To test this, Adrian rolled up some 3mm diameter Polymorph rod, and switched the heating current on. 300 mm of 0.2mm nichrome wire has a resistance of about 12 ohms, and he was running it at 12 volts (i.e. 1 amp / 12 watts). This brought it up to temperature (about 130 degrees C, or a thermistor resistance of about 350 ohms) so quickly (less than a minute) that he had to turn the voltage down to prevent overheating. This is good, as it means it should be easy to do PWM temperature control with a PIC and a power transistor.

(Note the extremely rusty retort stand; this was done on a Saturday morning in Adrian's lab at home, not the well-equipped ones at Bath University...)

The multimeter on the left is measuring the thermistor's resistance, and the bench P.S.U. on the right is supplying the heater.

He pushed the Polymorph rod through with a force of between 20 and 30N, which gave extrusion at 2mm per second.

Vik :v)