Cubes in a Sphere (Fred Holder)

In the July/August 2004 issue of The Woodturner Magazine, published in England, there was an advertisement for the Stoneleigh Turning competition for 2004. The featured picture at the top of the page intrigued me and I had to know how to do it. It was obvious from the photo that the original blank was a sphere with six equally spaced stepped holes. This gave the effect of decreasing-sized cubes inside the sphere. The sphere in the photo had six levels of cubes.

Apparently the ball in the photograph was somewhere in the neighborhood of 3-1/2" in diameter. There are at least a couple of ways to do this project: drill steps with Forstner drills or draw circles of the appropriate size and then, using a square end scraper, cut the holes to the proper depth.

Since I normally make the Chinese Ball from 2-1/2" spheres and have a chuck to hold that size sphere, I opted to use that size. I had no idea what size drills to use, so I began to experiment. My first attempt provided a ball with three steps plus a hole in the middle, but the holes didn't intersect one another to give the desired effect of cubes inside the sphere. I finally worked out that the proper depth for a step was 1/2 of 3/8" or 3/16" and the diameter change of drill size needed to change by 3/8" as the drill size changes larger or smaller. At first this didn't seem to work. Then I realized that the original size of the sphere should have been about 2-1/4". I compensated and drilled the first hole 5/16" deep and all of the others 3/16" deep from the bottom of the preceding hole.

Picture 1: This was my first successful attempt to make this project. It is made from Elm and has an African Blackwood base. All holes were drilled with Forstner bits.

In the Beginning
To begin this project, you must choose a spot on the end grain to be the north pole. Then, using this as the starting point, lay out six equally spaced holes on the surface of the sphere. As shown in Figure 1, a straight line from the north pole position to the equator of the sphere is determined by the formula x (radius on x axis) squared plus y (radius on the y axis) squared equals z squared. "z" is the length of a straight line from the north pole to any point on the equator.

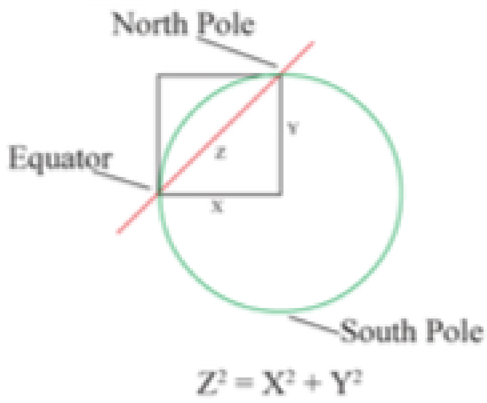


Figure 1. This shows a method of determining the dimension to set your pencil compass to lay out the six equally spaced holes.

This formula simplifies down to z equals the radius times the square root of 2 (or 1.414). For the 2-1/2" sphere, set your pencil compass to the 1/2 of the diameter of the sphere; i.e., 1.25" times 1.414, to obtain a value of 1.7675".

Here is where one of the first inaccuracies can come into play. It is unlikely that one can set a pencil compass to that precise number. I made up a flexible cardboard template of that length as determined with my digital calipers. Laying the template from the north pole across the surface, I marked three locations about 120 degrees apart on what would be the equator. Then measuring from each of these locations, I made a mark near the south pole. I selected the center of these three marks to be the south pole.

I then mounted the sphere between centers on the lathe and drew a circle around it at the equator location. I engaged the indexing pin and marked one of the holes. I moved 90 degrees (six holes on my Nova DVR 3000 index head) and made another mark. Two more equal moves and I had four equally spaced holes marked on the equator line. At this point, I was ready to start drilling holes. If you can manage to set your pencil compass to the 1.7675" dimension, you can easily layout the holes with the compass. Select a pole position and insert the point. Draw a line around the sphere. On that line select some point and draw another circular line around the sphere. Now at one of the intersections of these two lines, draw another line around the sphere. This gives you a location for the other pole position and four equally spaced lines on the equator line. Of course, all of this assumes that the ball is perfectly round.

Picture 2. In this photo, the tail center is being used to align the ball on center before the chuck is tightened.

Mount your sphere in the chuck with one of the positions aligned with the axis of rotation of the lathe determined by inserting the tailstock center into the intersection of the lines. Lock the chuck down and replace the tailstock center with the drill chuck and a 1-1/2" Forstner drill bit mounted in it. Drill into the sphere until the outside edges of the Forstner drill bit is ready to cut the surface of the sphere. Make a mark on the side of the drill bit that is 5/16" from the surface of the sphere. Drill down to this line. Check to make sure that your hole is 5/16" deep. If it is, use a fine point pen to mark a line on the drill bit to indicate the depth of cut. This is for use on the other five outside holes. Figure 2 shows the relationship of any four holes drilled on the equator at each drill depth.

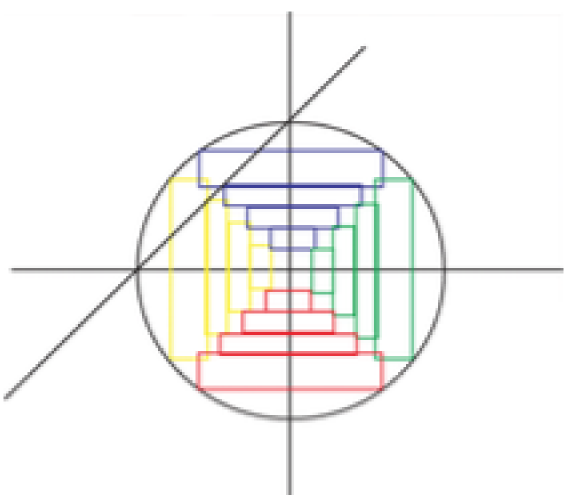
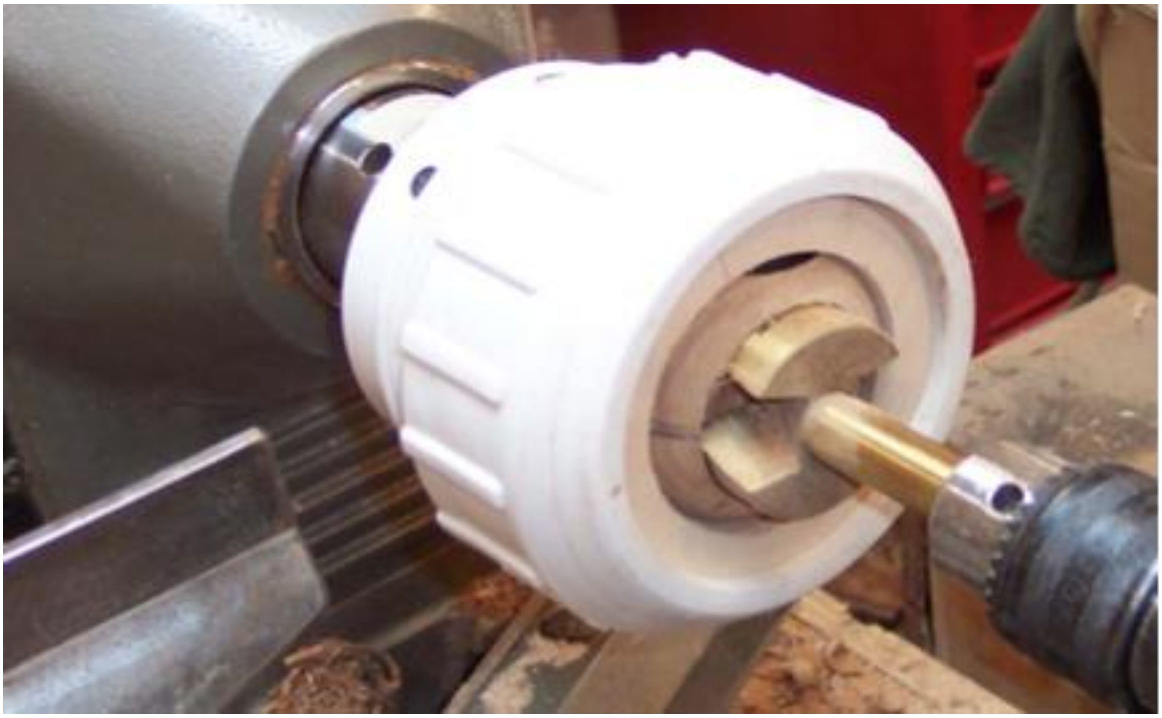


Figure 2. This drawing shows what is happening inside the sphere if a cross section was taken through the center of any four holes.

Note: If the wood is fairly hard and heats up while drilling, I suggest that you arrange to flow air onto the wood and drill bit while drilling to prevent heat cracks and possible failure of the project.

You now have a decision to make. You can align each of the other holes and drill the 1-1/2" hole for each of them before changing to the next smaller size drill. Or you can drill holes with all of the drills with this set up. I'm personally not sure which is the safest. I have done it both ways and had failures doing it both ways.

Picture 3: This set up shows the operation of drilling the first step at any given position. Note the mark on the drill which was made after the first hole was drilled in the ball.



Picture 4: By drilling two adjacent holes, you can check to ensure that you are drilling to the proper depth to obtain the optimal overlap of the holes to create the effect of cubes.

All of the rest of the holes to be drilled must be 3/16" deep from the bottom surface of the previous hole and in each case they are 3/8” smaller than the preceding hole. Therefore, the next size down drill is 1-1/8” in diameter. I recommend that you back off your tailstock spindle as far as it will go and make a mark on it to indicate zero. Then make a mark again when the tailstock spindle has moved out 3/16". With the tailstock spindle set to the first mark, move the tailstock assembly in until the drill bottoms against the surface of the previous hole. Lock down the tailstock assembly and drill in until the 3/16" mark appears. Retract the drill and check the depth of the hole. If the drill slips in the chuck or the tailstock slips on its mounting, your hole will not be the right depth. Therefore, I recommend checking each hole for depth. The next hole to drill is the 3/4" hole. It should also be drilled 3/16" deep. Repeat this operation for the 3/8" drill and you are ready for the next hole location.

Picture 5. This photo shows that all of the first holes have been drilled and then the other levels on this hole have also been drilled.

When all holes are drilled, you should be able to look into the holes and see what looks like decreasing sizes of cubes all connected to the previous layer at their points. A project such as this requires a stand. You could simply make a little egg cup-type stand to set it in; however, it would be hard to keep the item oriented properly using this type of mounting. Therefore, I felt a permanently attached base would be better. I turned the base for the one illustrated in the photo at the beginning of this article out of African Blackwood. I turned a small tenon on the top of the base and drilled a matching hole in the sphere. This hole needs to be located in the center of one of the triangular area between three holes. This gives the best orientation, in my opinion, for the finished project. What I've just described is how I did the first one of these, made out of a 2-1/2" sphere. Unfortunately, my 40+ year old mathematics doesn't seem to allow me to work out the formula to determine how deep the first hole needs to be drilled on any size of sphere and what size diameter hole is required. I thought I could just use the same formula going up in size as I do in going down in size, but something didn't seem to work here either. What I have determined is that by drilling two adjacent holes of an estimated size, I can determine at what depth that size hole will overlap and give the desired opening at the interception. Using this method, I was able to increase the size of the sphere slightly to give four steps in the sphere. I had to use a different size starting drill, which changed all of the other drills used. Each drill still had to be 3/8" smaller than the previous one and was drilled into the sphere 3/16" deep from the previous level. In this case, the last hole drilled was 1/2" instead of 3/8" as for the smaller sphere. This project required me to make up a larger chuck out of three inch PVC compression fitting.

Picture 6. This photo illustrates the first successful version of this project and the number two version which is made from a larger sphere and contains four steps inside each hole.

Making the Ball Chuck

Picture 7. This photo shows the basic components of the ball chuck that I use. Left to right: screw on cap, plywood washer to fit between the sphere and the cap, male part of the PVC compression fitting is fitted with a hardwood block with a spherical recess. This one has sandpaper glued in to grip.

My first chuck of this type was made from a 3” PVC compression coupling. I cut off one end to make a very nice chuck. I glued a 1 inch, 8 tpi nut into a block of elm and turned it to fit inside the coupling, glued the wood into the coupling, inserted four screws to help the glue, turned a hemispherical depression for a 2-1/2” sphere in the elm, turned a piece of 1/4” plywood to fit inside the lid, put the lid and plywood onto the chuck body and turned a hole in the plywood to fit onto a 2-1/2” ball. I then drilled a hole to insert a piece of 3/8” dowel to use as a lever for tightening and loosening the cap, glued a 3” sanding disk into the bottom of the hole (after cutting slots all of the way around), and I had a very serviceable ball chuck. The only problem was that the cap was too big for my hand and I had problems screwing it down and loosening it. I repeated the operation with a 2” compression coupling and used a Oneway Chuck insert instead of a 1 inch 8 tpi nut. Now I have a chuck with a screw-on lid that I can hand tighten and loosen and that can be adapted to any lathe that I can buy a Oneway Chuck insert for. It works great.

These chucks are very easy to make. It takes me about an hour to make one. I’ve found that either a Oneway Stronghold Chuck Insert or a piece of cross grain oak with 8 tpi threads to fit a Nova Chuck Insert work very well for me. However, you can mount the wooden block onto a dedicated faceplate to fit your lathe.

Another thing that I’m doing these days is to coat the spherical hollow with hot melt glue. I then take a round nose scraper and spread the glue evenly on the surface of the spherical hollow. When I’m ready to chuck up a sphere, I turn on the lathe and sand the spherical hollow lightly with 80-grit sandpaper. This slightly warms the glue surface and allows it to grip the sphere very firmly. I should caution, do not warm it too much or you may find your sphere permanently attached to your chuck.

Have fun with this new way to decorate a sphere!