SEGMENTED TURNING IN PRACTICAL TERMS

INTRODUCTION

There is a lot of science to the art of segmented vessels. The prospect of facing the details can be daunting even for the experienced woodworker. It needn't be. This article is an

attempt to simplify the process. While other means can be employed, the table saw will be used for cutting segments in this procedure.

What is a segmented turning? For our purposes, we will stay with the architecture that glues segments into a ring and then glues the rings into a vessel for later turning on a lathe. The vessel may be a simple bowl or a complicated shape such as a vase. With this basis, we can define our segmented turning as a stack of rings each made up of a number of trapezoids or triangles.

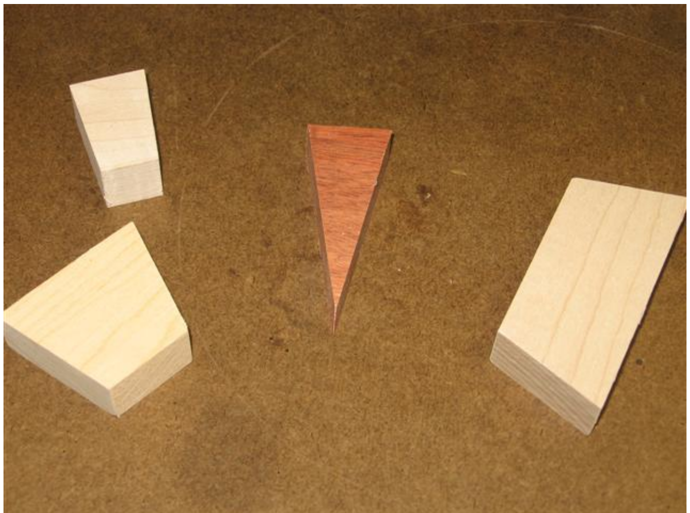

Figure 1. Segments are either trapezoids or triangles depending on the application.

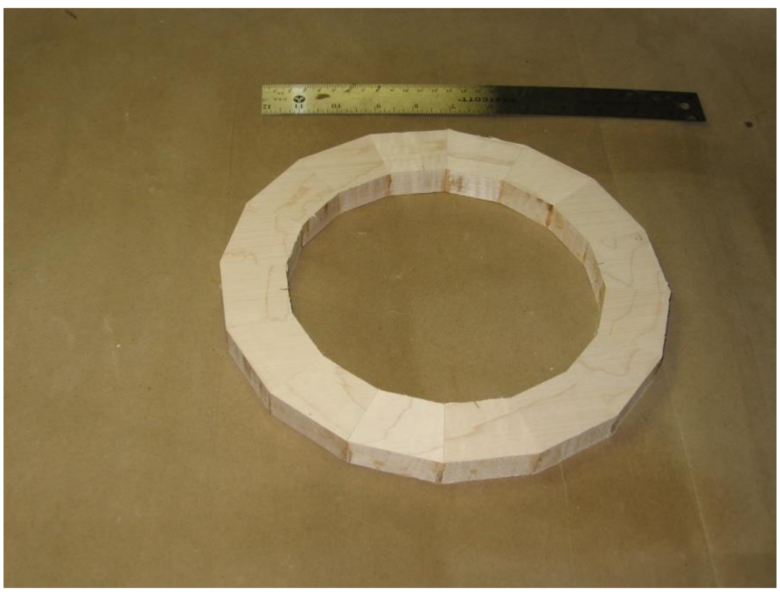

Figure 2. A ring of Segments

After segments are glued into rings, the rings must be leveled. The finished ring, ready for gluing to other rings must be flat on both sides and sides must be parallel. An obvious way to accomplish this is to send the rings through a drum sander. Other means are possible, but care must be taken to meet the flat and parallel criteria.

Once the rings are glued to each other they are ready to be turned. The simplest method is to use a chuck or faceplate to hold the piece and to turn the facets off of both the inside and outside of the vessel. When this has been accomplished, the turner can then shape the piece in the usual manner and finish it appropriately.

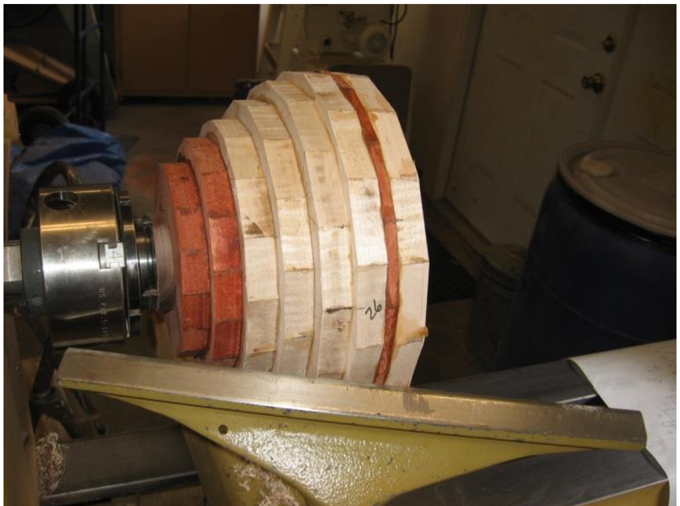

Figure 3. A partial Vessel on the Lathe

That's a quick look at the procedure. Now let's go into some detail.

METHOD

There is a straight forward way in which to make segmented rings for various purposes such as vessels or furniture pieces. That process is to make the proper number of segments to go around a ring of segments and leave no gaps between them. This boils down to making segments that are the correct length and are cut at the correct angle. This doesn't need to be complicated but sometimes is made to be that by attempting to use substitute methods; for example, making segments to almost meet at their ends and trimming them to fit. This is sometimes accomplished by gluing up half rings and sanding each half until they meet properly; a practice that results in additional work and sometimes leaves less than desirable results. Figure 4 shows a comparison. Figure 5 shows the methodology used. The less than precisely cut segments were glued into half rings and then the half rings sanded on a disk sander to make them fit. The result is a ring that is not quite round; thus making it difficult or impossible to align to the adjoining ring.

Figure 4. Comparison of doctored joint and good one

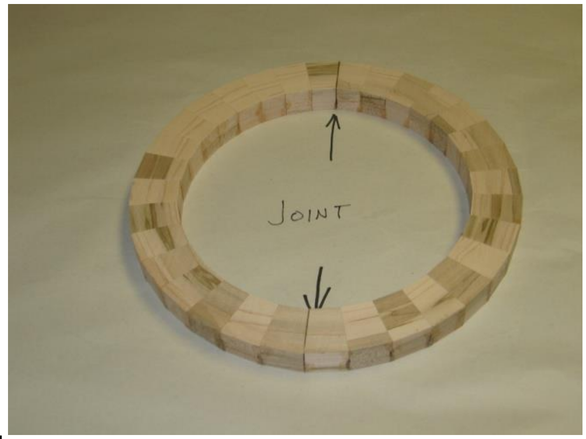

Figure 5. Joining two half rings

While it sometimes becomes necessary to take remedial action because of a mistake or accident, it does not have to be a part of the basic method. There can be no argument against doing just what was stated before; namely to make the proper number of segments to go around a ring of segments and leave no gaps. This is done by cutting these segments to the precise angle and length. Once this is accomplished, one has but to glue the segments together in a ring and make sure that they are co-planar.

The segments in a ring are cut from carefully machined boards. We'll discuss this in detail later, but for now, we need to understand segments. Figure 6 shows two segments with the parameters marked on them.

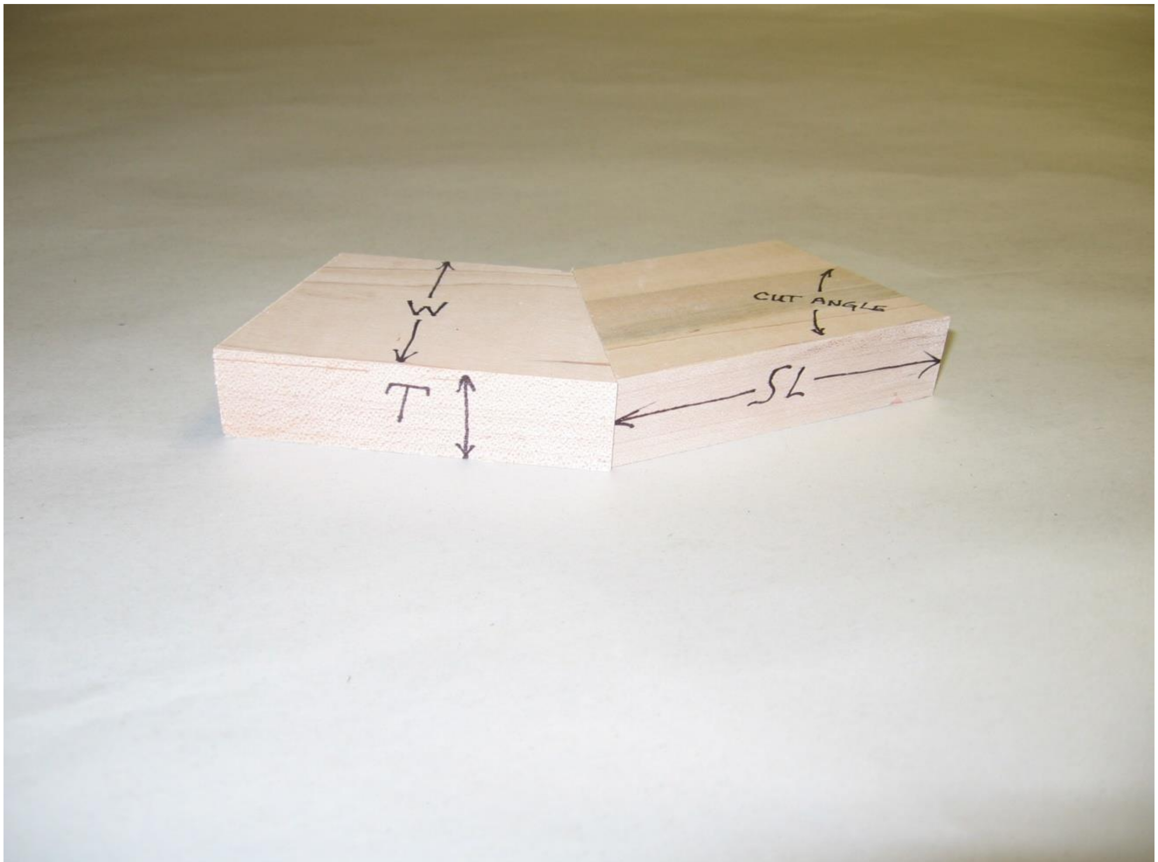

Figure 6. Two segments. The non-critical parameters W and T are on the left. Critical parameters SL and Ca are on the right.

A word here about the width parameter (W). While there are reasons to keep the width of all segments in a given ring the same, it is not critical to do so. To some degree, the same can be said of the thickness (T) since the ring will be sanded after the glue up; however, keeping thickness and width constant within a ring makes things go easier in the sanding and turning that follows. Sometimes, for the sake of expediency, it may be advantageous to use boards in which these parameters are slightly different. Look back at Figure 4.

The critical parameters for a segment are the cut angle (Ca) and the segment length (SL). If these parameters are not precisely cut, then the ring will not close.

Whatever your method for creating a segmented vessel, it is best to have a work plan. As you develop your design, it is a good idea to think ahead to consider how you are going to implement it. This work plan will be helpful in preparing for each step, ensuring that you have the needed tools and supplies.

This is the method we'll describe:

1. Design and detail the piece.
2. Cut and glue the segments into rings.
3. Glue the rings into a vessel, or part of one, ready for turning on a lathe.
4. Turn the piece on the lathe
5. Finish it.

There is more to it than this simple description and there are variations in each step, so we will go into the detail of each and develop our work plan details as we go.

DESIGN AND DETAIL:

It is not imperative that one follow this procedure in the design process, but it is important that you follow some thought out procedure. This happens to be one that I use. It's based on seminar instruction[1], reading source material[2], and personal experience. It works for me, and it is probably a good starting place for you.

1. Layout your design on a piece of quad rule paper. First draw a vertical center line. You can draw only one side of the vessel although it helps to envision the design if you then fold it over and trace the mirror image. Get your shape the way you want it and draw a shadow line to represent the inner wall inside the curve of the outer design by the thickness you want in the final piece.
2. Decide on the vertical thickness of each of the rings. Consider the shape of the vessel to ensure that your thickness pattern complements rather than impedes the design. Then draw horizontal lines across the layout representing rings.
3. Decide what the width of the ring needs to be to ensure that the ring includes the outside wall and the inside wall of the intended shape. Draw in vertical lines to represent the inside and outside edges of the ring. See Figure 7.
4. Make a chart, as on Figure 7, to include the design parameters of each ring.
5. Measure the distance of the outer ring edge to the centerline and write it down for the radius (R). This radius is that of the ring at the center of the ring segments, not the ultimate radius of the piece.
6. Measure the distance from outer ring edge to the inner ring edge and write that down for the width (W).
7. Measure and record the thickness of each ring (T).

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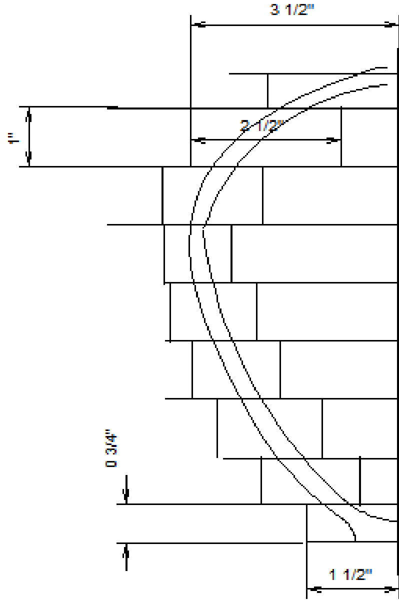
[1] Linda Salter at Provo Woodturners Symposium, June 2004.

[2] Segmented Turning : A Complete Guide by Ron Hampton (and Internet sources)



#	R	W	T	N	Ca	C	SL	BL
9								
8	3 1/2"	2 1/2"	1"					
7								
6								
5								
4								
3								
2								
1	1 1/2"	1 1/2"	3/4"					

Figure 7. Sketch of left side of Vessel with chart underway.

8. Decide how many segments to use for each ring. Keep in mind the design requirements. If you want to keep the cut lines aligned in a certain way, the number of segments must be equal or an even multiple of each other. Once the decision is made on number of segments (N), then the cut angles can be calculated (Ca).

- Figure 8 shows a typical segment top view. A segment is normally just a trapezoidal piece of wood.

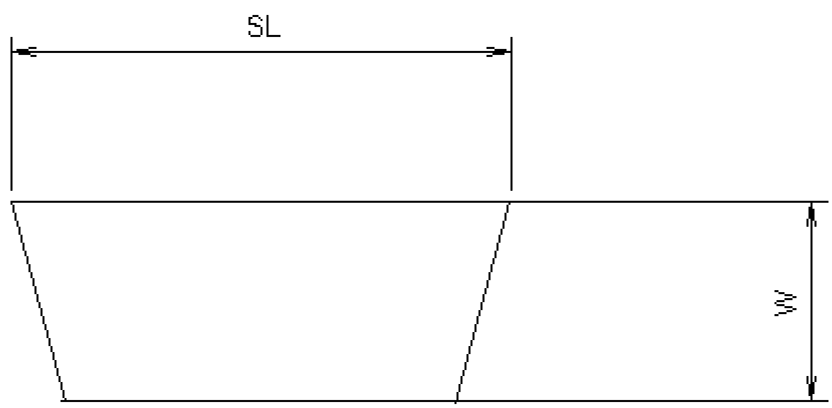


Figure 8. The Segment is a trapezoid with the length SL and the width W. The angle of the sides is determined by the number of segments in a ring.

9. Calculate cut angles by dividing 360 degrees by the number of segments. Since the segments will be cut equally on each end, divide that angle by 2.
   Example: If there are to be 12 segments for a ring, then the included angle is 30 degrees. Divide that by 2 to get the cut angle of 15 degrees.
10. Once the chart is filled to this point, the radius and number of segments are known, so the segment length can be calculated.

For a close approximation[3] of segment length, divide the circumference of the ring by the number of segments. To compute the segment this way, use the following formula:

Segment length = 2 x 3.14 x R / N

Where: R is the radius and N is the number of segments from the chart

To calculate the segment length more accurately use the following formula:

Segment length = 2 x R x Tan (Ca)

Where: Ca is the cut angle and R is the radius from the chart

Note: In some instances, there is a filler piece placed between the segments in a ring. If it has a thickness that could affect the ring circumference substantially, it should be subtracted from the segment length. An example would be a ¼" filler and a 1" segment length. That could affect the circumference dramatically.

11. Now that all dimensions of the segment are known, it is time to develop the dimensions of the lumber needed to make the segments. Note that, the length of wood necessary to make a certain number of segments is less than the length of the segments multiplied by the number of segments (i.e., N x SL) and there must be some part of the wood left to hold onto to cut the final segments, and the width of the blade must be accounted for. To calculate the length of the piece of wood from which to cut the segments.

Board Length = Safety factor + N x [(SL + Blade width) – W x Tan (Ca)]

Again: N = Number of segments

SL = Segment Length

W = Width of the segment

Ca = Cut angle

[3] This can cause considerable inaccuracy where the number of segments is small. See Appendix II for details.

The safety term is whatever length you feel is safe for you to be able to hold onto the wood as you cut the last segment. That should probably be between 4 and 6 inches for most vessels.

If one decides to use the N x SL approach be forewarned that the wider the board (W) the more waste one can expect.

12. Before finishing the detailing step, decide on the type(s) of wood to be used for each ring and note it on the chart. If there is a special pattern, note that as well.

    Note on consolidation: When two or more rings share the same thickness, width, and wood type, they can be consolidated when practical. The safety factor can be reduced by this process thus saving wood.

PREPARING WOOD:

The product of the detailing process is a cut list. The chart created conveys all the needed information; wood type, thickness, width, and length. Prepare wood for each ring using the appropriate tools to dimension the thickness, width, and length of each piece. Make sure that all edges are square to each other and that each piece is straight.

	Board prep			
#	**LENGTH**	**Width**	**Thick**	**Color**
	Inch	**Inch**	**Inch**	
1	**18**	**2.250**	**0.50**	B
2	**18**	**2.250**	**0.75**	W
3	**15**	**1.750**	**0.75**	W
4	**15**	**1.250**	**0.50**	B/W
5	**15**	**1.250**	**0.50**	B/W
6	**15**	**1.250**	**0.50**	B/W
7	**15**	**1.250**	**0.50**	B/W
8	**15**	**1.250**	**0.50**	B/W
9	**15**	**1.250**	**0.50**	B/W
10	**15**	**1.250**	**0.50**	B/W

Table 1. Sample cut list giving length, width, thickness, and type wood..

In addition to making a piece of wood for each ring, make four or five extra pieces of one item on your list to use for testing your setup. It is good practice to prepare all the wood at this time so that you will not have to break into your procedure in subsequent steps.

Note: A computer spreadsheet program is ideal for calculating all remaining parameters once R, W, N, and T are known. See Appendix I for a description.

CUTTING SEGMENTS:

This procedure assumes the use of a table saw. Segments can also be cut using a radial arm saw, band saw, or miter saw. Those machines will require other set-ups and are not the subject of this article.

Segments are cut from the wood that has been prepared. While the table saw miter gauge could be modified by addition of a fence to cut segments for segmented turnings, its accuracy and repeatability are not likely to produce consistently satisfactory results. For this reason, there are several aftermarket miter gauges available to do this sort of work. They have a common disadvantage; namely, they are expensive. There is, however, an alternative; and that is to make your own jig to suit your individual needs. There are several designs for sleds to fit this need in books and on the Internet. See figure 9 for one that I use.

It’s critically important that segments for a given ring are equal in length. To get repeatable lengths a stop block is employed. As long as the segments are of equal length a little inaccuracy in actual length can be tolerated. Make sure you select a sled design that doesn’t trap the segment between the blade and the stop block.

Most important is that the cut angle is accurate. There is no room for compromise here without resorting to remedial action such as discussed earlier. This is time consuming and unnecessary. To avoid cut angle inaccuracy, take the time now to cut test pieces to make test rings. The rings must close completely with no gaps between segments. It there is a gap on the inside of the test ring, the angle must be reduced. If there is a gap on the outside, the angle must be increased. Make adjustments and cut segments for another test ring, and repeat the process until you have no gaps. You will need to do this for each angle in your design, so group your cuts so that all of one angle is cut before you go on to the next. Typically, there will be only one angle cut for a given vessel, but sometimes there will be more; for example: a turning may have 12 segments for all rings except one that will have 24 segments to highlight the waist of the turning.

Figure 9. Sled for cutting segments. Fence is at an angle of 11.25 degrees. The stop is graduated in millimeters for ease of setting the segment length.

With the angles set and the stop block in place, you are ready to cut segments. This is a good time to discuss safety. Use a method that keeps your hands away from the blade. It's sometimes difficult to use a blade guard. This is one of those times. If at all possible to safely do so, you should use yours.

You will be cutting segments that are typically pretty small. If they are hit by the rotating blade after being cut from the work piece stock, they will fly off, sometimes disappearing into the shop and sometimes hitting you. To pull the segments away from the blade, I use an unsharpened wooden pencil with rubber eraser as an extension of my hand. Doing this keeps my fingers several inches away from the blade. Additionally, the fence protrusion partially shields the rotating blade while holding the segment in place.

The process of cutting segments is straight forward from here. First, set the stop to the desired length (SL). Now cut off one end of the workpiece to start the sequence with that end at the cut angle (Ca). Next, move the piece and put the cut end against the stop block. Then cut your first segment. It should be a trapezoid whose long edge equals the segment length (SL). Continue cutting by moving the workpiece between each cut until you've cut the correct number (N) of segments.

GLUING SEGMENTS INTO A RING

As stated earlier, segmented turnings are made up of rings of segments. In general, there are two strategies for cutting and gluing segments. One can cut all segments and then glue up the rings or cut segments for one ring and glue that up. Which strategy you choose to use will depend on your circumstances. There are advantages and disadvantages to each.

The advantage of cutting segments for one ring and immediately gluing it up are:

1. Relief from repetitive cutting.
2. No need to segregate segments.
3. Economy of clamps.
4. Checking setup accuracy as you go.

There will be several to many rings in a typical segmented vessel. Depending on the number of segments for each ring and the number of rings, there could be upward of several hundred pieces involved. If these are all cut at one sitting, boredom and physical fatigue could affect your accuracy and safety. Repetitive cuts over an extended number of segments are reason to be concerned in an operation in which concentration is critical.

The need to segregate segments may not be immediately obvious, but consider that in many cases the segments for one ring may be very close in size to another. Sorting them out could be an unwanted chore. If you find yourself in need of keeping segments separated, consider having containers for the separate sizes.

Each ring will require the use of at least one hose clamp and sometimes several chained together. Assuming the use of yellow carpenter's glue[4], by gluing as you go you will be able to reuse clamps after a ring has been allowed to cure for 30 minutes or so. This means that by the time you've cut your third ring, the clamps from the first ring can be available for use.

Setup accuracy can be lost in various accidents; e.g., by simply bumping your sled. By gluing a ring as you cut the segments, you are maintaining a constant check on accuracy. Problems are spotted immediately rather than after cutting everything at once; thus, you'll loose, or be forced into remedial actions for, only one ring of segments.

With all these advantages, it may seem that there is no need to take the alternative strategy of cutting all rings at once, but there may well be. For example, the use of epoxy, and some other adhesive types, requires mixing. If this is the case then it may be more reasonable to cut them all at once or at least in batches to minimize the work of mixing and cleaning up the adhesive paraphernalia.

In any case, it's advisable to think the procedure through before embarking on either strategy.

It's best in any glue-up to make sure you're ready with all necessary tools and materials before spreading the glue. This procedure will help with that:

1. Gather all segments and make sure there are no Irish pendants hanging from them that will ultimately keep them from closing on the adjacent segments. Use sandpaper to lightly knock off heavy fuzz or splinters from the edges. Avoid rounding edges on the segments which could result in voids in the final vessel.
2. Arrange the segments into the ring and place a hose clamp around them. Tighten the hose clamp and make sure that the segments close without gaps. Then back off the hose clamp so that it can be removed. Leave a little slack to enable easy replacement of the clamp after glue has been applied.
3. Apply glue to both mating edges of all segments. You don't want voids that may show up as gaps later. A shortcut in this step, for the typical segment, is to clamp all segments together so that glue surfaces, the angular edges, are adjacent to other glue surfaces enabling the application of glue in one step rather than on individual segments. See figure 10.
4. Once glue is applied, arrange the segments into the ring again making sure that any pattern of segment placements is satisfied. Put the clamp back on and tighten it, closing the segments into the ring. Loosen the clamp as required to make adjustments and, using a block of softwood and a hammer, tap on the segments to flatten the ring. Tighten the clamps and wipe off excess glue.

Set the ring aside to cure and go to the next ring.

[4] Aliphatic resin wood glues are available from several manufacturers.

Figure 10. Shortcut for gluing. Segments are aligned and clamped so that glue can be applied to all needed surfaces.

Figure 11. Assembled Rings.

TRUING RING SURFACES

Mating surfaces of rings must be flat, parallel, and smooth. This is probably best done on a drum sander but can be accomplished by other means. The options range from hand sanding to truing on the lathe. See figure 12.

Hand sanding can be accomplished with the adhesion of coarse sandpaper to a flat surface followed by application of elbow grease. Scrubbing the ring across the sandpaper will remove irregularities from the surfaces. If this is your method of choice, be sure to take extra care when gluing up the ring to ensure that the segments are as level as possible and that excess glue is wiped away.

The lathe, being a part of the overall tool requirements for segmented turnings anyway, is available for the truing operation. Sandpaper jigs can be fashioned to flatten the rings while they spin on the lathe, or with skill, turning tools can be used as well. Remember that the surfaces must be flat for good glue adhesion. See figure 13. Figure 14 shows how to flatten a ring on the lathe using a flat platen with coarse sandpaper.

GLUING LAYERS OF THE VESSEL

Each layer of a segmented vessel is a ring of segments. After flattening the rings, removing ridges and excess glue, the rings must be glued together. To accomplish this, some form of alignment is required.

A rotational alignment of joints between segments has the objective of lining up with some feature of the adjacent rings. The staggered brick arrangement is typical in which the ends of segments in adjacent rings are aligned with the center of segments in their counterpart.

Another consideration is concentricity. If rings are not aligned with their centers along the center of the vessel, the segment alignment will be offset. This poses a problem since the centers of most rings are in the space inside the ring.

To accomplish both concentricity and rotational alignment, mark the spot on the adjacent ring to be aligned with segment joints on its counterpart. Four marks should be adequate for alignment purposes. See Figure 15.

Figure 12. Using Drum Sander to flatten the rings after assembly.

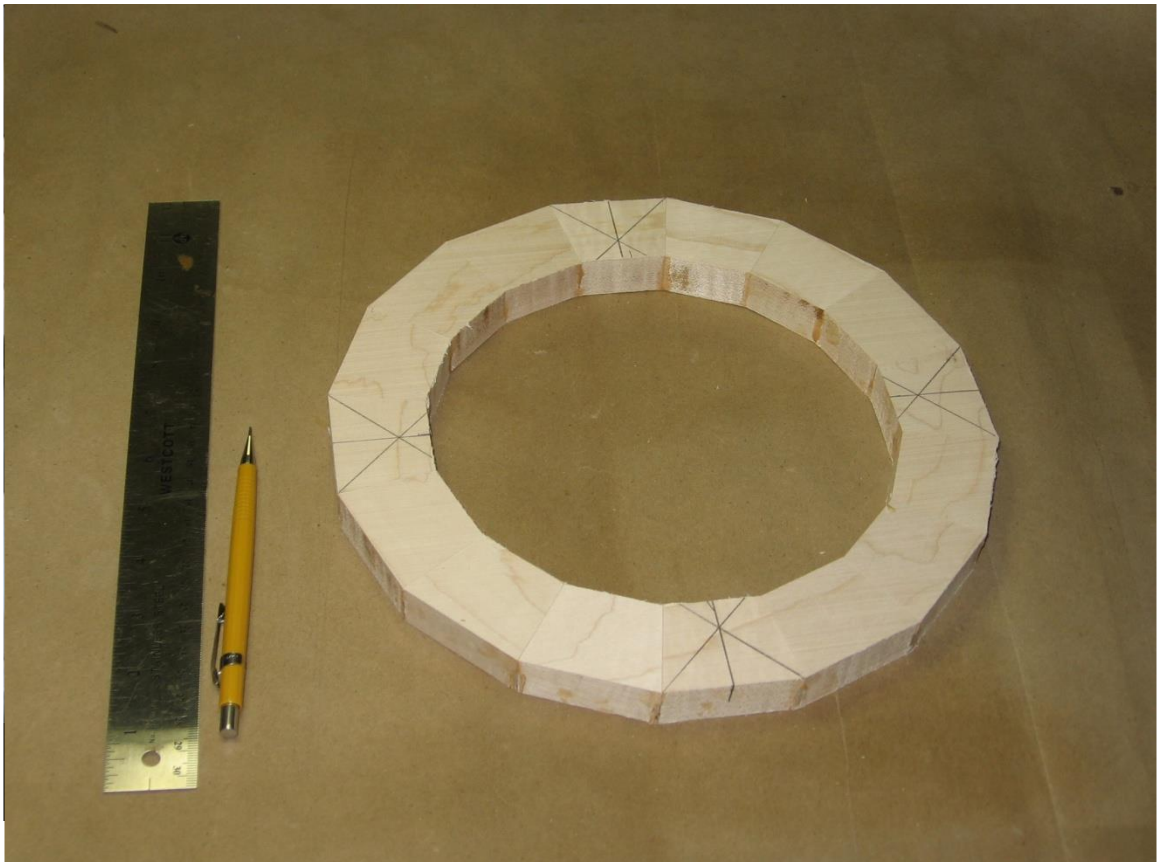


Figure 14. Using a sanding aid to flatten a ring on the lathe.

Figure 15. Marks on four sides of the ring are sufficient for alignment.

Alignment marks are made by drawing a line across the ring from the center of a segment on one side of the ring to the center of the segment opposite. Then a perpendicular line is drawn across the ring from the centers of the two segments that are at 90 degrees with the first. Then, if needed, the lines are extended down the edges of the ring.[5] Finding the center of the segments could be done by measuring, but by drawing a series of chords from the outside corners of the included segments all around the ring, and then drawing the cross lines through the intersection of the chords, one can eliminate the need for tedious and error prone measurements. This is especially helpful on small segments.[6]

It's tempting to conclude that gluing up your rings with the help of the marks you've just made will be all that's involved. Many turners do just that by gluing the rings by pairs then fours and so on. There is nothing wrong with that for a few rings, but it is very difficult to maintain alignment as the stack begins to grow. In a vessel with 20 or more rings, the small errors compound and cause problems in alignment that are hard to correct. Figure 16 shows two pairs of rings being assembled into a stack of four. The alignment marks were used to align the centers of one ring's segments to the end of segments in the adjacent ring. This method demands that one pays attention to both the rotation and concentricity of the rings or the vessel.

[5] When adjacent rings are the same diameter or close, it's helpful to have marks on the edges where they are more visible.

[6] It pays to have a mathematics teacher in your workshops. In my case, she saw me doing it the hard way, and tactfully suggested the better way.

Figure 16. Two pairs of rings have been glued together using the alignment marks to align the center of segments on one ring with the edge of segments on the next.

Another method or attaching adjacent rings is to use the lathe to hold one ring while the other is aligned using a disk with concentric lines as shown in Figure 17. This method still requires close attention to alignment and use of the alignment marks described above.

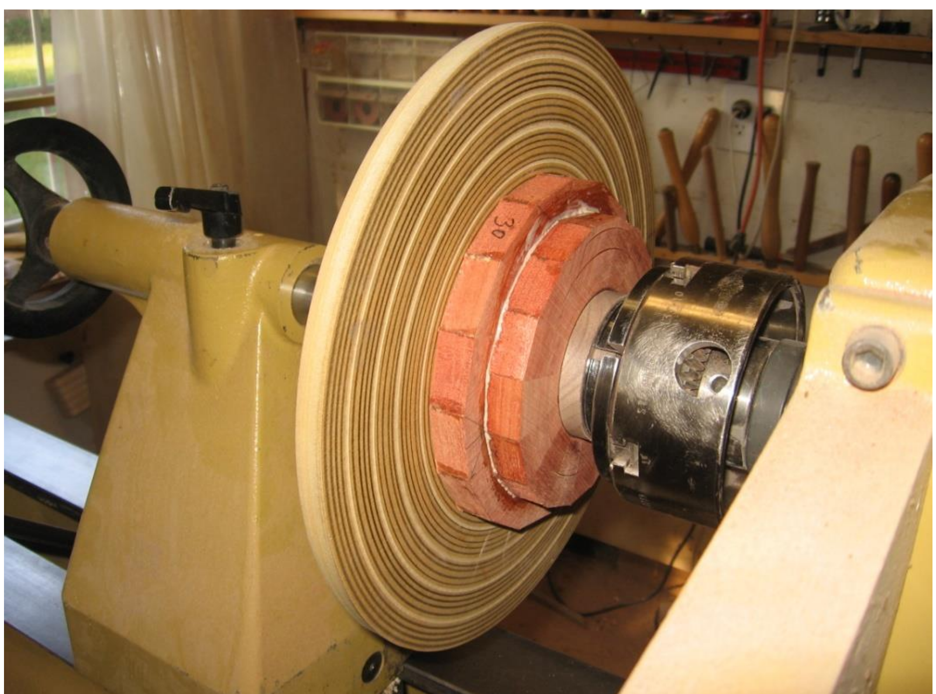


Figure 17. Assembling rings using alignment disk on lathe

The major drawback to this second method is that it requires more time than the first, but it provides a better handle on alignment. The lathe can be used as a clamp for the smaller ring sizes, but larger rings may require use of additional clamps to ensure proper closure between adjacent rings. See figure 18.

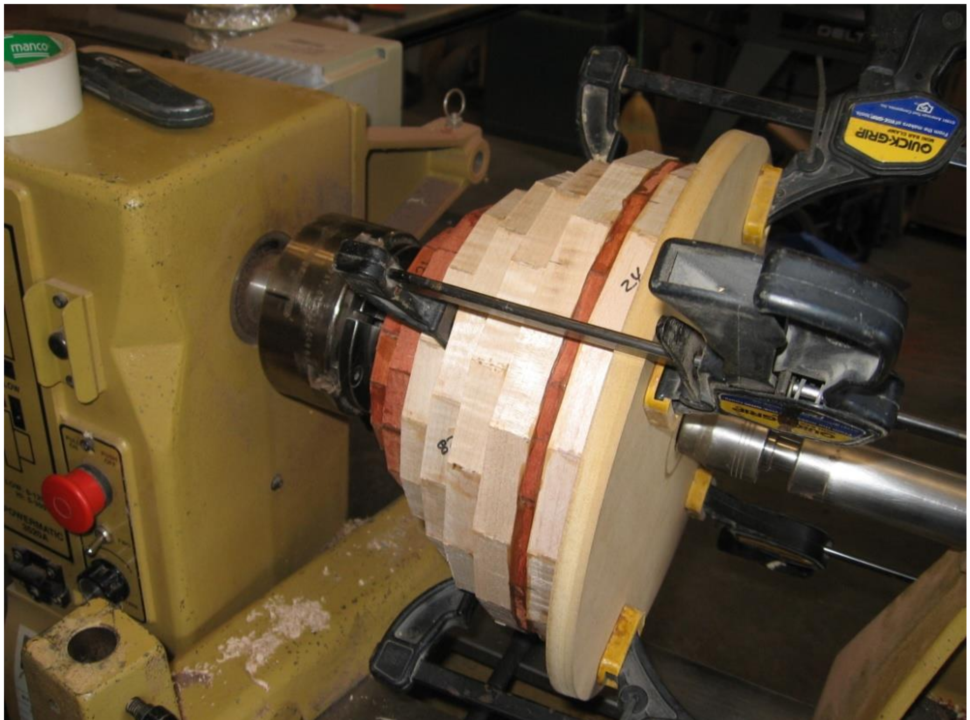


Figure 18. Use of clamps to ensure closure for larger rings.

Some designs are best handled by assembling all rings prior to turning. Other designs, for example closed forms, are best handled by assembling parts of the vessel, turning those parts separately, and then assembling the whole before final turning. That will be decided as you design your vessel and should be included in your work plan.

TURNING THE VESSEL

Segmented vessels are turned just like any other faceplate work piece. The work piece can be attached directly to the holding means, but most times the addition of a sacrificial block is advisable. The key for safety of the vessel and the turner is to let the glue dry thoroughly before attempting to turn. Whenever possible the vessel is held between centers. Turning is usually done with a faceplate or chuck on one end with the tailstock and a rotating center at the other.

Figure 19 shows two halves of a vessel on the lathe ready for turning. These halves are secured by double sided tape and held between centers so that the outside of the vessel can be turned to rough shape before separating the halves for shaping the inside.

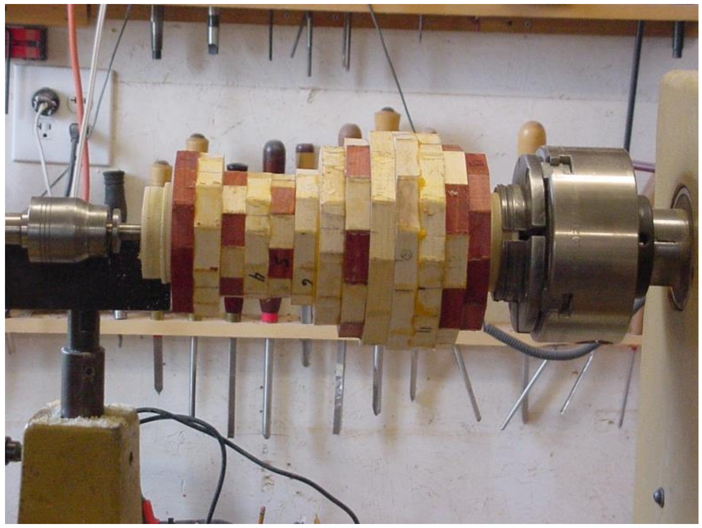


Figure 19. Both halves of a vessel on the lathe ready for turning. This goblet has an open top and thus can be turned whole. If it were a closed vessel or one with a small top hole, it would be turned in pieces and then assembled.

Turning wood with trapezoids for segments presents some advantages, but there are some drawbacks. A product of the basic design is that most of the wood on the surface of a segmented turning is side grain since the end grain is hidden in the segment joints. Another feature of the design is that as the segments present themselves to the tool, the facets of the trapezoids can be severed leaving splinters to tear away from the work piece leaving damaged surfaces and presenting a danger to the operator. Care must be taken until the ring is round to avoid this happening. A light touch rather than aggressive cuts will minimize or eliminate this danger.

The fact that the surface you're turning is side grain presents opportunities not found in other turning practices. For example, the use of scrapers is practical in many applications where it would be inadvisable otherwise.

Your sequence of cuts depends on the circumstances. Under some conditions, it is best to remove the facets (make the rings round inside and out) before attempting shaping operations. At other times you can shape as you go.

If you are turning the vessel as one piece, shape the outside and inside as you would ordinarily. If you are turning the vessel in sections, after shaping the outside of the vessel, remove the wood from the inside. Turn the inside down to what will be the final level and sand to completion if required. Then reassemble the vessel and turn the outside to completion.

TURNING SEQUENCE PLANNING:

It's best to have a plan to follow when you are turning something that requires changes in orientation and fixing methods.

Typically, you want the vessel to end up on the lathe in a certain way; either with the base to the headstock or the top to the headstock. This is determined, of course, by the last turning operation in your plan. For this reason, it's helpful to think of the sequence in reverse; i.e. knowing how you want the piece oriented in the final step, how do you need it to be oriented in the immediately preceding step, and so on. This is important for economy of operations, but has the practical benefit of not having to realign the piece and possibly true it up more than necessary.

With this in mind, it's helpful to have a sketch showing the sequence. First sketch the final orientation. Now what was the operation just completed before that? It may be helpful to take a specific example and some personal habits together to come up with a sequence diagram. Follow Figure 6.

First let's define a certain kind of vessel. In this case we'll take a closed form vase. Typically in segmented designs, this sort of vase is turned in two pieces and then put together before final turning. The final step is usually to take off one of the fixing means; either the top or base. Since the opening is usually at the top, we'll need to remove that fixing means before the base fixing; i.e. turn off the top before the bottom. So the last orientation of the piece on the lathe is with the top to the headstock. Since in this step the top fixing would have been removed in a previous step we will require some temporary fixing means (a turned jam chuck or a mandrel) for the top of the vessel.

Probably the immediately preceding step would have been to turn a jam chuck or mandrel to use in the final step. We've already stated that the top has been removed from the vessel to get us to the final fixing, so the step before that then required the base to be at the headstock so we could turn off the top fixing and shaped and dressed the top of the vessel.

Immediately before dressing the top, we would have shaped and possibly sanded the whole outside of the vessel. That could have been done with either top or base at the headstock end, but since we need the vessel orientation in the next step to be base to headstock, that's how we'll fix it.

Before turning the outside to shape, we needed to do the final gluing of the two halves. Again this could have been done with either orientation, but since we need the base to headstock orientation in the following step, we'll again do this step with that orientation.

The last steps before gluing the halves together for final outside turning are to turn the insides of both halves down to near final thickness. We'll need to mount each of these for turning. The top half by it's fixing means at its top and the bottom half at the bottom fixing means. Again in the following step we'll need to have the base to the headstock, so that's the way we want to leave it. So we'll turn the inside of the top with its fixing to the headstock, remove it, and fix the base with its fixing to the headstock.

Now we know we've changed the fixing from a top orientation to a base orientation in this sequence of steps. So at this point in our reverse sequence, the top is at the headstock end.

Immediately before turning the insides, we had turned the outside shapes to very near final form; leaving only a minor final matching operation after glue up of the two halves. This was done by using double sided tape to hold the halves together. Well since we need the top to headstock orientation for final turning the top's inside, we'll do this step with top to headstock too.

Now is where personal habits come into play. You could have just put the two halves together at this point, but turning off the segment facets puts a bit of stress on the fixing means as it bumps along, I like to do this as early as possible, so that I avoid stressing the fixings during the more critical stages to follow. So I may turn off the facets before putting the halves together; however, this isn't a hard and fast rule. Sometimes it makes more sense to put them together as you start and turn off outside facets then. It's up to you.

How I orient the vessel halves depends on the following steps. Since I want the top to headstock in that operation, I'll do the base first with it's fixing to the headstock; followed by the top half with its fixing to the headstock.

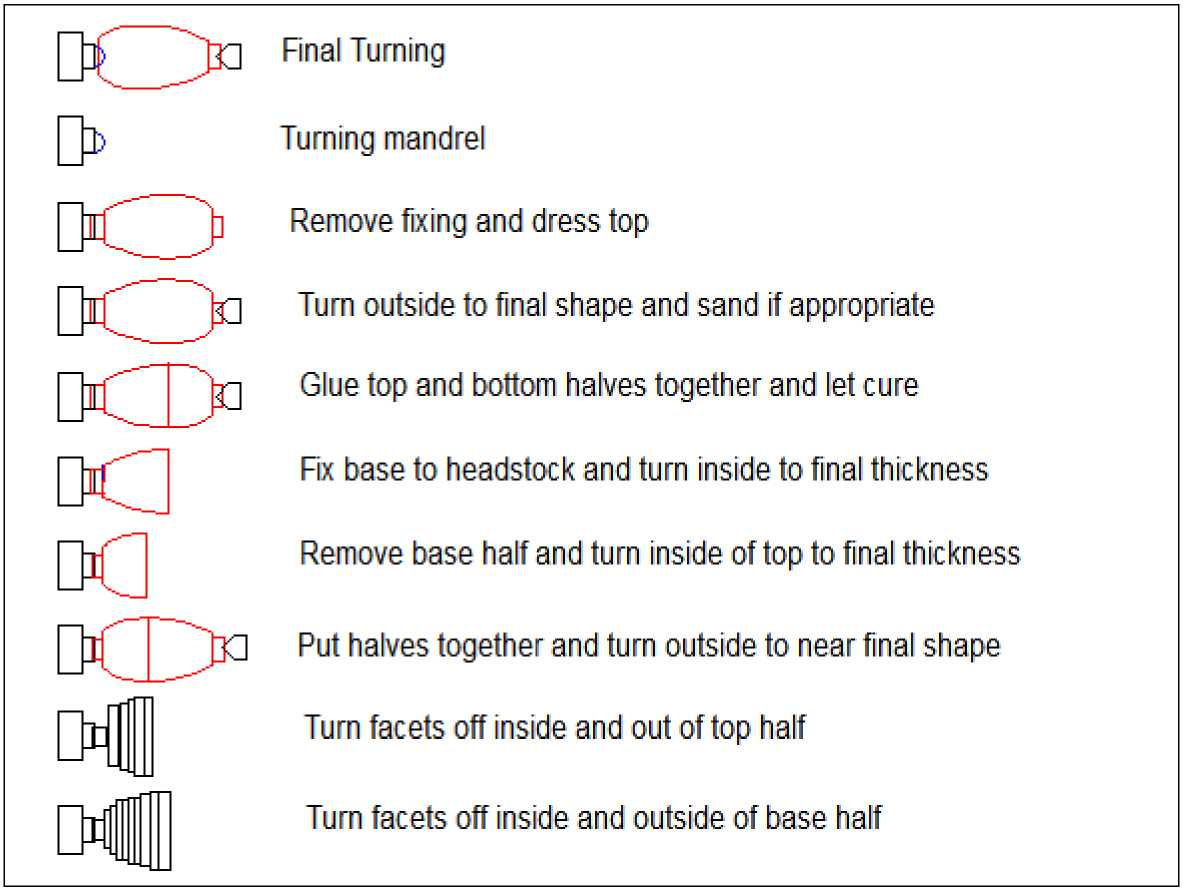


Figure 6. Turning sequence for closed vessel (Example)

So here's a typical sequence of operations:

1. Put the base half on the headstock end and turn off the facets.
2. Put the top half on the headstock end and turn off its facets making sure that the diameters at the mating joint are close.
3. Leaving the top fixing in place, and using double sided tape, align the halves between centers. The tape will help keep the vessel in place, but the fact that the vessel is now between centers is the main fixing means. Turn the vessel to near final shape.
4. Leaving the top fixing in place, carefully remove the bottom half and turn the inside of the top half to final thickness. Remember that there is still some turning to do on the outside, so don't take off too much.
5. Remove the top half from the lathe and install the base half with its fixing to the headstock. Turn the inside to final thickness. Make sure that the thickness of the mating surface is the same or nearly the same as that of the top half. This will minimize inside turning after the vessel is assembled.
6. Leave the bottom fixing in place, glue the top half and bottom half together. Bring up the tailstock to bear on the top end and tighten to get the appropriate squeeze out of glue at the joint. Let it cure for several hours.

7. Leave the bottom fixing in place, turn the vessel to final shape and sand if appropriate.
8. Leave the bottom fixing in place, turn off the top fixing, and dress the top.
9. Now turn a mandrel or jam chuck as necessary to provide a fixing means for the finished top.
10. Reverse the vessel on the lathe with the top fixed to the headstock end with whatever means you've chosen and turn off the bottom fixing and dress the bottom.

In all, we've changed the orientation of the vessel three times. We started with the base to the headstock; changed to top to headstock; changed again to base to headstock; and finished up with top to headstock. In none of the operations did we switch ends in a critical alignment step.

Not every vessel will follow the above sequence. You'll need to think through the process. If you follow the reverse sequence process, you should be able to devise a plan that minimizes changeovers.

FINISHING

Finishing is a matter of personal choice. Finishing materials that are used for other turnings or furniture can be used in their usual way. Just as in other forms of turnings, it's advisable to apply finish to the inside of closed vessels to seal them to the same degree as the outside. This can more easily be accomplished with closed forms prior to final assembly. The danger in doing this is that it will be easy to get finish material on the glue joints thus weakening them. Take steps to avoid this.

FINAL WORD

I've presented one type of segmented wood turning with emphasis on one procedure. The purpose of this article is to help someone with woodworking skills but little knowledge of segmented technique to be able to make his/her first vessel. I expect that once into it, one will develop his/her own procedure to better suit personal tools and practices. That's progress. I hope they will share their experience with the rest of us.

APPENDIX I

COMPUTER SPREADSHEET FOR COMPUTING SEGMENT PARAMETERS.

Use of a computer spreadsheet to calculate the parameters for segmented turnings is a labor saving device and promotes accuracy in creating cut lists and worksheets. There are several such programs available but I use the Open Office spreadsheet which is very close to the MicroSoft Excel program in use but is free for the download at http://download.openoffice.org/1.1.4/index.html .

The table below is printed from the above program. The first 6 columns are inputs and those following are calculated by the program.

The user plugs in the parameters as follows:

R, the radius of the ring is measured from the center line to the outside of the rectangle drawn to include the inside and outside walls of the vessel plus a contingency distance to allow for inaccuracy in turning.

W, the width of the segment is measured from the inside of the rectangle to the outside.

T, the thickness of the segment is the vertical height of the rectangle.

N, the number of segments in a given ring is determined by the designer.

FL, the filler is a sliver of wood between the segments put there to highlight the joint for decorative purposes.

Safety factor, the amount of board you want left after cutting N segments. This is up to you to decide depending on the circumstances. Small segments are usually done with 4 to 6 inches of safety factor. Larger segments may require more.

BW, the blade width is also required. Measure the width of your blade. Standard blades are usually 0.125 inches wide; i.e. they leave a 1/8" kerf.

The computer computes the rest of the parameters.

Ca, the cut angle is the angle cut on both ends of a segment to make the trapezoid that forms a ring. It's computed:

$$Ca = 180 / N$$

SL, the segment length is the length of the long side of the segment trapezoid. It's computed:

$$SL = (2 \times R \times \text{Tan } Ca) - FL$$

BL, the length of the board from which the segments are cut. It's computed:

$$BL = \text{Safety Factor} + N \times [(SL + \text{Blade Width}) - W \times \text{Tan } Ca]$$

	Goblet							
#	R	W	T	N	FL	Ca	SL	BL
1	2.250	2.250	0.500	12	0.000	15	1.206	13
2	2.250	2.250	0.500	12	0.000	15	1.206	13
3	1.250	1.250	0.500	12	0.000	15	0.670	10
4	0.875	0.875	0.500	12	0.000	15	0.469	8
5	1.250	1.250	0.500	12	0.000	15	0.670	10
6	1.875	1.875	0.500	12	0.000	15	1.005	12
7	2.500	2.000	0.500	12	0.000	15	1.340	15
8	2.750	1.500	0.500	12	0.000	15	1.474	18
9	3.000	1.250	0.500	12	0.000	15	1.608	21
10	3.000	1.000	0.500	12	0.000	15	1.608	22
11	3.000	1.375	0.500	12	0.000	15	1.608	20
12	2.750	1.500	0.500	12	0.000	15	1.474	18
13	2.500	1.250	0.250	12	0.000	15	1.340	18
SAFETY FACTOR			4	Inches				
	BLADE WIDTH		0.125	Inches				

Appendix II.

Differing means of calculating Segment Length

Segment length may be approximated by just dividing the circumference of the ring by the number of segments desired in the ring. This approximation becomes very close to the desired segment length (one that will result in a ring of the desired diameter) as the number of segments increases. At the low end (e.g. 8 segments), the error in the resulting diameter can be significant. Consider the following chart for a ring of diameter 10.

Diameter of Ring ==		10					
			Length of	***Segment***			
Number of	Angle		Formula (1)	Division (2)	R	R'	Err(R-R')
Segments	(deg)						
8	45.00		4.142	3.927	5.000	4.619	0.381
12	30.00		2.679	2.618	5.000	4.830	0.170
16	22.50		1.989	1.963	5.000	4.904	0.096
24	15.00		1.317	1.309	5.000	4.957	0.043
32	11.25		0.985	0.982	5.000	4.976	0.024
36	10.00		0.875	0.873	5.000	4.981	0.019
40	9.00		0.787	0.785	5.000	4.985	0.015
48	7.50		0.655	0.654	5.000	4.989	0.011

Method (1) for calculating the segment length (SL) is:

SL = 2*R*Tan(Ca)

Where R is desired radius and Ca is the Cut Angle.

Radius (R) in this calculation is a defined value; i.e. it was derived from the process of measuring the distance from the centerline of the planned vessel to the end of the segment that was drawn in to encompass the sidewall of the vessel.

Method (2) calculates the segment length by dividing the circumference of the ring by the number of segments, so:

SL = 2*Pi*R/N

Where N is the number of segments and R is again the measured value from the design process. But this time R is the hypotenuse of a triangle scribing the center of the ring to the center and one end of the segment.

Figure B-1 shows the segment length when calculated using the tangent formula. The rationale for this method is that when the radius R was derived from the original design layout, it was measured to the center of the outside of the segment. Thus, the outside edge of the segment is tangent to the circle which R inscribes and the radius goes to the center of the segment.

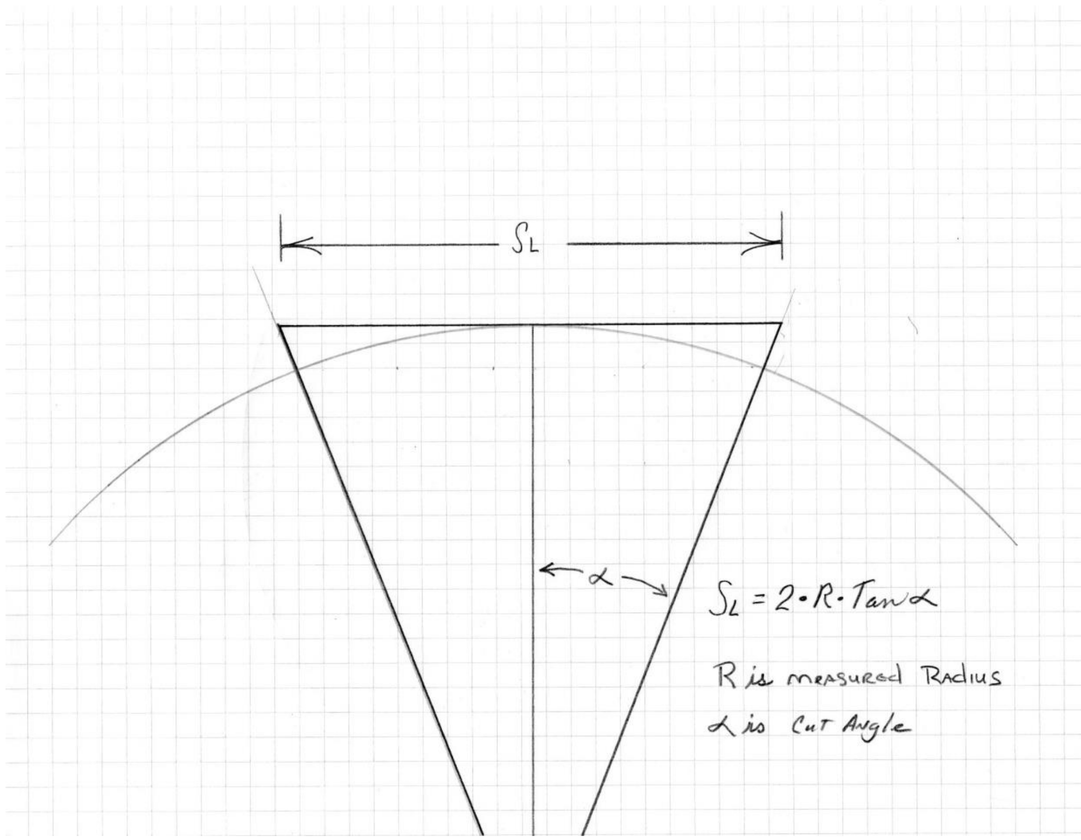


Figure B-1. The segment length when using the tangent formula.

On the other hand when the segment length is determined by dividing the circumference by the number of segments, the segment length is shown in Figure B-2. As shown in B-2, the segment length is inside the circle. Now the circle's radius goes to the end of the segments.

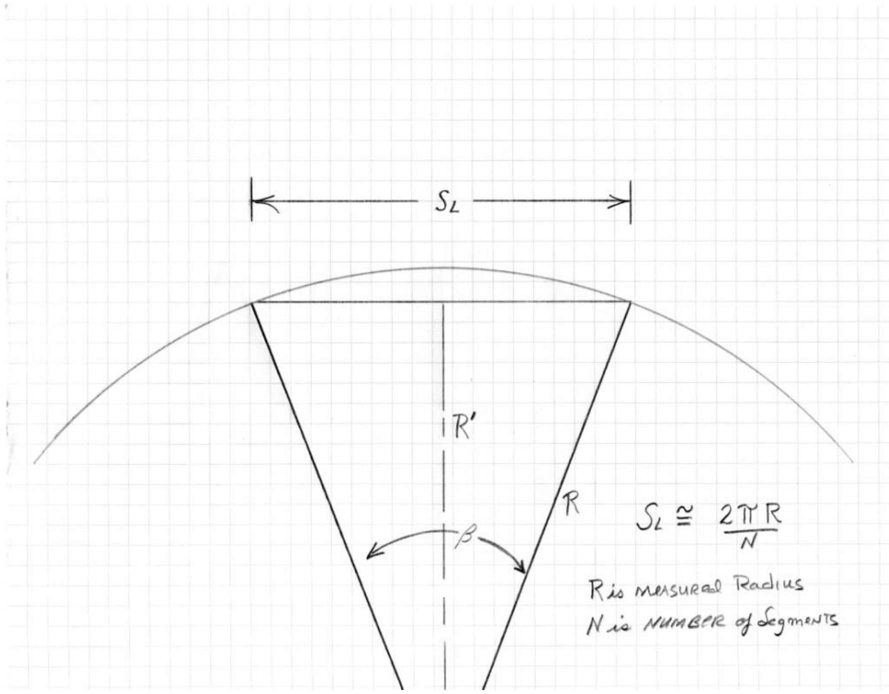

S_L
R'
R
β
$S_L \cong \frac{2\pi R}{N}$
R is measured Radius
N is number of Segments

Figure B-2. Segment length when using the circumference formula.

This phenomenon results in the circumference method producing a smaller radius than the design dictates. The radius of the new circle is:

R` = R Cos(Beta/2)

Where Beta is the encompassing angle for the new segment and R is the desired radius.

Figure B-3 combines the two methods to show the difference in results. The error is shown in Table B-1.

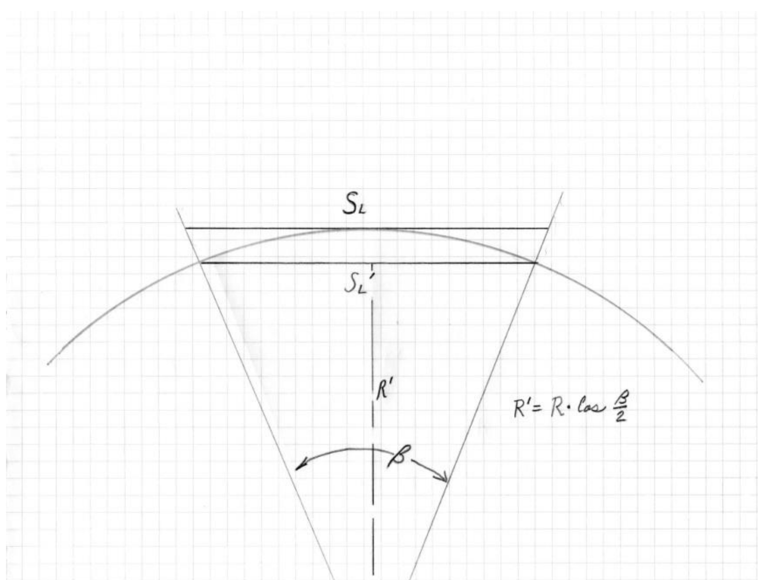


Figure B-3. Comparison of the two methods.

As the number of segments gets larger, the length of each segment gets smaller, R` => R, and the circles converge; thus the difference in results between the methods begins to be negligible.