VARIABLE ECCENTRIC CUP CHUCKS

The variable eccentric cup chucks in axial position on top, and maximum eccentricity on bottom.

INTRODUCTION: Spheres are symmetrical in every direction. This does makes them rather hard to hold for turning. But the nice thing about this is once you do have a way to hold spheres, you can orient them for further turning any way you like. An axial pair of cup chucks will let you turn features that go all the way around the sphere. A fixed eccentric pair of cup chucks will let you turn arcs and lines that go part of the way around the sphere. It's fairly simple to make axial or fixed cup chucks for turning spheres between centers, but a pair of variable eccentric cup chucks extend the design capabilities by letting you control how long and how deep the arcs or lines are. This article demonstrates how to build a pair. To complete sphere holding capabilities in the next issue I'll describe a vacuum/jam/tape chuck for holding a sphere at just the headstock end.

The Variable Eccentric Cup Chucks have two pieces each, a Base and a Cup. The Base has two 7/6" offset axes: the threaded mount, and a tenon that fits into the Cup. The Cup also has two 7/16" offset axes: the mortise that fits on the Base's tenon, and the cup that holds the sphere. When the offsets are in opposite directions the total offset is zero (7/16-7/16=0). When the offsets are in the same direction the total offset is 7/8". When the angle between the offset is in between, the total offset is in between. How this works is obvious by now to me (everything is obvious once you know the answer) but is not especially obvious at first. You could trust me.

Or you could have a look at Diagram A which shows the cup and base at three different rotations with respect to one another. The cross indicates the lathe axis and the star indicates the cup axis. On the left, the offsets subtract and the offset is 0°. On the right the offsets add and the total offset is 7/8". In the middle, with the offsets at 45 degrees to one another, the total offset (remember Pythagoras?) is 0.625.

Diagram A: How the eccentricity can vary.

The chucks are made of PVC, which neither the cheapest nor easiest material to work with. But it takes threads well, and the Base has to be threaded to be mounted, and the Cup has to be threaded for the cup screw. PVC also withstands denting from the set screw. Having both pieces made of the same weight material allows higher rpm when the cup is axial.

The Bases are threaded 3/4x10. This lets you use some 3/4" all-thread (or a cut off bolt) to mount on the headstock with a chuck, and to screw onto a Oneway pattern center to mount on the tailstock.

ECCENTRIC DRILLING JIGS: Both the Base and the Cup require drilling non-axial holes. This could be attempted on a drill press, but doing it with jigs on the lathe improves accuracy, and the eccentricity of the two parts has to match to work properly. Jigs, made of 1/2" plywood are designed to fit the PVC rod I had, which were slightly oversize at 2.55" and 3.05". If your PVC is significantly different you can modify the scale in the printer dialog box so that the diameters match.

Diagram B: Patterns for the eccentric drilling jigs.

Attach the patterns to 1/2" plywood with spray adhesive as in Fig01. Then cut out the jigs using a bandsaw or scroll saw as in Fig02.

Fig01: The patterns attached to 1/2" plywood

Fig02: After cutting out the jigs.
PREPPING THE PVC BLANKS: Now cut two pieces of 2.5" PVC rod to 1.5" long, and two pieces of 3" PVC rod to 2" long and test the fit in the jigs as in Fig03. Be aware that cutting the PVC on a band saw can result in the rod suddenly rotating into the blade and ruining your PVC stock or perhaps your entire day. It is safer, if perhaps less accurate which can be fixed later, to clasp the PVC in a vise and cut with a hand saw or reciprocating saw.

Mount the PVC pieces in turn in a 4-jawed chuck with #2 jaws and turn each face perpendicular to the cylinder sides as in Fig04. Turn a small dimple in the center of one face of each piece. Go back to the band saw and cut a shallow (1/32" to 1/16") groove on the rim of each piece. Draw a line from the groove through the center dimple to the opposite side of the rim and then again use the bandsaw to cut a shallow groove where marked on the opposite side of the rim. Fig05 shows the result.

Mount a smaller PVC blank in the 4-jawed chuck with #3 jaws using the eccentric drilling jig with the matching sized hole. Line up one of the grooves on the side of the blank with the longest sawn slot in the jig as in Fig06 and then tighten the chuck securely. Turn on the lathe at a moderate speed and mark the center of rotation. Lock the lathe head with your indexing feature, and by rotating the blank and jig as one, align the line joining the two edge slots parallel to the tool rest. Now use your indexer to mark the face of the blank at regular intervals as in Fig07. I used 30 degrees, but it doesn't really matter as long as you do both small blanks the same. Fig08 shows the blank after marking all of the lines.

Remove the blank from the chuck and make a shallow cut on the edge at one end each of the lines on the face as in Fig09. You can now use a hacksaw to mark the zero line on the larger blank with a hacksaw as in Fig10.

DRILLING THE BLANKS: Mount the larger blank in the 4-jawed chuck with #3 jaws using the jig with the larger hole. Align a sawn slot on the rim with the longest cut in the jig. Tighten the chuck securely. Very securely, as you don't want the blank to slip. Insert a 1-3/4" Forstner or sawtooth drill bit in the drill chuck as in Fig11. Drilling big holes in PVC will go a lot better if the speed is very slow and you use lots of lubrication. I put my lathe in the low speed range and used WD-40 for lubricant. A
drilling/tapping fluid would also work. Turn on the lathe at a SLOW speed and advance the drill bit into the PVC. Withdraw the drill bit, clear the swarf, and re-lubricate frequently. Watch to make sure there's no slippage and keep drilling to a depth of just over 1". Fig12 shows the blank after depth is reached. Fig13 shows both large blanks after drilling.

Now mount a small blank in the 4-jawed chuck using the appropriate jig aligning the zero line with the largest slot in the jig as in Fig14. Again tighten the chuck sufficiently that there will be no slippage. Mount a combined drill and countersink in the drill chuck to make a starter hole as in Fig15. The combined drill and countersink, unlike a standard drill, is too short and rigid to deflect when starting a hole. Now put a 21/32" drill bit in the chuck as in Fig16 and drill through the blank, using a low speed and lubricant. Withdraw the drill and clear the swarf when needed, else the swarf will melt, jam, and generally make a mess.

TURNING THE TENON: Mount a small blank in the 4-jawed chuck with #2 jaws and slightly bevel the rim as in Fig19. Now flip the blank over and mount it with the other end out. The bevel will let the blank bottom out in chuck. Now turn a slightly less than 1" deep tenon on the blank as in Fig20. You can use ordinary turning tools, but take light cuts. Rather than turning to measured size, check the fit with the hole in the large blank. You want a fit that can turn, but not rattle about. Clean up the flange and bottom of the tenons in Fig21 so that the tenon can insert all the way into the hole in the large blank. Fig22 shows the completed bases.

Now mount a mini-tap guide in the drill chuck and lock the lathe spindle. Place the nose of a 3/4x10 tap in the hole and bring up the point of the mini-tap guide into the dimple in the back of the tap. Advance the mini-tap guide to compress the spring so the mini-tap guide can follow the tap, keeping it aligned as the tap advances. Turn the tap with a tap wrench or adjustable wrench as in Fig17. Use lubricant, and advance the tailstock occasionally to keep the mini-tap guide engaged as tapping advances. Tap all the way through the blank. Fig18 shows the drilled and tapped small blanks.

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Fig19: Bevel an edge on the small blank so it can fit all the way into the jaws.
Fig20: Turn the tenon to fit the hole in large blank.

Fig21: After truing the flange.

SET SCREWS: Insert the base in the large blank and turn the base so that one of the middle graduation lines lines up with the zero line. Mark the side of the large blank on the side away from the tapped hole in the base as in Fig23 (the wall of the tenon is thin where the tapped hole is, so the set screw should bear on the other side). Remove the base and use a square and line up the square by eye with the zero line and the center of the hole. Mark the side at this point. Drop down 1/2” from the mark for the set screw location as in Fig24.

Clamp the large blank on your drill press, using a square to align the mark above the hole center as in Fig25. Use a small combined drill and countersink to start drilling. Then switch to a #7 drill bit and drill through the blank wall as in Fig26.

Fig23: Marking the side away from the tapped hole.

Fig24: The marked set screw location.

Fig25: Aligning the blank in a drill press vise.

Fig26: Drilling with a #7 drill bit.

Remove the blank from the vise and tap with a 1/4x20 tap as in Fig27. Insert 1/4x5/8” set screws in the holes as in Fig28. Fig29 shows the pair of eccentric cup chucks to this point. The chuck on the left is set at the axial position. The chuck on the right is set at the maximum (7/8") eccentric position.

Fig27: Tapping for the set screw
**TURNING THE CUP:** Cut two pieces of 3/4x10 all-thread about 2” long. You could also use partially threaded 3/4” bolts, and cut off the head (this option may mount more securely). Insert the all-thread about half way into the Base as in Fig30. Mount the chuck via the all-thread in a 4-jawed chuck with #1 jaws as in Fig31. You could also use a collet chuck. You could even use a large Jacobs chuck if you're prepared to deal with it vibrating out every now and then.

Make absolutely certain that the chuck is in the axial position with the zero line at the zero gradated line. Then bevel the rim of the chuck so that the size of chuck is the size you want (you can make other size cups later if needed) as in Fig32. I can't give you a hard and fast rule for chuck size or the steepness of the bevel on the inside of the chuck. I've found a chuck size of 2-1/4” to be good for the 3” spheres I work with most frequently. The steeper you make the bevel, the more exactly the sphere will register in the chuck. The shallower you make the bevel the wider a range of spheres the cup will hold without marking. Using a small bowl gouge turn a beveled recess on the face of the chuck as in Fig33.

**FOAM PADDING:** Cut a circle of 2mm craft foam about 1/2” greater in diameter than the size of the beveled cup and cut a radial line to the center of the circle. Hold the foam in the bevel and mark the overlap as in Fig34. Cut on the mark to remove a pie shaped segment. Apply spray adhesive as in Fig35, and then apply the foam to the inside of the bevel as in Fig36. Unless your bevels are exactly the same, keep track of which foam piece goes with which cup. The foam will help grip the spheres more securely and help prevent putting compression marks on them.

**IT REALLY DOES WORK:** For use, mount one cup chuck on the headstock via the all-thread using a chuck. Mount the other cup chuck by screwing it onto the 3/4x10 threads of your Oneway pattern tailstock. Fig 37 shows the pair of cup chucks in the axial position. Fig38 shows a sphere mounted with the cup chucks at maximum eccentricity. This is a LOT of eccentricity, and you'll have to really slow the lathe down to use this much. But you don't have to, as you can set the eccentricity to whatever you want. Use the graduated marks to set both chucks the same.
Fig37: A pair of cup chucks in the axial position.

Fig38: A pair of cup chucks mounting a sphere at the maximum eccentricity.

TOOLS:

- Bandsaw
- 4-jawed chuck with #1, #2, and #3 jaws.
- Drill chuck
- 1-3/4" drill bit
- Combined drill and countersink
- 21/32" drill bit
- 3/4x10 tap
- Tap wrench
- Drill press
- #7 drill bit
- 1/4x20 tap

MATERIALS:

- 1/2" plywood
- 2-1/2" PVC rod
- 3" PVC rod
- Drilling lubricant
- 1/4x5/8 set screws
- 3/4" all-thread or 3/4" bolts
- 2mm craft foam
- 3M #77 spray adhesive

AUTHOR: David Reed Smith turns and tinkers in his basement in Hampstead, Maryland. Subconsciously he seems to be convinced that he who dies with the most jigs wins. He welcomes comments and questions via email at david@DavidReedSmith.com. This article, along with many others, will be available on his web site: www.DavidReedSmith.com.