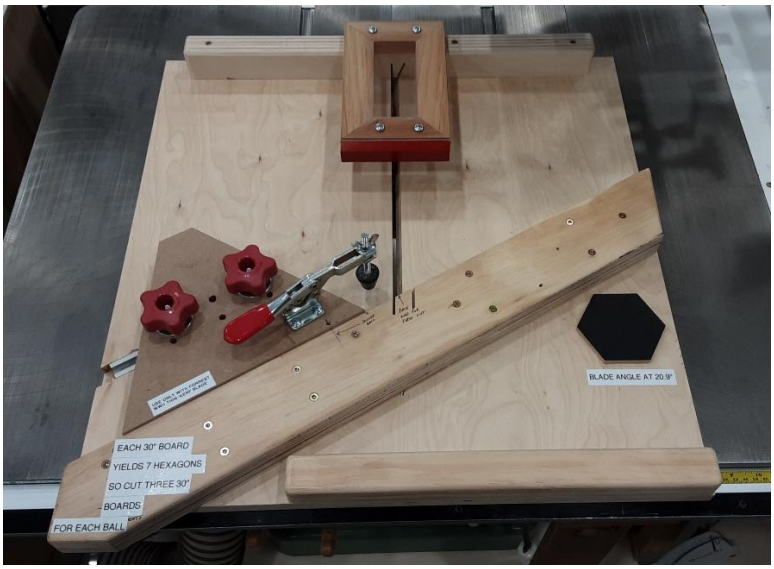
Notes on Making a Segmented Soccer Ball

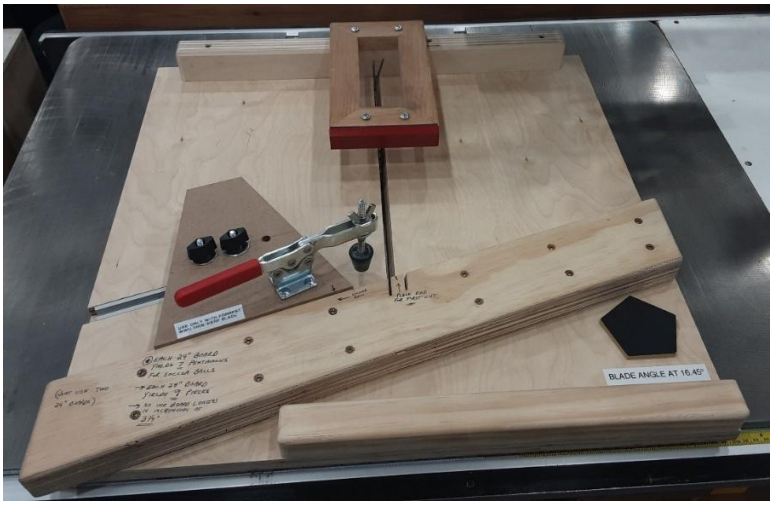
Preliminarily, I should note that what follows below is a discussion of how I build a wooden soccer ball (or a "football" if you are from many places outside North America) that is roughly the 8.6" minimum diameter (at standard minimum inflation level of 8.5psi) of an official size 5 soccer ball (which can be as large as 9.0" at the maximum inflation level that is officially allowed). You can, of course, make one whatever size you want, but you will have to adjust the length of the sides of the polygons accordingly. Also, I should note that what follows below is simply a discussion of how I do it and is not intended in any way to state or even imply that these are the only techniques you should use. I have seen soccer balls made using techniques vastly different than what are described below and the end results have been equally excellent. Again, this is just how I do it, with a few mentions of how others approach different aspects of the process.

1. First you will need to build jigs for cutting the hexagons and pentagons, since there are no commercially available options that I am aware of (Pete Marken – where are you when we need you?? – although I doubt there would be enough interest in this unusual project to make such sleds commercially viable). Anyway, use your best crosscut or combination blade for this project – and mark the sleds that you will build so that you only use that blade with the sleds in the future. There are different types of sleds for this purpose:
    a. sleds that have bases that are built on an angle so you can leave your table saw blade set at 90 degrees (see Paul Bartlett's excellent videos on how to do this) or

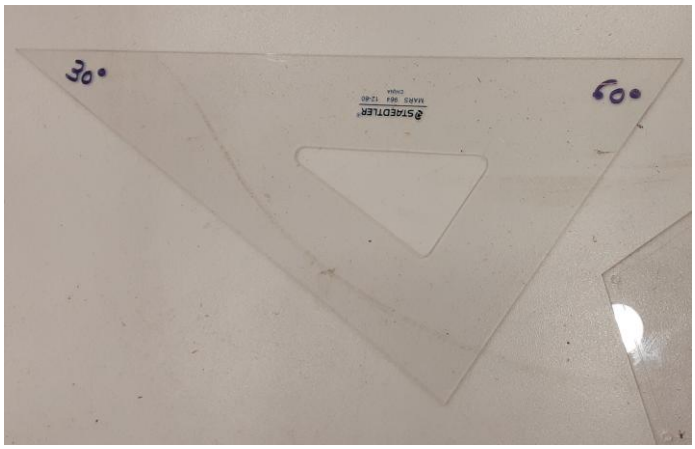
b. sleds built with flat bases that require you to tilt your table saw blade to the required angles (see DIY Montreal's equally outstanding videos on how to do this).

I opted for the latter approach. Here are the sleds I built using the basic design discussed by DIY Montreal. As you will see, these are not single-purpose sleds intended to be used just for making soccer balls; rather, they are built in such a way that they can be easily adjusted to make a wide range of sizes of either hexagons or pentagons designed for many woodworking purposes in addition to simply making soccer balls. Yes, it is a time and cost commitment to build sleds like this but they are very versatile and are super accurate for tasks as demanding as making soccer balls.

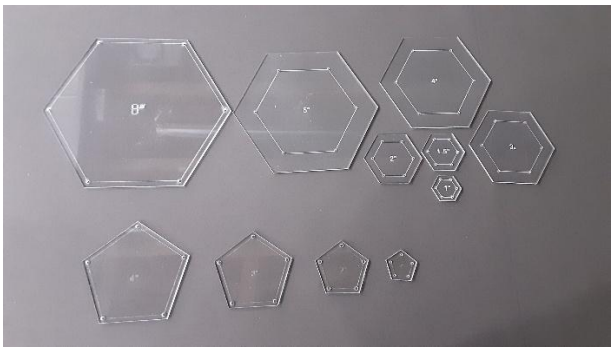




After building the basic sled bases and sliding stops, make sure your blade is initially set at 90 degrees. Cut a slot just down to where the fence will be, then set the fence angles (60 degrees on right side of blade for the hexagon sled, 72 degrees for the pentagon sled). You can use a digital protractor for the pentagon sled, but I found it simple and highly accurate to just use a 30-60-90 acrylic drafting triangle for the hexagon sled. These are available on Amazon at a very reasonable price.



CNC-cut templates for pentagons, hexagons and octagons are also available from Amazon in addition to the usual squares and triangles (usually found by searching for quilting templates in those shapes). They make the setup of the fences on these jigs quick, easy and crazy accurate.



2. Once the fence angles are set, an equally critical step is to set the blade tilt angles – **20.9 degrees for the hexagon sled and 16.45 degrees for the pentagon sled** (the actual figures are 20.9052 and 16.4722 according to Google's AI bot, but there aren't any devices readily available to woodturners that can measure angles that accurately – nor is there a need to since we aren't designing equipment for NASA here – so we'll just go with 20.9 and 16.45 degrees since most digital protractors and angle cubes currently available only measure in increments of 5 hundredths of a degree). As noted, you can use either a digital angle cube or a digital protractor for this. I use both to confirm the setup, which can be challenging since those devices rarely agree perfectly, given their inherent accuracy limitations (the older models are accurate to only about .2 or .3 degrees, although I understand that some of the new digital protractors are accurate to 0.1 degrees). Once you get the blade angles set accurately, it is a good idea to cut a blade angle block to facilitate future setups. Here are the ones I use.

I find the best method is to first set the blade angles using the blade blocks first. The best way to do this is to hold it against your miter gauge set at 90 degrees to ensure an accurate reading against the body of the blade raised to its highest level. I typically put a light behind the blade so that, as I stare down the length of the blade, I can more easily see any gap between the setup gauge and the blade body. **Don't forget to unplug your table saw before doing this!!**

Then verify their accuracy with a large digital protractor or your most accurate digital angle cube – preferably both. I have several brands of cubes but find that the TiltBox II from Beall Tool Co. is the most accurate, as verified (as best I can) by multiple highly accurate squares from the likes of Woodpecker, Bridge City, etc. (supposedly accurate to 0.0006"… but who knows for sure). Other brands seem to be off by .01 or .02 degrees, but the Beall seems to be dead on. Of course, that is not to say all their cubes have the same accuracy – my results may simply be typical variations in the products of each manufacturer.

3. After the blade angle is set, run the sled through again, cutting only slightly into the fence, of course, and then remove the small waste strip that will result.

4. Then set the adjustable stops on the fences so that each face of the pieces is about 49 millimeters (roughly 1.93 inches).

   Using the 49mm size should result, after turning and sanding, in an 8.6” or slightly larger diameter ball, which, as noted above, is the minimum diameter of an official size 5 soccer ball. And even if you are off a little here in the length of the face of each piece, at the very least check to make sure that the top edge of the face of each hexagon edge is exactly the same size as the face of each pentagon edge. If they don’t match exactly, your joints won’t close properly.

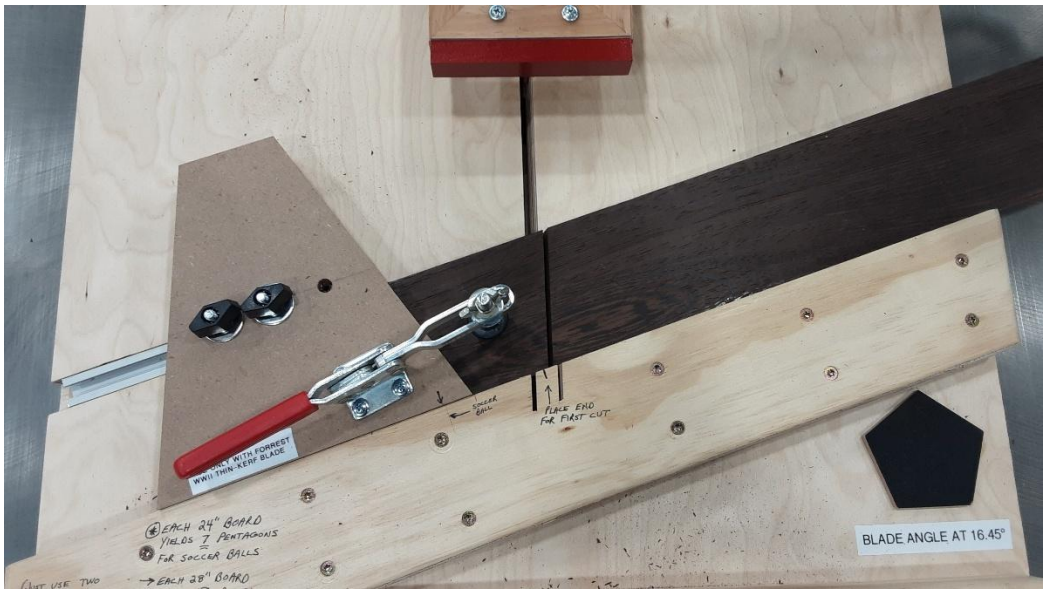
5. Then mill the stock you will need: all pieces need to start out as 1 x 4 (3/4" x 3.5"), and both boards should be of identical thickness. Best practice is to run all the boards through a drum sander (if you have one) just before making the pieces so that you ensure identical thickness. You can, of course, use boards thicker than ¾" but there really isn't any reason to do so. And I've never made a ball with boards much thinner than ¾" but I don't think I'd try it, given how thin the walls get after turning and sanding.

   Both edges of the boards need to be perfectly perpendicular to the faces. Lightly joint/cut the edges if necessary (1/32" or preferably less) if you are not sure they are square to the faces of the boards, since the final width of the nominal 1 x 4 hexagon board can tolerate a loss of about 1/16" – but no more – you will need the full remaining 3 7/16+" if you make your facets the recommended 49mm length. The pentagon board can, after jointing/cutting, be as narrow as 3 1/4", so there is plenty of room to get the edges of those boards square to their faces.

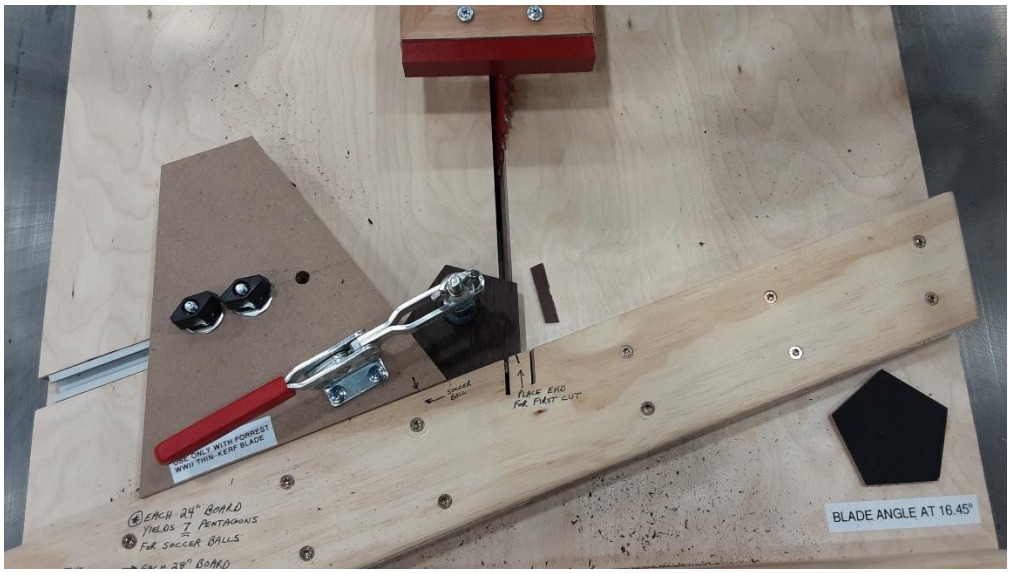
   You will need a total of about 8 linear feet for the hexagons and a total of 4 linear feet for the pentagons (I cut them into smaller sections so they won't hang out too far over the side of the sleds – meaning you don't actually have to have 8 and 4 foot lengths but can actually use up shorter boards as long as they are of identical width and thickness). **Ideal board lengths are 2 @ 24" for pentagons (yields 7 pieces each for a total of 14 pieces) and 3 @ 30" for hexagons (yields 7 pieces each for a total of 21 pieces)**. So these board lengths give 2 extra pentagons and 1 extra hexagon so you can weed out any "bad" pieces (such as those with unusual grain patterns that won't look good on the finished piece).

6. Then cut at least 20 hexagons and at least 12 pentagons. The first cut on each board should be set up by holding it so that the full width of the board is to the *left* of the tilted blade (on a *right*-tilting saw like mine, anyway).

The board then gets flipped and clamped against the adjustable stop.

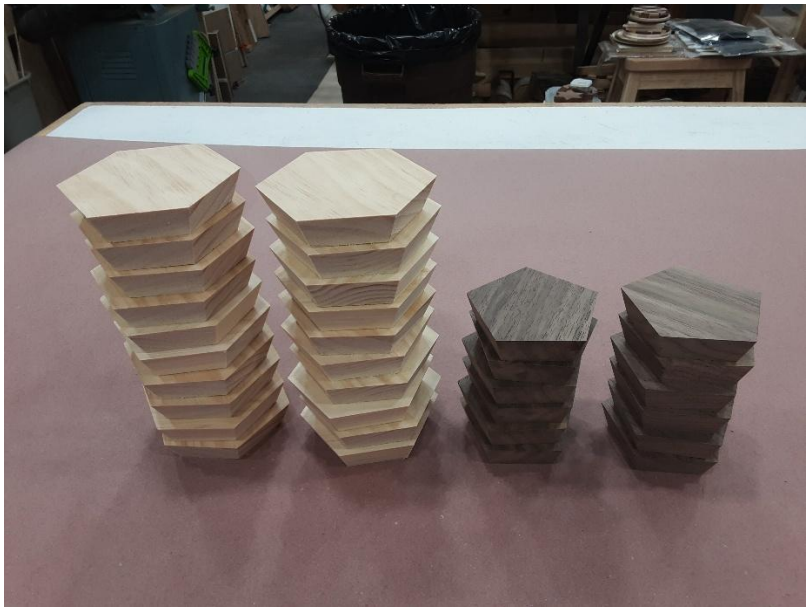


Successive cuts are completed on the small piece that has been cut off the main board by then rotating the piece clockwise until all sides are cut.



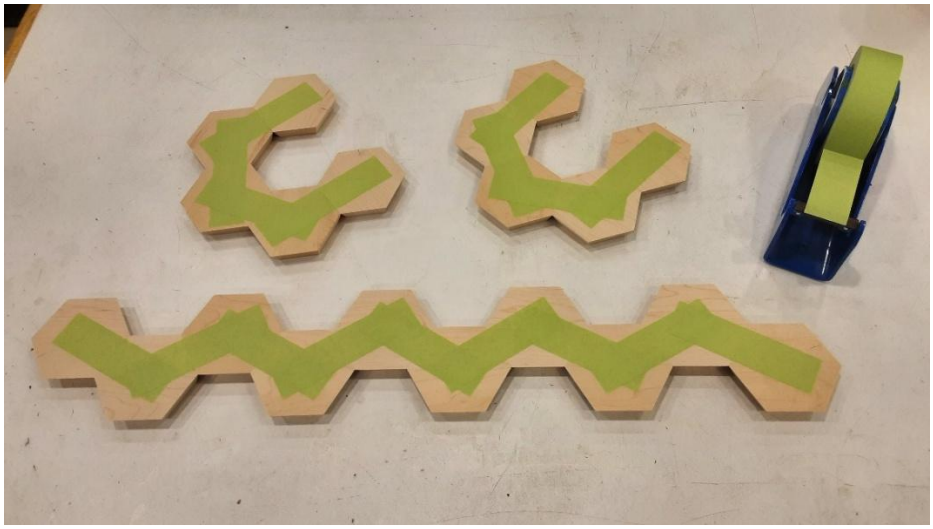
Repetitive cuts like this can cause one to lose focus (you'll be making over 180 cuts per ball!), so take occasional breaks to stay focused. While cutting each piece, make sure the piece is tight against the fence and the adjustable stop before cutting each facet – be extra careful here since the pieces can easily seat slightly "off" and that will seriously impact their ultimate fit. Good lighting at the table saw is a must here so that you can clearly see whether the pieces are properly seating against both the fence and the stop. I clip a gooseneck light onto the outer edge of my table saw top to make sure I have excellent lighting while making these cuts.

Once done with all cutting, check all pieces to make sure they are consistent: hold the large flat faces of two pieces together and rotate one piece through all sides. If all sides match with all rotations, the cuts were accurate. Check each piece the same way – I know it is tedious but you don't want to first notice a mis-cut piece in the middle of your glue-up. Then check once again to make sure that the length of each face on the hexagons exactly matches the length of each face on the pentagons.

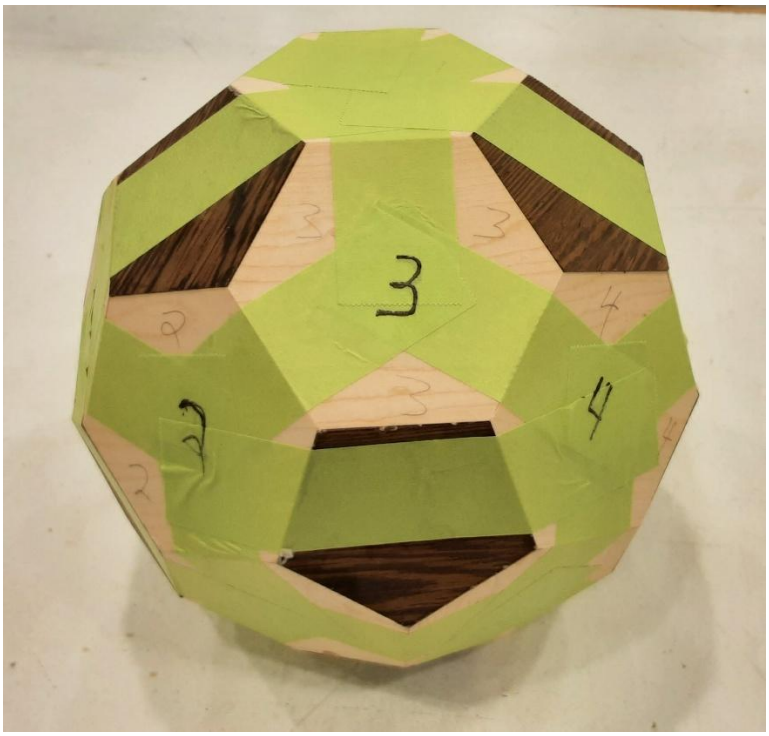


7. Next you should do a dry assembly to verify the correctness of your cuts. I use Scotch Rough Surface Painter's Tape for this since it is easier to work with than standard masking tape. I use the 1.41" width tape rather than the 1.88" so that you can still see both edges of the joint to tell if either end has a gap. I do *NOT* use blue painter's tape since it isn't "sticky" enough to hold the pieces together well enough during the glue-up phase.

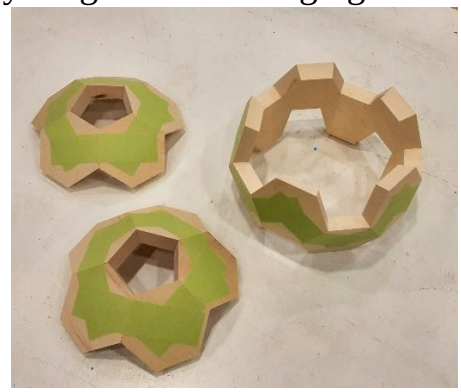
   What seems to be the easiest way to tape up the pieces is to tape 5 hexagons for the "top" and 5 for the "bottom", both sections being laid out flat in close to a circle. Then tape 10 hexagons in a zig-zag pattern for the middle.

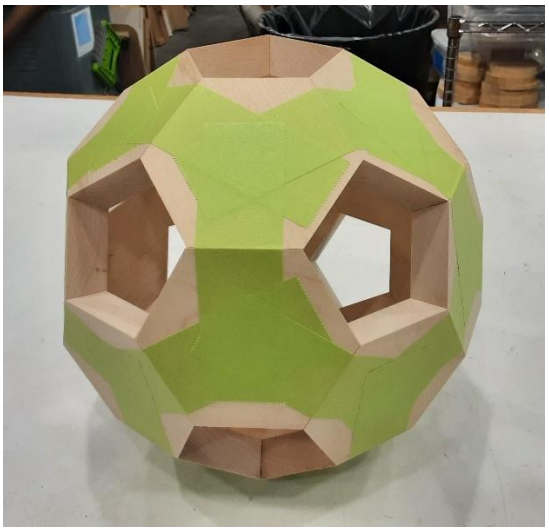


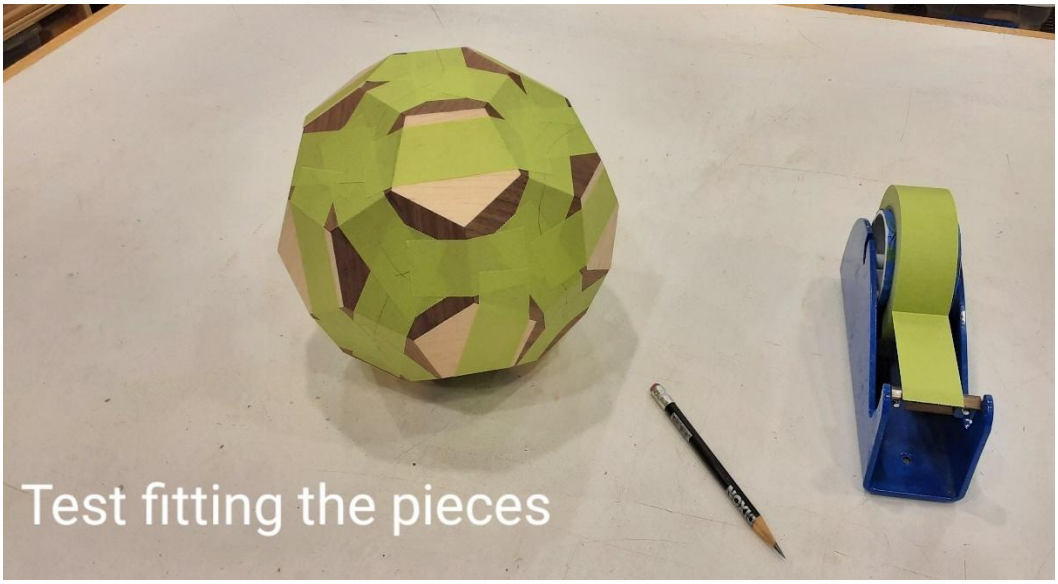
At this point, you may want to put numbers on the outside edges of each of the 10 hexagons in the zig-zag pattern to facilitate the later installation of band clamps. Here is what it looks like after glue-up – forgot to take a picture of it prior to that – sorry….



Tape each of these 3 sections separately and then tape all 3 together, marking which pieces of tape were the ones holding the three separate sections together. Dry test the fit of the pentagons by dropping them into the openings to insure they fit properly, taping them in place temporarily. (Sorry that the pictures below are not all of the same ball. I forgot to take pictures of all phases for each ball so I have to use ones from different color balls. What is important here is the process so try to ignore the changing colors of the parts…..)







If all the pieces fit properly, remove the marked temporary tape sections, lay the 3 separate sections out flat again, then apply glue to both faces of just the facets being joined at that time. I would use one of two procedures here depending on what type of glue I intend to use and whether or not I have enough band clamps and/or #107 rubber bands (7" x 5/8") available:

a. If you only have standard wood glue available, keep in mind that it has a fairly short open assembly time. So your "clamping" options will pretty much be limited to the use of tape and perhaps large rubber bands. It takes me a minimum of 25 minutes to apply the glue to all joints and tape everything together (I'm sure others are much faster at this, but I'm old and slow…), so the glue will likely be too well set at

that point to make band clamps effective. That means if using standard wood glue you need to be as careful as possible when taping the joints together. I do the middle section first, set it aside and then quickly do the "top" and "bottom" sections, and then add those two one at a time to the middle section. (Thanks to Andy Arconti from Baltimore Area Turners/Chesapeake Woodturners for the great assembly suggestion in his video to use this 3-piece method). Then insert the pentagons and tape them in place. Again, the goal here is not to have any open joints if at all possible, since there won't be much clamping pressure other than what you can apply with the tape and a whole bunch of rubber bands.

b. My preferred approach is to have glue available that has a longer open time since that allows me to use band clamps. Titebond II Extend (white but dries clear) is minimally acceptable since it has an open assembly time of around 20-25 minutes, but Elmer's Glue-All (also white but dries clear) is even better since it has an open assembly time approaching 35 minutes (depending on temperature and humidity conditions, of course) – and you will likely need all of that time, especially with the first few of these that you make. (Do not be misled here – Glue-All is NOT the same as their School glue - and it is more than sufficiently strong for this purpose; in fact, I use it on any glue-up that is complicated and will take longer than usual.) As per most glue manufacturers' recommendations, you can increase working time by either (a.) lightly moistening the surfaces to be glued before applying glue or (b.) diluting the glue with 5% water (as a reminder to myself, fill the red silicone glue pot almost ½" from the top and add 2ml of water and stir thoroughly – that gives you the 5% dilution ratio). Apply the glue to both faces of each joint in the 3 sections as detailed above, moving as quickly as you can. Then insert and tape the pentagons in place. Once everything is taped, quickly start applying the band clamps (or rubber bands if using only that technique) around the sphere, placing one over each of the 10 hexagons in the center section that you created. So you will need 10 band clamps (or ***way*** more rubber bands if using that technique). The "base" of each band clamp should rest in the middle of a hexagon (do ***not*** install on pentagons since that can force some of your joints to open) so it is firmly supported as you later tighten each clamp. Don't fully tighten the band clamps until all are installed.

Once all are installed, tighten each one a little at a time as you move around the sphere, repeating with successive small increases in pressure with each circuit around the sphere until all clamps are moderately tight. Don't tighten the first one all the way and then the second one all the way, etc. That will not give the results you want. And even if doing it a little at a time, do not in the end try to tighten them excessively, since that much pressure really is not necessary and may force some of the joints to open. Just moderate tightening is sufficient, since band clamps can exert tremendous force. If done correctly, you should see that most, if not all, the joints will close up nicely as the band clamps apply pressure in a relatively uniform fashion equally around the sphere if they are appropriately spaced. Clearly, buying ten band clamps for this purpose is a significant investment and not everyone will want to do this. But if you intend to make a bunch of these soccer balls, that investment will prove quite worthwhile.

8. After the entire assembly has dried for a couple hours, remove all the band clamps (or rubber bands) and all the tape so air can get to all the joints and let it dry overnight if you used traditional wood glue, or for 24 hours if you used Glue-All, as it has a bit longer cure time.

To verify that you cut the pieces to the correct size for what will end up as a regulation size 5 soccer ball after turning (between 8.6” and 9.0” in diameter), the dimension of the rough ball at this point (measured from the ***flat side*** of opposing hexagons) should be approximately 8.8” or so – assuming you made your hexagons and pentagons about 49mm on each facet. Mine end up about 8.88”.

9. Next, we need to get the rough ball mounted on the lathe. There are many ways to do this.

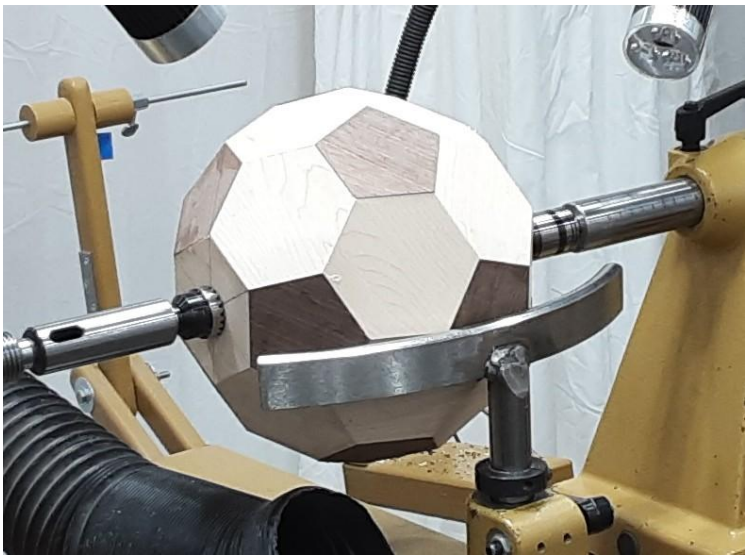
    a. One way is to glue waste blocks on opposing sides of the ball and mount it between centers against those blocks. But I found it difficult to accurately get those blocks mounted in such a way that the ball was accurately centered.

    b. You can also use cup centers or other custom-shaped centers to hold the ball by pressure. This works great for some folks, but isn't my preferred method.

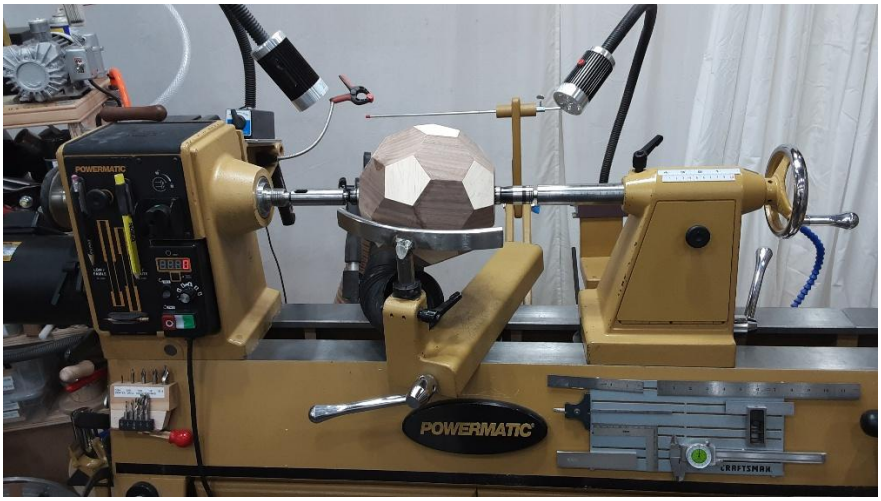
    c. I am more comfortable with the security of actual metal centers holding such a large piece on the lathe. So I opted for the alternative method of just marking the centers of two opposing hexagons (draw lines from opposite corners of the 6 corners on each hexagon) and then making very slight dimples at those center points (**do NOT punch these very deep at all – just press your awl lightly into the wood to give yourself a clear entry point for the points on the steb centers**).

    Then mount the ball on the lathe using safety (steb) centers so that there are no deep depressions made into the mounting surfaces (standard centers will likely leave point holes deeper than you will turn away, meaning you would have to fill them – and those fills will be rather

noticeable). The spring-loaded points on steb centers leave quite shallow depressions, as do the outer teeth on such centers.



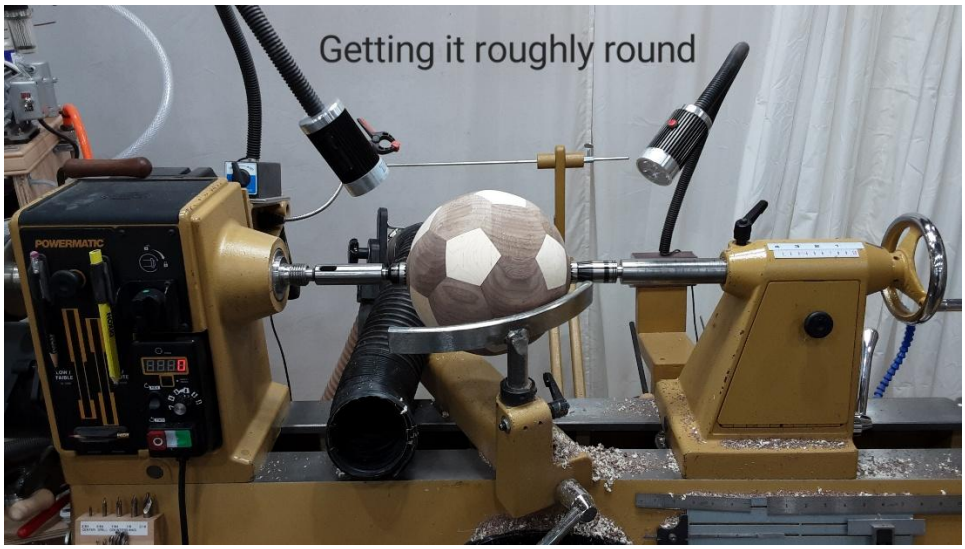
So, if done correctly, all the marks left on the hexagons by the steb centers will be turned away when the nubs are removed or sanded away in the final finishing process, resulting in an unmarked final surface.



If you *will not* be using a sphere jig, turn the ball as round as you can using a bowl gouge or carbide tool, leaving a nub about 1/8" high near each steb center that you will turn off later. **Use a turning speed of just under 1000 rpms.**

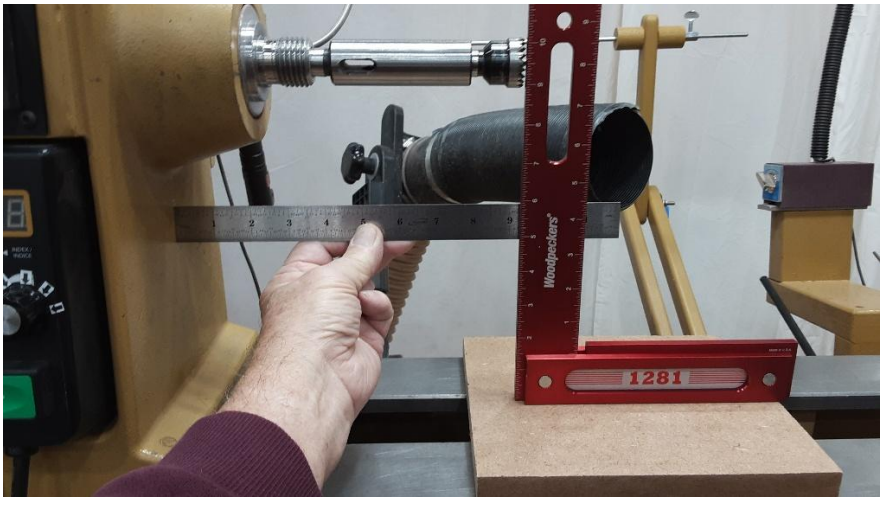
If you *will* be using a sphere jig after rough turning, you will likely need to mount the ball using a spindle extender off the headstock end (illustrated in the

photos above and below), since otherwise you may not have enough room to operate the sphere jig on that side of the ball. The next step is to rough turn the bulk of the ball as round as possible **using a turning speed of just under 1000 rpms**. You want to rough turn it so that there is about 1/8" exposed near each steb center, and pretty much all the flat spots have mostly disappeared on the rest of the ball. Use whatever tool you prefer for this – a bowl gouge, a carbide tool, etc.



Then carefully set up your sphere jig to ensure it is perfectly centered on the ball. This can be complicated so I use a guide stick to set the sphere jig at the correct distance off the headstock.

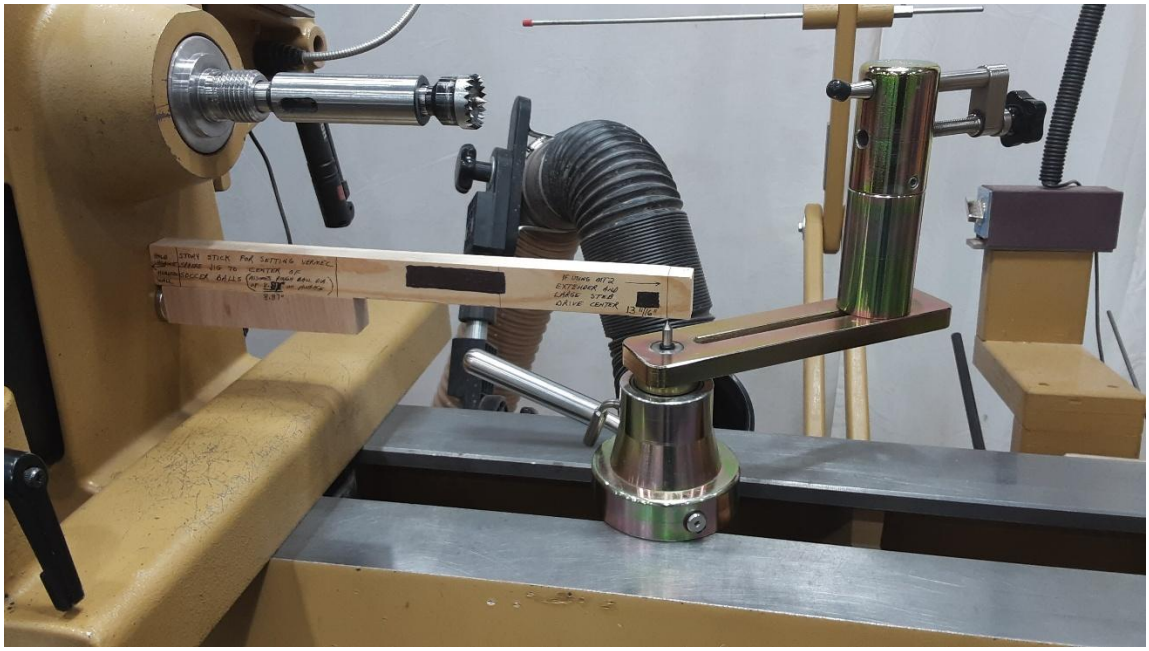
To make the guide stick, I install the spindle extender in the spindle, insert a large Sorby steb center in the extender, and then place a tall 90 degree square on the bed ways and hold it right up against the teeth of the steb center.



I then measure the distance from the headstock wall to the edge of the square. On my PM3520C, that distance is 9 9/32” or 9.2812”. I then deduct from that measurement 1/32” (or 0.0312”) for the amount the teeth of the steb center penetrate the hexagon when the rough ball is tightened between centers (yes, that is all these teeth penetrate the hard maple I typically use for hexagons – but you may have to adjust this figure if you use softer woods for your hexagons since the teeth will likely penetrate deeper in those cases). The resulting total is 9.25”. To that figure I then add ½ of the width of the rough ball. You can measure that width by using a standard large caliper, locking it at the width you have measured and then measuring the width of the opening between the caliper legs. But I find it much easier to use a set of digital calipers (picture shown below). In my case, the rough balls are about 8.88”, so I add half of that or 4.44” to the 9.25” noted above. I then mark a line on a stick that is that total distance from one edge (in my case, 13.69” or 13 11/16”) and use that to set the center pin of the sphere jig. If done correctly, this should get you extremely close to the very center of the ball so its weight won’t be out of balance.

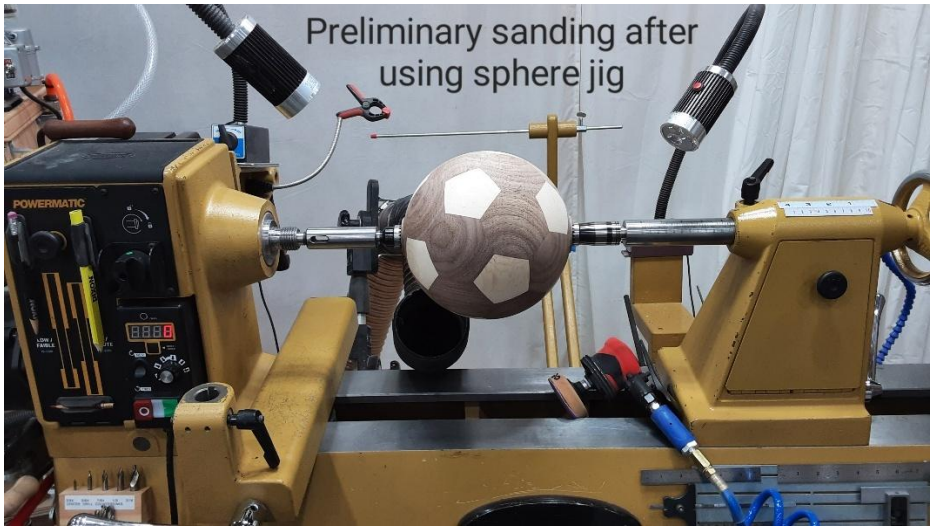
Here are the digital calipers that I use:

And here is what the stick looks like that I use to set up the sphere jig centering pin. Note that for ease of use, I have attached a magnet to the headstock end of the stick so that I don’t have to hold it at the same time I am trying to manipulate the sphere jig to get it placed on center.



10. Next complete the rounding of the ball with the sphere jig to a diameter of *at least* 8.65”. This will leave enough material that will be removed in final sanding such that the ultimate result will be the desired finished diameter of no less than 8.6” (but as much as 9.0” if you want to stay within the regulations...).

Then do your preliminary sanding. I use a pneumatic random orbit sander and start at 120 grit to remove the very small "grooves" left by the cutter on the sphere jig, using a turning speed of around 500 rpms.



Once the preliminary sanding is done, assess which joints need to be filled. Don't bother filling any joints before this since some of the gaps that may have appeared initially will disappear as you turn away the outer rough surface of the ball. It is only worthwhile doing this once you are done turning, sphere jigging and preliminary sanding.

NOTE: Don't frustrate yourself here. If done correctly, there should not be any large gaps to fill. But no matter how carefully you cut, assemble and glue the pieces, there will pretty much always be a few joints that need to be filled very slightly.

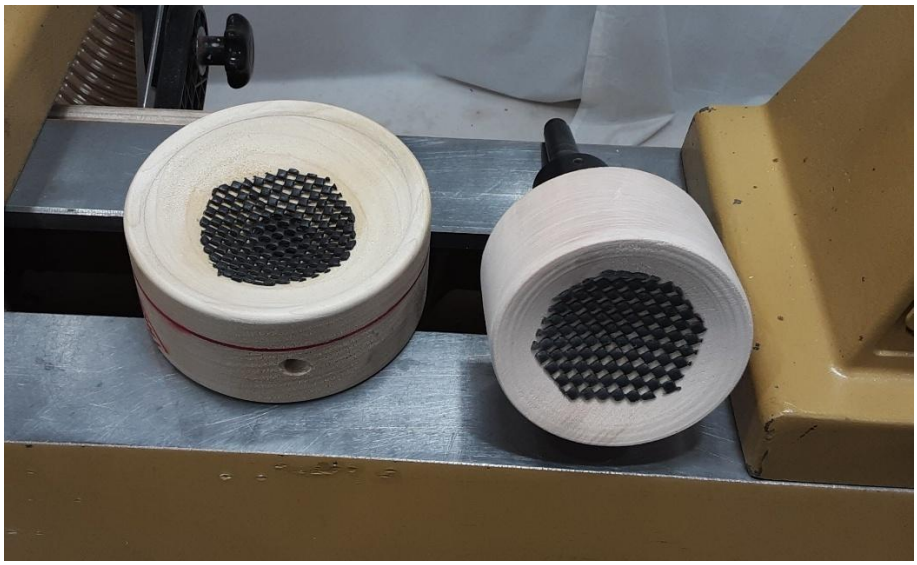
To fill any small gaps, I just use sanding dust from whatever wood was used for the hexagons:

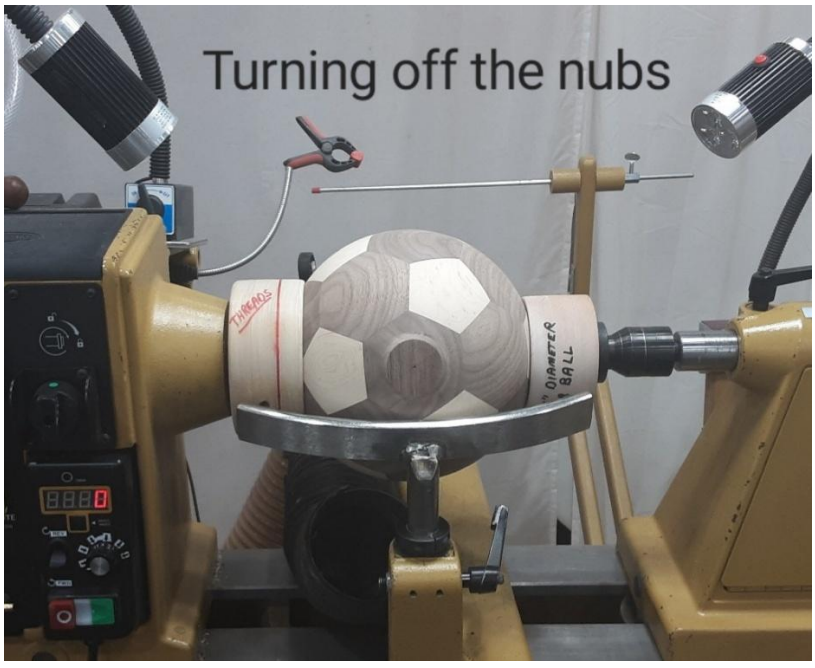
a. I sometimes "make" the dust using my oscillating belt/spindle sander – without the dust collector turned on, of course), carefully brushing it off the top of the sander table, mixing it with glue, then filling the joints.
b. Alternatively, if I remember to do it while cutting the pieces, I will first clean out and vacuum under the table saw as completely as I can. Then cut the pieces, leaving relatively "pure" sawdust matching the particular wood I am using. I collect that sawdust, then use a small kitchen sifter to sift out the finer particles that make the perfect "paste" to use for

filling any gaps. Better yet, use a coffee grinder to take the coarse sawdust and turn it into a fine powder before adding glue and filling the joints.

Once the paste filler is dry, I first sand those spots with a 120 grit hand sander and then power sand the whole ball again using 120 and then 180 grit.

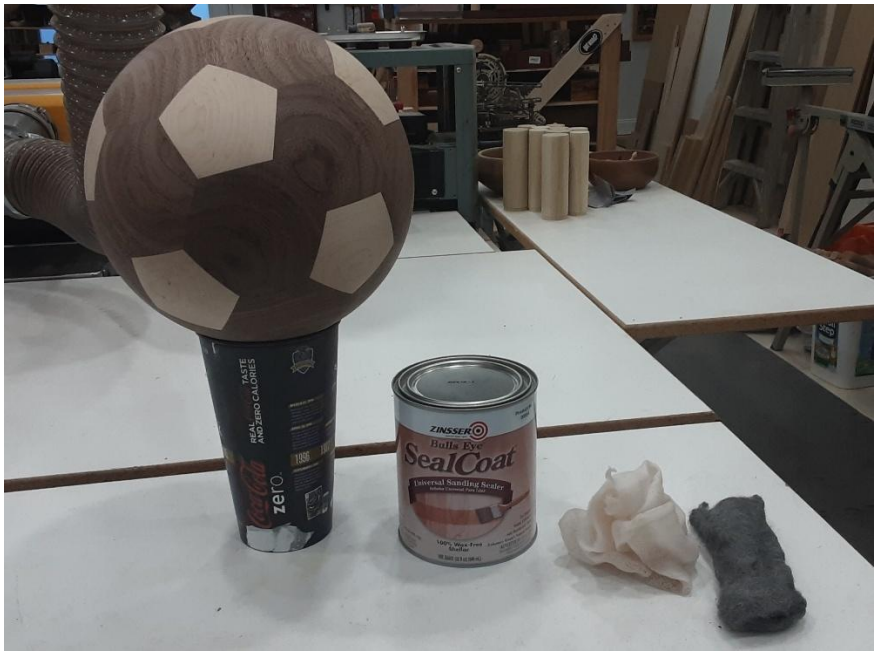
11. When done, remove the ball from the lathe, then install your cup centers (see further details in #14 below) and re-mount the ball with the nubs at the 12 and 6 positions.





When mounting the ball to turn off the nubs, use a pencil or other point tool held on a tool rest and spin the ball by hand to ensure the ball is mounted so that both center points of the nubs are pretty much perfectly aligned; this makes the turning off of the nubs a little easier. Use good lighting when doing this to highlight the "ghosting" that appears at the top of the ball and remove the bulk of the nubs by initially using a standard cutting orientation of the bowl gouge – not a scraping action since the nubs are so big at that point that a scraping action may cause a serious dig that will damage the otherwise perfect sphere. And don't go too deep when cutting off the nubs since that may also throw off the near perfect rounding job you just did with the sphere jig. Get it close, then at that point it is safe to use a light scraping action with the bowl gouge to remove the small remainder of the nub, followed by using the random orbit palm sander with 120 grit paper to finish it off. I then do the final sanding of the whole ball down through 320 grit on the pneumatic sander, rotating once with each grit to make sure I get the areas that were under the cup centers.

12. I then use compressed air to blow the sawdust off the ball, tack cloth it thoroughly and then apply 1 coat of sanding sealer to the ball. I lightly sand it with a 0000 steel wool pad (a synthetic steel wool pad would actually be preferable since it doesn't leave any wool residue) after the sealer dries, blow off the residue and wipe it with a tack cloth again.



Then I spray on multiple coats of satin spray lacquer (I use Deft, Minwax or Watco, depending on what is available locally). To do this on a round ball of this size, I simply set it on a tall plastic cup on a turntable and spin it as I spray.

Don’t spray too far down the ball (only slightly past half-way) as you are doing this, since you don’t want any lacquer build-up to accumulate around the area where the ball meets the lip of the cup. Spray lacquer is very forgiving, and, once you rotate the ball and re-spray what had been on the bottom, you won’t notice any overlapping of the spray coats. The coats all blend very nicely as long as you don’t apply too much at once. Remember, several light coats are much better than a couple heavy ones. I spray two coats on the top half of the ball, rotate it 180 degrees and spray two coats on the bottom. When dry, I rub the ball with 0000 steel wool, blow off the residue and wipe it down with a tack cloth. Then I apply one final coat to both the top and bottom halves. When dry, I give it one final polish with the steel wool pad, blow off the residue and give it a final wipe with the tack cloth. Done and done!

13. Do you need a sphere jig to get the ball perfectly round? Not really. These assemblies are almost round to begin with, so they don't take much turning to smooth out and get very close to round. But a sphere jig would facilitate the process – and would certainly maximize roundness if that was critical for some reason. To be candid, I have many balls done both ways and there is no way to tell from a distance which one was done with a sphere jig and which one wasn't. Even when fondling them by hand it isn't super easy to tell which is which – although there is definitely a difference to someone with a discerning touch.

14. Further details on cup centers: I originally used Rubber Chuckies as cup centers, but their small size (about 2") made it difficult to repeatedly re-mount the ball accurately; I have found the re-mounting process to be much easier if I use much larger shop-made cup centers. These centers must be turned so that their curvature matches the 8.6" diameter of the sphere; also, you should glue a small (3") patch of something like open weave indoor non-slip rug padding so that the sphere will not move while turning (I found it did not work as well when I tried to use a large piece of this padding that covered the entire cup center since the sphere would not "center" as well). Even with these centers, the sphere will rarely re-mount with perfect accuracy (unless you use a sphere jig – in which event it re-mounts with amazing consistency), but it is much better than when you use the smaller Rubber Chuckies for this purpose.

15. To facilitate the rounding process (prior to getting a sphere jig), I cut a 8.6" circle on the bandsaw and used the scrap around it (cut off so the "base" of the semi-circle is 8.6" wide) as the pattern to check to see how round the ball was getting. And the circle itself was useful in turning the shape and depth of the cup in the shop-made cup centers.

If you have any questions about this process, please feel free to email me at jim@firststatewoodturners.org or jimwhattam@gmail.com.

Thanks for reading this!

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