**Making Blanks for Segmented Turnings**
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A segmented turning blank is made up of pieces of wood glued together, in contrast to a blank made of a single piece of wood. Segmented blanks can be made by four basic methods, or combinations of methods, as described further below. Most segmented blanks require exacting design and joinery skills. Perhaps the best introduction to this topic is the series by Jim Rogers. Tage Frid offers a brief discussion of this topic. Woodturning Online has a section devoted to segmented turning, which offers many useful discussions and some beginner projects.[a]

**Figure 1**. Two Segmented Bowls. The first bowl, on the right, is radiata pine and cedar. The second bowl is maple, walnut and mahogany..

The main purpose of making segmented turning blanks is to create interesting patterns of grain and color beyond the possibilities of solid wood. A great variety of patterns is possible, depending on the composition of the "boards" used to make the segments, especially with concentric rings or staves. For example, the boards can be made up of strips of contrasting woods to form checkerboard effects. A wide variety of other laminations can be used. The position of the rings can be rotated slightly at each layer to create a spiral effect, and so on. (See Figs 1 and 2) Segmented blanks also use wood more economically than do solid blanks, because less wood is turned away and discarded.

The simplest form of segmented blank is formed by gluing large pieces of wood together, vertically or horizontally, to form a solid blank. Interesting patterns can result after turning on a lathe. These are not usually called segmented turnings, however. If contrasting woods were used, they sometimes may be called inlaid turnings (although this is a misnomer). They are relatively simple to make – each piece is jointed well and glued to another piece.

**Figure 2**. Bowls from a Board and Stave Constructions (Bernstein's Bowls) Photo from Wikipedia

When people speak of segmented turning, they usually mean a turning made from glued-together rings. Each ring is made up of narrow (e.g., 1¼" wide) boards in which the end grain has been mitered at the appropriate angle and glued together end to end to form a ring. Then the rings are glued together in layers to form a turning blank. The long grain shows all around the inner and outer surfaces of the turning. This can make a very attractive surface

[a]http://www.woodturningonline.com/Turning/segmented_turning/index.html

with some woods that have showy grain like curly or fiddleback maple. It allows interesting patterns and inlay effects using wood of contrasting colors.

This requires excellent joinery technique. The wider the segments (inside to outside) and the higher the number of segments, the more accuracy is needed. My first segmented turnings were octagons, which was a good choice. As you gain experience, you can work your way up to finer work, e.g., 12 or 24 sides.

Blanks made of half-rings or staves are variations on this idea. The half-ring type is sometimes called “bowl from a board”. Semicircular rings are cut from a board and glued together to form a conical blank.

In a stave-constructed blank, compound-angle segments (staves) are cut from a board and glued along the long edges. (A stave is often longer than it is wide, and is meant to be sloped or vertical in the finished turning, as in a barrel.) Stave-constructed blanks can be quite long, as in a lamp standard, or short, as in a bowl. Typically, a long stave-constructed blank has parallel sides. A stave-constructed bowl blank may use many-sided polygons and compound angles.

A segmented turning can combine ring construction, stave construction, and solid, non-segmented wood in a single piece. The design of a durable segmented turning, however, has to take wood movement into account. Wood expands and contracts according to its moisture content (ambient humidity). The change in dimension may differ substantially between radial and tangential grain (i.e., plain-sawn and flat-sawn faces). Cross-grain constructions, especially of thicker rings or solid pieces, may fall apart if the piece is exposed to large changes in humidity, e.g., summer humidity vs winter dryness indoors.

### *Choosing Wood for Segmented Blanks*

The ability to use wood species of contrasting colors is an important advantage of segmented turning. Furthermore, when small quantities are required, we can consider rare and exotic species that otherwise might be too expensive. Malcom Tibbets classifies the wood species that he has used in his career into three groups, as follows.

Minor species (“limited-use”): alder, ash, aspen, birch, lacewood, madrone, mahogany, soft maple, both red and white oak, padauk, poplar, redwood, teak, and zebrawood. Acceptable (“OK”) species include spalted beech, spalted birch, cherry, ironwood, limba, Osage-orange, walnut, and wenge. Tibbetts’ personal favorites include apple, blackwood, bloodwood, bocote, bubinga, carob, ebony (Gabon or Macassar), holly, jarrah, figured maple, hard maple, spalted maple, mesquite, mountain mahogany, myrtlewood, persimmon, pink ivory, purpleheart, rosewoods (pau ferro, East Indian, Honduras, Brazilian, cocobolo, flamewood, tulipwood), yellowheart, and ziricote. He prefers these species because of color and figure. Except for the rosewoods they all glue well and most of them are tight-grained, which means they will polish nicely.

Some of the woods listed above are irritants or sensitizers. These include blackwood, cocbolo, ebony, myrtle, olivewood, paduak, rosewoods, teak, and wenge. Surfacing segmented rings, especially, can produce lots of dust, so proper dust control, including a facemask, may be a necessary precaution.

*Moisture Content*. Simply put, wood used to make segmented blanks should be dry, certainly not green. About 10% moisture content (MC) or lower should be OK if all the wood in the piece is at about the same MC. Because many different woods may be mixed in a segmented turning, it is important to ensure that you do not mix wood of very different MC, especially green and dry woods. Wood whose MC is in equilibrium with the ambient air should be OK even if the MC is a bit higher, except that ambient humidity can change with the seasons. The orientation of different layers also may present stability issues if the wood dries or expands to different extents.

If the wood is not as dry as you would like, consider that over the small distances involved, dimensional changes due to moisture content might only amount to 1/32" or less. Having noted that, note also that radial (across the rings) dimensional change with moisture content is much greater than change tangential to the rings. Therefore, from this perspective it makes sense to cut flat segments so that the radial face of a segment is toward the inside and outside, leaving the tangential faces for the tops and bottoms of the rings. Appearance matters too, of course. Sometimes the radial (quartersawn) face is prettier, sometimes not.

### *Designing a Segmented Blank*

Making a segmented blank is straightforward, but getting rings of the right appearance, diameter and width can be complicated. A sketch, at least, is necessary. Basic issues, before you put pencil to paper, are the efficient use of rare or expensive woods and the general efficiency of stock use. It is more efficient to locate features where the diameter of the form is more nearly constant (cylindrical). In contrast, a wide ring is needed where the diameter of the form changes sharply. Most of that ring will be turned away, however, so this may not be an efficient use of expensive wood. Secondly, it is wasteful, for example, to specify a ¾" thick ring when your stock is 1" thick. even with a thin kerf saw blade, you may never find a worthy use for the 1/32" - 1/16" piece you trimmed off. Why not try to use it in your design as a 1" thick piece? In the same vein, it may seem to make sense to buy short pieces of exotic wood for making flat segmented rings, but usually the end pieces are useless.

1. Draw the object in vertical cross-section, showing the profile and wall thickness. Establish the vertical centerline.

2. Draw rectangles, which represent the segments in cross-section, along the profile. For example, if the bottom ring will be ¾" thick after it has been assembled and flattened, draw a rectangle ¾" high on the profile. That will show you how wide the segment has to be to enclose the curved profile over that height. Depending on how many sides your polygons will have, allow extra (at least ⅜") on each side for turning the rings into circles and smoothing them. For segments or staves with compound angles, the procedure is essentially the same, except that you have to draw the parallelograms representing the staves at the correct vertical angle. This will help you decide how thick the stock needs to be to get the curvature you want. Each ring must cover its part of the profile, including the thickness of the wall.

3. Consider the species and colors of the segments, including feature effects

4. Calculate the segment length and amount of stock needed to make each ring. When designing a bowl, recognize that a circle inscribed within a polygon must have a smaller diameter that the diagonal of the polygon. For example, an octagon with diagonal 8" can be turned into a circle with a diameter no larger than about 7 ⅜". Nonetheless, when mounted on the lathe, the diagonal of the polygon will be the limiting size of the blank, unless the corners are first cut off. My lathe can swing 9", so the largest polygon I can turn has a 9" diagonal, which corresponds to a circle with about an 8½" diameter.

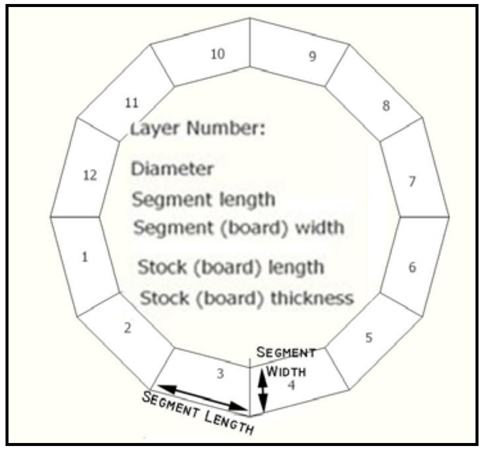


**Figure 3**. Segmented Ring Layout Diagram. A page containing 6-8 of these templates will assist in placing feature segments correctly

Software is available for the PC that assists in the design process. Depending on what aspect of a segmented turning I wanted to draw, I have used 3D Design Pro, Woodturner Pro, and Google Sketchup. Each has its uses but also significant limitations. 3 D Design Pro merely draws a 3-D rotated view of a profile that you draw. Woodturner Pro is a complementary program to 3D Design Pro. It is useful for deciding on the number of rings, number of segments per ring, and segment widths; calculating angles, and producing a cut list for each ring. For designing rings with many features, where placement of contrasting colors is important, I make a page of blank segmented rings which I can then number and use to show the placement of the various colored pieces.

***Making Segmented Blanks***

The three fundamental issues in segmented turning are how to make segments of precise angle and length, how to flatten rings and build them into blanks, and how to mount a hollow blank on the lathe.

*Cutting Segments and Making Rings*

The basic unit of a segmented turning is a properly made segment. For example, a 3" tall octagonal blank might have 32 segments organized into four rings. This requires skilled joinery, because the segments have to fit together perfectly to form rings and the rings must be flat and well joined. Otherwise, the finished turning will be unattractive at best and may fall apart.

Each flat segment should be cut from long grain, i.e., with end grain at the ends of the segments. (A mixture of long grain and short grain segments may not endure wood movement from changes in humidity.)

Each segment in a ring must be of equal length, and each angle must be precisely correct. For example, the segments for making octagonal rings must be mitered at *precisely* 22.5° (I suppose, within 0.05 degree), or the ring will not “close” without gaps. I doubt that most miter guides, even expensive post-market ones, would be precise enough. I use a miter sled on a table saw to cut segments. (See *Making a Sled for Cutting Segments*) Others prefer a chop saw or even a band saw. Very thick segments, e.g., 2" thick or more, can be treated like staves, and ripped with a tilted blade.

The stock from which segments will be cut should be surfaced to consistent thickness, in order to reduce the effort required later to flatten the rings.

Most bowl profiles require rings of different diameters. The length of the segment is proportional to the diameter of the ring, given the number of segments. The constant of proportionality is the tangent of the bevel angle. For example, if the ring is an octagon, the bevel angle is 22.5°. The tangent of 22.5° is 0.414, and the relationship is

segment length = tan (a) * diameter
segment length = 0.414 * diameter

So, an octagonal ring with an 8" diagonal requires a segment that is 3 5/16" long. Tables are available with segment sizes pre-calculated (See Table 1).

Table 1. Number of Sides, Miter Angle, Tangent, and Segment Length by Ring Diameter

| Sides (*s*) | Miter An-gle (a) * | Tan-gent | Segment Length L (in.) by ***Ring Diameter*** (in) to the nearest 1/16" | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | ***5*** | ***5.5*** | ***6*** | ***6.5*** | ***7*** | ***7.5*** | ***8*** | ***8.5*** |
| 6 | 30.0 | 0.577 | 2 ⅞ | 3 3/16 | 3 7/16 | 3 ¾ | 4 1/16 | 4 5/16 | 4 ⅝ | 4 15/16 |
| 8 | 22.5 | 0.414 | 2 1/16 | 2 ¼ | 2 ½ | 2 11/16 | 2 ⅞ | 3 ⅛ | 3 5/16 | 3 ½ |
| 10 | 18.0 | 0.325 | 1 ⅝ | 1 13/16 | 1 15/16 | 2 ⅛ | 2 ¼ | 2 7/16 | 2 ⅝ | 2 ¾ |
| 12 | 15.0 | 0.268 | 1 5/16 | 1 ½ | 1 ⅝ | 1 ¾ | 1 ⅞ | 2 | 2 ⅛ | 2 ¼ |
| 16 | 11.25 | 0.199 | 1 | 1 ⅛ | 1 3/16 | 1 5/16 | 1 ⅜ | 1 ½ | 1 9/16 | 1 11/16 |
| 24 | 7.50 | 0.132 | 11/16 | ¾ | 13/16 | ⅞ | 15/16 | 1 | 1 1/16 | 1 ⅛ |
| * equals 180°/***s*** Measured relative to the saw blade, i.e., as a miter gauge would read. | | | | | | | | | | |

Length of stock needed equals the perimeter of the ring (the number of segments times the length of a side) plus an allowance for saw kerf, (roughly 1.5" for a 12-sided ring). If the stock can be flipped over between cuts, however, the length of stock needed is less than that. Every other segment would require [L- 2*h*tan(a)] inches, where h is the width of the segment. For example, when making a 7½" diameter, 1" wide, 12-sided ring, each odd numbered segment (1,3, . . .,11) would be 2" long (plus a saw kerf). That's about 6 x 2⅛ = 12¾". Each even numbered segment would require only [2 - (2 x 1" x .268)] = 1½", (6 x 1½" = 9"). So, the 7½" 12-sided ring would require about 21¾" of stock, not 26½".

## Cutting Segments

Once you have made and adjusted the sled, adjusted the miter saw, etc, cutting segments is straightforward. (See *Making a Sled for Cutting Segments*) If the stock is uniform on both sides, it can be flipped between cuts. This minimizes the number of necessary cuts and the amount of wood wasted.

If a board has a markedly different appearance on one edge than the other, you may choose to cut the segments individually, so that one edge is always toward the outside. Also, very hard-to-plane wood should have the grain direction (rising or falling) the same for each segment for easier flattening (see below). Cutting individual segments, however, is somewhat inconvenient, because you can't flip the stock over. Sometimes, it is well to keep the segments in the order cut, so that color or grain changes will be gradual.

Until you are certain that the fence angle is dead on, dry assemble each ring, put it in a hose (band) clamp, and inspect for gaps. If the segments fit together with tiny gaps, the best solution is to adjust the fence on the sled. However, as a work-around, the ring can be glued up as two semicircles separated by two dowels or, preferably, shims set on the side where the gap is. (Be careful not to apply glue to the edges that will not be glued together at this point.) Locate the shims or dowels so that all the gaps close under clamp pressure. Then the two semicircles can be sanded until they mate perfectly before being glued together. (See Figure 4 and Rogers, Part 1.)

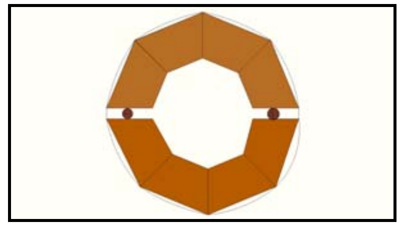

**Figure 4**. Split Ring. Actually, a rectangular spacer may work better than a dowel, which tends to dent the wood under clamp pressure.

Sanding a half-ring until the edges are 180° is a normal part of assembly as long as a small amount of wood (say, 1/32" or less) has to be removed. If very much more than that is sanded away, the ring will be elliptical. At least, this will make the ring a bit more difficult to center. It will require some caution when you begin to turn it round, and may distort some designs that depend on an equal amount of wood being removed all around the ring, e.g., a polka dot design made from a lamination. (Of course, the latter can also enter into design, if you want a contrasting layer to appear only on opposite sides of the turning.)

Tibbetts, the authority on segmented blanks, recommends sanding each glue surface. I prefer to use a blade that gives me a smooth cut. You should inspect each cut to make sure that it is free of scratches, crumbs, and broken fibers that might get in the glue joint, etc. A light even rub on a piece of sandpaper resting on a dead flat surface might be helpful. I have not found that disk sanding has been helpful. Although I have made "perfect" joints without sanding, I have not been able to make a jig for a disk sander that could give me the precise angles needed.

After each segment is cut and the fit is ascertained, spread each bevel with PVA adhesive (Titebond II or III), lay the segments in a ring on a dead flat platen with a non-stick surface, and clamp them with a hose clamp. I prefer a platen of melamine-coated MDF. I apply and buff off a coat of paste wax to keep squeeze-out from gluing the ring to the surface. You can also lay down a piece of waxed paper.

Apply glue evenly to both mating bevels and rub the surfaces together to help spread the glue and (possibly) improve penetration. Push each segment down against the platen so that one side of the ring (at least) will be flat, or nearly so. When you tighten the band clamp you should see squeeze-out at every joint.

## Flattening Rings

When the adhesive has cured (overnight) the rings must be flattened. That is, the segments must be trued up – all in the same plane *and* perfectly square to the axis of rotation. This step is important because it determines both the strength and the appearance of the glue joints between rings in the finished bowl.

Flattening rings is a bit tedious and different people recommend a variety of methods. I normally use different methods for each side of the ring. First, I flatten one side of the ring using either a sanding disk or a bench plane. If I can flatten the whole diameter of the ring with my sanding disk, I use that. The ring must rest on the sanding table mounted on my lathe. so the diameter of the ring has to be equal to or less than the radius of the disk. For rings with larger diameters, I flatten the rings with a bench plane. I use a modified bench hook to hold the ring secure while planing and to reduce the pressure on the glue joints (Figure 5). Work your way around the ring, planing with the grain (tangentially) using a slicing action rather than repetitive forward and back planing motions. Use a very sharp plane iron,, and be careful that the toe of the plane does not strike the corner of an adjacent segment and splinter a piece off. (Even if this were to happen, however, the a chip on the inside of the ring would be turned away.)

**Figure 5**. Octagonal Ring and Bench Hook-Plane Stop. The triangles are just screwed to the bench hook. The right-hand one is easily adjustable for various sized rings.

At first, you can use a block plane to roughly level off any proud segments, but final flattening should be done with a plane that is long enough that the toe and heel span the ring while you are cutting, e.g., a jointer plane.

No light should be visible between a straightedge and the ring at any position. When the ring is nearly flat (within a few thousands of an inch) you can finish flattening by rubbing the ring on a piece of 80 or 90 grit sandpaper laying on a flat surface, e.g., ¾" MDF. I have used a thickness planer (the blades were very sharp) but this is dangerous. If the ring is not flat, the planer rollers may break it apart. Also, since the grain runs in many directions, the planer may cause severe chip-out. If you try this, use a carrier board, hem in the ring well with waste blocks, and take very light (1/64") cuts.

When one surface is perfectly flat, I normally glue it on the blank, and flatten the other side on the lathe. This is the fastest way to flatten a ring, but it takes some care. The surface of the ring must not only be trued (i.e., flat) it must be perpendicular to the axis of rotation. For example, if the ring is hollowed out, i.e., thicker toward the edges, the glue joint may look OK when the blank is glued up but then the gap will show as the profile is turned. If I have a lot of wood to remove, i.e., if the segments were not nearly the same thickness, I start with a gouge rolled over on its side, using a slicing cut. Then I move to a small square-end scraper, and then to a scraper at least as wide as the segment. I finally use a sanding block long enough to span the diameter of the ring.

Others recommend a drum sander or belt sander. I feel that a hand-held belt sander would be much too difficult to control. Some use a so-called safety planer on a drill press. If the ring is thick enough, I may mount it on Cole jaws (fingers screwed into flat plates mounted on a four-jaw chuck). Then I dismount the ring and check it for flatness using a straightedge. When one side is flat I turn the ring around and repeat the process.

### *Making and Mounting the Blank*

Obviously, the blank must have a closed bottom to become a bowl or vase, and may need a top as well. The two issues here are (a) to find a way to mount the rings (or the assembled hollow turning blank) on the lathe and (b) to glue the rings concentrically, almost perfectly so for a deep bowl or vase.

One method for mounting a segmented blank is to cut out a solid bottom and mount it between centers. Turn the bottom to size and turn a tenon on one side that will fit a chuck. Or, you can use a glue block attached to a faceplate. The glue block can be fairly long, to provide working space between the headstock and the turning. Glue the solid bottom to the glue block and turn the bottom, at least into rough shape. After the bowl is turned, you can cut it off of the glue block, reverse the mount using Cole jaws, and clean up the bottom.

The method described in the preceding section, mounting one ring at a time on the lathe as you flatten each ring, is recommended by Rodgers and other experts in segment turning. One advantage of this approach is that each ring can be centered exactly on the lathe because it can be spun slowly *by hand* next to the tool rest. Any off-centeredness will be obvious, and can be corrected before the glue tacks up.

The disadvantage opf this method is that it takes much longer than gluing the rings up all at once, because the adhesive should be allowed to cure at least an hour before turning each layer. Also, although the surface of each ring will be trued up easily enough on the lathe, it is too easy to turn the ring out of square with respect to the axis of rotation. You need to check it frequently with a straightedge laid across the rim, and this is best done off the lathe so that you can hold the ring in front of a bright light. Finally, you can get much more clamp pressure using a gluing jig than you can (or should) using the tailstock.

Another method is to glue up many rings at one time. This requires that both sides of each ring be flattened off the lathe, but all of the rings can cure overnight under pressure from clamps or a glue press. By careful measuring and letting the Titebond II “grab” before applying clamp pressure, I can get the rings fairly concentric, and the blank well balanced. As a compromise, of course, you can glue up part of the blank. For example, if you leave it wide at the top, the inside will be easier to rough out. Rogers describes making a vessel in two halves, building up the top half separately from the bottom half. That would be a way to make a closed vessel that would be impossible to hollow out if made in one piece, or even a bowl with a partially closed top.

You can use the tailstock to press a flat plywood disk against the right side of the blank to support it while you roughed out the exterior profile. Then just remove the plywood to turn the inside of the bowl.

Roughing the inside of the polygonal rings into circles is best done with a parting tool, or a gouge rolled over on its side for a shearing cut, coring out the corners, i.e., cutting “down” from the top surface through the ring, just inside the polygon.

Open Segmented Blanks

Open segmented turning is similar to ring construction, but small gaps are left between the segments. Successive rings are offset so the segment overlaps with the ring above and below. This type of segmentation can appear delicate but is generally quite strong.

Bowls and hollow vessels are the most frequent example of segmented turning, but longer forms like lamps can also be made this way.

***Bowl From A Board***

Depending on how the board is formed and how the rings are arranged, very interesting patterns can be obtained in "bowl from a board" (BfB) constructions. The fundamental idea of BfB is to cut solid or semicircular rings out of flat stock and glue them back together into a bowl blank. (Technically, segment and stave constructions also are ways to make a bowl blank from a board, i.e., flat stock, but are not usually called by that term.) This is normally a very efficient use of wood. Flattening rings is much easier than with segmented blanks, but accurately cutting rings on a band saw is considerably more difficult than cutting segments on a table saw.

In my opinion, of the three kinds of construction described here, BfB is the most difficult to execute well. Based on my experience so far, this is mainly because of the difficulty of cutting accurate half-rings with a band saw and the fragility of the blank once it is glued up and ready to be turned. Even a well-made blank is easily shattered by a minor catch. To balance that, however, rings cut from a properly surfaced board require less tedious flattening than do segmented rings. From a design perspective, BfB bowls tend to have straight sides, even more so than stave-constructed bowls. On the other hand, you can produce some very interesting “modern art" designs with BfB that you can’t get with the other methods.

Many methods are available for forming the rings. The most common, probably, is cutting half rings on a band saw. The stock is cut in half lengthwise to create two rectangles, and then semi-circular rings are cut from each of the two boards. Pairs of matching half-rings are jointed and glued together into rings. (Figure 6 shows a cross-section drawing of half of a BfB blank made from a board that was cut into five half rings at an angle of about 60°. The rings were about ¾" thick and then stacked.)

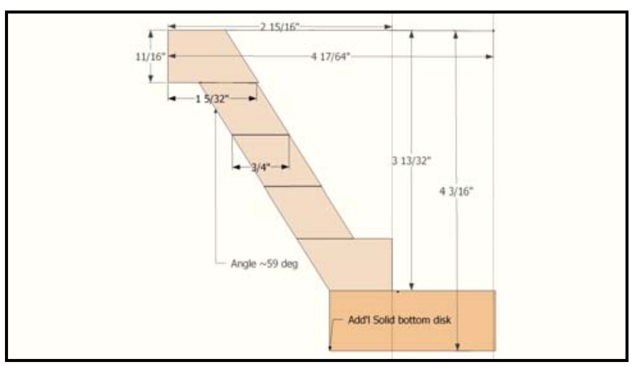


**Figure 6**. Cross Section of Blank (Five half-rings cut from a board and stacked).

Usually, the sides of the rings are cut at an angle, typically 45-60°, so that when each pair is glued together into a ring, the ring will be shaped like a short, truncated cone.

Another method is to cut whole rings on a lathe using a parting tool. This a bit tricky freehand but may be much easier if the stock is not too thick and a fixed tool holder rest is used.

Alternatively, the rings can be cut at

90°. This is easier to cut but a somewhat less efficient use of wood. The rings are cut from *two* different pieces of stock so that the rings overlap. For example, if the top ring is 8" in diameter and 1" wide, and cut from the first board, the next ring would be 7" in diameter and 1" wide, and cut from the second board. This would give a ½" overlap between the rings, and so forth.

Cutting rings on a bandsaw is theoretically straightforward but somewhat challenging in practice. The main difficulty is that the work is difficult to hold in position while the bandsaw table is tilted. Also, the half-rings are cut separately but need to mate perfectly when they are re-joined. Here is the procedure that works well for me:

1. Make a cross-sectional sketch of the blank. The design geometry of BfB blanks is different from those of ring or stave segmented blanks.
a. Decide the approximate dimensions of the bowl. Bowl dimensions are more constrained with BfB construction than with other kinds of blanks because the radius and depth of the blank are related. In a BfB design, the depth is somewhat determined by the number of rings, and the number of rings is somewhat limited by the radius of the blank. For example, if the blank has a maximum radius of 4½" and each ring is ¾" wide, you can get a maximum of 5 rings from the board. So, to make a deeper blank, you can't increase the number of rings beyond that limit.

You can make a BfB blank deeper mainly by using thicker stock, decreasing the width of the rings (so that you get more rings from a given radius) or increasing the angle of the sides. The last two approaches require the walls to be narrower. (Of course, you can always tweak the depth by adding non BfB rings to the top or bottom.)

b. Decide how thick the walls of the blank should be. (Note that because the rings are parallelogram in cross section they are actually wider than their nominal width. For example, cut at a 45° angle, a ¾" wide ring actually is 1½" wide). The nominal width of the ring is the theoretical amount of overlap between rings. The design minimum should probably be about ½", but this is does not leave much room for error in cutting or in centering the rings when you glue them up. Small errors creep in, and they all tend to reduce the maximum wall thickness that can be turned from a blank. I find that ⅝"-¾" would be a safer choice, especially when you are starting out.

The sides of a BfB construction tend to be straight. Thicker walls will allow you to shape the sides somewhat. Also, the sides tend to be more fragile when you are initially roughing them out, compared to other constructions. Making the walls thin may be a false economy.

c. Decide on the thickness of the stock and the cutting angle. For example, one pleasing proportion would be a 5" deep by 8" diameter bowl. If the radius of the largest ring is 4", you can cut 4, ¾" wide rings from the board (neglecting the width of the saw kerf). Allowing for a 1" thick solid disk for the bottom of the blank, each ring must be 1" thick. Once you know that the rings will be 1" thick by ¾" wide, you can calculate the angle by

$$\text{tangent (angle)} = \text{rise/run} = \text{thickness/width} = 1/.75 = 1.333$$
$$\arctan 1.333 = 53^\circ$$

This calculation is more precise than you need. Eventually, you will lay out the angle on the stock itself. The question at this point is whether you prefer this angle, whether your bandsaw will cut this angle, etc.

2. Prepare the boards per your design, e.g., glue up strips of contrasting wood species such as maple and walnut. It's a good idea to put a dark board in the center to help conceal the eventual glue line. Also, keep in mind that the thickness of the rings is very important, and that surfacing the glued-up board may reduce its thickness significantly. (1/16" or so). If you want a 1" thick piece of stock that is flat on both sides, start with 1¼" strips and be careful to push them down against a straight flat board as you make up the board..

3. Surface the glued-up stock board on both sides to obtain smooth glue surfaces and uniform ring thickness for when you stack and glue the rings.

4. Use a compass to draw circles on the stock. The circles will be guidelines for laying out and cutting half rings. The distance between them should equal the nominal width of the ring, e.g., ¾" plus an allowance for saw kerf. They do not have to be evenly spaced. If you widen them near the outside, the bowl will flare somewhat. Make sure that the compass point leaves a center mark on the stock. (See Fig 7)

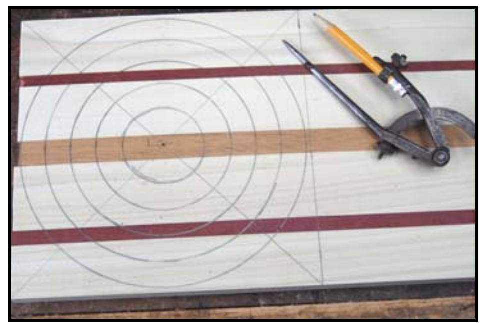

**Figure 7**. Concentric Circles Scribed On a Built-up Board

5. Cut the board in half through the center of the circles. The cut should be smooth and straight. If not, joint the cut edges. An excellent way to do this is by folding the two halves as if they were covers of a book, aligning the edges, and then planing or block sanding the edges until they joint well (perfectly– no light shines between the boards when you hold them up to the light). These edges show more prominently in BfB construction than in flat segmented construction.

6. With the two half-pieces side by side, with their edges aligned and the circles showing on the outside, mark the cutlines for the rings. Accuracy at this step is very important. Because the two half-rings are cut separately, the cut marks have to be as perfectly symmetrical as possible. The idea is that the cut lines match the circle lines and that they are symmetrical around the center point. Otherwise, the rings will not match up correctly when you rejoin the rings. (See Figure 8.)

a. Mark off right angles across the edges corresponding to the circles you drew in step 4.

b. Mark off the cut angles from corner to corner. This should form a chevron pattern if the marked sides of the boards are both facing outward.

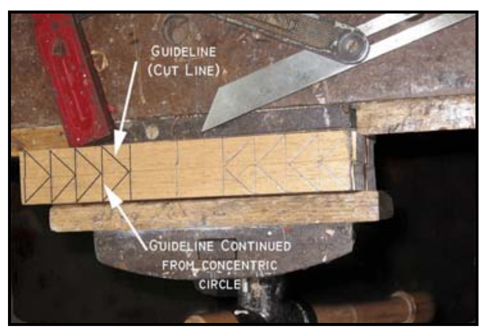


**Figure 8**. Laying Out Half-Ring Cuts. Looking down from above: the two halves are side by side in a vise. The concentric circles have been continued across the edges and cut lines have been drawn between the "corners".

7. Set up the bandsaw and cut the half-rings. The semicircles must be cut accurately, and a jig is very useful. (See Figure 9 and ***Circle Cutting Jig for a Bandsaw***.)

8. Check the fit, and re-assemble the half rings on a dead flat glue-resistant surface, e.g., waxed melamine or plywood covered with waxed paper, using PVA glue. Normally, I just rub them together and let then rest undisturbed until the glue has cured.

If both ends of the ring do not match perfectly, the ring is not ready to be mounted. When you try to turn a ring in which the end of one half-ring protrudes even a little bit, you risk a bad catch that can shatter the blank. It may be best to sand or saw the edges until they are smoother, with no part of the ring jutting out.

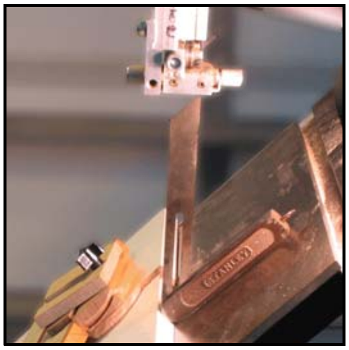

**Figure 9**. Bandsaw Table Tilted to Match Angle on Bevel Gauge. Circle jig is visible at lower left.

9. Mount the rings on the lathe. Follow approximately the same procedure as described above for segmented rings. I sometimes prefer to use a separate solid disk as the bottom of the blank. That disk can be glued to a waste block or held in a four-jaw chuck, etc. The next layer comprises the two semicircular disks that were left after you cut the rings. (If you used the "turntable" attachment described in ***Circle Cutting Jig for a Bandsaw*** they will have semicircular guide holes in them. Flattening the rings is still necessary, but only light sanding on a flat surface should be required if the board was surfaced before the rings were cut.

**Figure 10**. Matching Half-Rings From Bandsaw

Arrange the rings in the correct order and orient them according to your design. Accurate centering is often more critical when mounting BfB rings than when mounting segmented rings.

9. Turn the profile and interior of the bowl. Keep in mind that a BfB blank may be more fragile than blanks of other constructions. For example, it is more subject to splitting if you catch the end of a half-ring. Also, be careful when removing wood – measure more, cut less. It seems very easy to turn through the wall of a BfB blank, because the wall thickness is not necessarily reflected by either the inside or outside surface of the blank, depending on how accurately you cut and centered the rings. Also, the maximum wall thickness may be less than with segmented or stave blanks.

**Figure 11**. Re-assembled Half Rings, ready to be flattened and Mounted.

10. Drill a ⅜" hole in the bottom of the bowl (where the ¼" hole is) and fill it with a dowel. If you added a solid disk for a bottom, and turned away most of the original bottom of the blank, this is not necessary.

### *Stave Construction*

Stave construction is another variation on segmented construction. Where segmented blanks and "bowl from a board" arrange the segments horizontally, in thin (1/16"-2") layers, staves are higher than they are wide, like the staves in a barrel. Some references call a stave with horizontal grain a *compound segment* and reserve the term *stave* for a segment in which the grain runs vertically. To me, a stave can also have its grain run horizontally. The issue is the height of the segment. Also, a stave usually slopes vertically. A ring segment lays horizontally (0° bevel angle). A stave would be, say, 3½" or more high and maybe ¾" wide. For a bowl blank, it would slope, say, 20-90°. (Compare figures 1 and 12.)

**Figure 12**. A Staved Blank and a Staved Bowl

For a bowl with sloping sides, the staves are trapezoidal, just like ring segments, except that they are taller and have compound angles along their edges. These angles are calculated by trigonometry (Appendix). There is a calculator on the internet at http://www.delorie.com/wood/compound-cuts.html See the book by Malcom Tibbetts and the article by Bob Pritchard.

Staves should be made with a sled on a table saw, or with a compound miter saw. Extreme accuracy is required for both the miter angle and the blade angle.

The easiest way to use a table saw to cut compound angles is to tilt the arbor. I prefer to leave my blade arbor set at 90°, so I tried a slanted cutting sled. This was successful for a very shallow 30° angle to the horizontal, but for a deeper bowl it is necessary to tilt the saw blade.

According to calculations, to make a blank whose sides has a slope of 60°, I would need a miter angle of 7.6° and a "tilt" of 12.8°. [b] A sled to produce a 12.8° tilt was

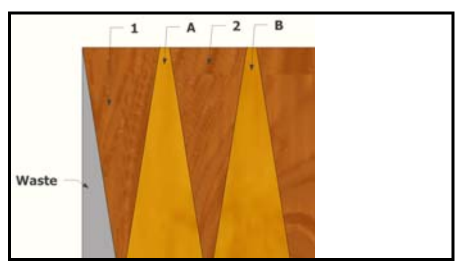


**Figure 13**. Cutting Staves – Alternate staves are used for each blank

[b]. Miter angle as it would be shown on a normal miter gauge, i.e., 0° is at a right angle to the path of the saw blade. The calculated tilt angle is measured from the normal vertical position of

impractical because it would put the workpiece too far above the table for the blade to cut it.

Note that each stave is a trapezoid, like the flat segments described above. Like flat segments, staves can usually be cut by flipping the stock over after each cut. Since staves show a lot of grain and figure, however, you have to consider the appearance of both sides of the board. Sometimes, the two sides do not match very well and the most pleasing effect will come from using every other segment. So, as you flip the board over after each cut, make two stacks marked 1, 2 . . . from one side of the board and one marked A, B, . . . from the other side. Keep them in the order that they came off the board. The two stacks of staves will make two blanks out of the same piece of stock. (See Fig 13.)

As described above, the segment length equals the tangent of the bevel angle multiplied by the desired diameter of the bowl (largest diameter). So, for a 12-sided blank, with a 7" diameter, the segment length L would be given by

L = tan(12.8) * 7" = .227 * 7 = 1.59", or about 1 9/16".

The length of stock needed depends on the segment length *plus* an allowance for saw kerf (⅛"), multiplied by the number of segments. That equals 12 times 1 11/16", or 20 ¼". Additional stock, however, will be required for the “extra” staves, i.e., the short side of each adjoining trapezoid.

You can determine the length of the short side by laying out two adjacent staves on a piece of paper, or you can calculate it as equal to the segment length minus two times the product of the height of the blank and the tangent of the angle.

L’=L - 2*h*tan(x),

where L’ is the length of the short leg, L is the length of the long leg, h is the height of the blank and x is the miter angle in degrees.

In this case, if the height of the bowl is 2.5" the additional allowance is

L’ = 1.59 - 2*2.5*.227 = 1.59 - 1.14 = .45"

so we should add about 6" (12 * ½") to the length of stock.

These calculations may seem like an unnecessary complication. It may be easier to lay out an example on the stock and measure the length required for two adjoining segments. The point really is that if the length [2*h*tan(x)] is greater than L, the staves will come to a sharp point at the bottom and the intended height of the bowl will not be possible.

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the table saw blade.

*Assembling a Staved Blank*

Once the segments are cut, they can be assembled into turning blanks (actually, two blanks, if desired). Assembling them is awkward, because they cannot easily be clamped. Assembling staves in pairs is the simplest, and works fairly well, although I prefer clamp pressure (see below).

To assemble staves by pairs, evenly spread on adhesive (Titebond II) and let the two faces sit apart for a minute or two. If the glue joints are end-grain, the adhesive may soak in, in which case you should apply just a bit more. Soon, the pieces will resist when rubbed together. Push them together, carefully align the edges, and set them aside for an hour or so. Assemble all the pairs this way, then repeat the process with the pairs, until you have made two halves, e.g., two pieces of six segments each. Let the two halves cure overnight.

Like the simple miters cut in flat segments, the compound miters cut into staves must be able to form semi-circular sections (semi-cones) if they will finally fit together into a circle. Therefore, we can again use the trick of assembling half cones and sanding them against a flat surface until they fit.

I initially sanded the half-cones on a sanding disk on my lathe, and then finished them by rubbing them on a piece of sandpaper laying on a dead flat board. They then fit together with no gaps. When you glue the half-cones together, use the same methods as described above for gluing staves. Be careful, however, to support the half-cones if necessary so that they cannot rotate apart and open a gap before the adhesive has cured.

The fit of my first set of staves was unsatisfactory. I calculated the average vertical (tilt) gap .0156", corresponding to an error of about 1°. The average miter gap was .0025, corresponding to an error in the miter angle of .04°. (These numbers are simple angle calculations, so are approximate.) The point is, the blank showed unsightly gaps even though the actual angles were very close to nominal. The gaps could be sanded away from the half-cones and the adjustment is not apparent to the eye.

*Recommended Methods.* Malcom Tibbetts recommends three stave assembly methods, All involve some clamp pressure.

1. Simply to wrap rubber bands around the segments.

2. Make an assembly & clamping jig. The jig comprises circular holes of different diameters cut into pieces of MDF. The holes are sized so that they can fit part way down the cone-shaped blank. Each is tightened down on the segments with long bolts or threaded rods. This method works best if the slope of the sides is 60° or more and if the segments dry-fit without any visible gaps, so they can be assembled all at once. (I assume that you could use it to glue half cones if you did not apply glue to the half-cone joint surfaces.) Lay out the segments on a flat table top with the wide side up. Apply masking tape to hold the segments together, and flip the set over. Apply glue to each mating surface. Then roll the segments together into a cone and place the gluing jig over the cone.

3. Use glue blocks, cut at the complementary angle to the slope of the sides, with hose clamps, as is done when gluing up segmented rings. For example, glue blocks with a 30°

angle will provide parallel clamping surfaces when fitted against a 60° sloping side. A tab is needed at the bottom to keep the caul from sliding up the blank under clamp pressure.

*Mounting a Staved Blank*

**Figure 14**. Two Staved Bowl Blanks. Note that the raw ends of the staves are sharp arrises, unsuitable for gluing. The bottom of the larger blank has been planed off on a lathe to make a flat surface for attaching the bottom disc.

Like segmented rings, staved blanks are often open at each end, so normally they would be glued to a solid piece, either another part of the blank or a glue block before turning. (See the lower blank in Figure 10.) The ends of stave blanks, however, usually do not have a flat surface suitable for gluing, since each stave is at angle to the axis of rotation. Therefore, you need a way to mount the truncated hollow cone so that you can flatten the end.

Make a temporary, narrow glue surface by mounting the blank with Cole (finger) jaws on a scroll chuck. (You could hand sand the end of the staves on a flat surface, but this would be extremely tedious.) If the outside diameter of the blank is too large to fit the Cole jaws, use a jam chuck, something along the following lines.

1. Turn a 4" diameter by 4" long cylinder out of scrap. Mount it in a scroll chuck and turn one end to a cone, approximately matching the inside angle of the blank (e.g., 60°.) You want a fair amount of contact between the cone and the inside of the blank.

2. Then make a 3/4"-1" thick disk with a slightly larger diameter than the opening in the small end of the blank. Mount it on the lathe and chamfer the edges of one side to form a steep cone.

3. Return the tapered cylinder from step 1 to the lathe and apply a piece of non-skid rubber foam (or double sided tape – something to increase friction).

4. Jam the blank against the covered cylinder. Put the smaller cone against the small end of the blank and hold everything in place with the tailstock.

5. Rotate this by hand and adjust it until the blank is well centered, and everything turns well.

However you mounted the blank, you now should use very light cuts to plane off the ends of the staves until you have a flat glue surface for the bottom disk. The glue joint has to be a flat and true as possible because you will be mounting the blank from the bottom end, and because the glue joint will show for the life of the bowl. There is no point to shaping the blank further at this stage, unless you can round off the corners of the polygonal blank a bit so that it will fit in the Cole jaws. It will have to be re-balanced later anyway.

When the bottom edge of the stave blank is flat and smooth, fashion a bottom section to close the blank. The bottom of a staved blank can be solid, but it will look better if you make a polygon with the same number of sides as the rest of the blank. It can be flat (usually) or shallow, say 30° (See Figure 10.) For a flat bottom, the length of each section equals the radius of the circle, so the bottom resembles a pie with, say, twelve slices. If the rest of the blank contains contrasting woods, the bottom can match that pattern. This is what I did in the bowls shown in Figure 8.

Prepare (flatten) the bottom and glue it to the main part of the blank. Finally, either glue on or turn a tenon on the bottom for a scroll chuck. Mount the scroll jaws, mount the blank, and turn the bowl as normal. Well, almost as normal. Staves that are ¾" thick require some careful planning and execution for the bowl profile — there is not much wood to allow catches, etc to be turned out of the bowl.

### ***Laminating Stock***

As mentioned above, the ability to use laminated stock is a main attraction of segmented turning. It is, however, considerably harder to design and execute than it may appear in a magazine article. (And segmented blanks are difficult and fussy enough, even without laminated stock.) As will become apparent below, I have had at best limited success with laminated stock. Designing laminations to produce a desired figure on the surface of a turning requires either experience or an excellent graphical imagination. It is much easier (for me, at least) to follow instructions to make a pattern designed by somebody else.

One easily overlooked but important consideration in making laminations is the work-ability of the wood. Layers will normally be cut on a band saw to maximize the number of useful pieces of expensive or scarce wood. Then, the saw marks must be planed or sanded off. In any case, each layer in a lamination must have consistent thickness and be jointed (surfaced) well if it is to make a strong and invisible glue line. Unfortunately, some woods that turn well are actually quite difficult to plane, while their sawdust can be allergenic or even toxic. Secondly, gluing up laminations from short pieces can actually reduce the number of useful pieces and is often a nuisance. Its better to order longer pieces of more easily worked stock. Save the short pieces of highly figured wood.for another use, e.g., segments of staves.

#### *Polka-Dot Feature*

Dennis Daudelin has described a “polka-dot” feature ring that is made up of two woods of contrasting colors laminated together horizontally. The wood that will appear as the polka dot is on the outside, and the background wood is on the inside. When the polygon (with straight sides) is turned into a circle, some of the background wood is exposed, producing the polka-dot effect.

This sounds simple, but the laminated ring has to be centered perfectly, or the dots will not be uniform. It is very difficult for me to lay up ring segments accurately enough. Actually, if the ring is off center by the thickness of the feature wood layer, say ⅛", one side will have dots and the other side will have no dots, showing either the feature wood or the background wood. I have not solved this problem, yet.

For a six-sided ring, Daudelin recommends that the outer layer be about ½" wide. For a 12-sided ring, it appears to me that the layer should be about ¼" - ⅜" wide. The procedure is simply to laminate a feature wood, say bloodwood, yellowheart, or Osage orange, to a strip of background wood such as holly or maple. The layers should be well jointed, e.g., sanded smooth, and well clamped, because the glue line will be exposed when the wood is turned away. The lamination should be normal width, e.g., about 1" - 1 ½" wide, depending on how thick the ring will be and how much change in diameter it will have to support. So, for example, the lamination would comprise a stick of feature wood ¾” thick by ⅜" wide by 35" long, glued to a piece of background wood ¾" thick by 1" wide by 35" long. (It’s necessary to make plenty of laminated stock because of the way that it must be cut.)

After the glue has cured, clean up, smooth, and square up the laminated stock and cut segments. With this kind of lamination, however, the stock cannot be flipped after each cut. The feature wood must always be on the outside, so each segment must be cut individually. This will waste a bit of laminated stock, which is why you will need to make extra. For a 8" diameter ring, I estimate that you would need about 35" of stock.

*Zig-Zag Feature*

Even a simple zig-zag pattern can be a challenge, as I discovered when I made one. I followed (somewhat) the description given by Tibbetts on p. 101 of *The Art of Segmented Wood Turning*, or should I say that his description lead me down the garden path. Like the rest of segmented turning, making laminations requires planning and precision.

**Figure 15**. Sled for Cutting Zig-Zag Pieces from Laminated Stock (See arranged pieces in upper left)

My first decision was the diameter of the zig-zag ring, because that would determine the length of each segment. An 8" diameter ring with 12 segments, would be composed of 2" long segments. I decided on a 45°angle, which lead me to four pieces per segment.

The length of lamination needed for each zig would be the hypotenuse of a right triangle whose base and height were ½", so I’d need 11/16" per zig. Allowing ⅛" for saw kerf, I would need 13/16"/piece. So, 13/16"/piece x 4 pieces/segment x 12 segments = 39" of laminated stock. It is very important that each segment in the zig-zag ring be identical. The easiest way to do that is to make them all from one piece of laminated stock.

**Figure 16**. Trimming the Zig-Zag Pieces (The pieces are resting on a Masonite sled, held in place by double-sided tape.)

For this learning exercise, I chose Radiata pine as the light wood and cedar as the dark wood. I ripped a piece of cedar about 1½" wide and ⅜" thick and then planed it to ¼" thick. I cut two pieces of 1½" W x ¾" thick pine and jointed them for gluing. I glued the three pieces together between cauls, with clamps about every 8". It is necessary to make sure that the lamination is clamped evenly along its length and width, and that the layers don’t slide sideways under clamp pressure, because this will limit the width of the finished segments.

When the glue was cured, I cleaned up the lamination with the table saw and hand plane so that it was smooth and square in cross section. Then, using a crosscut sled fitted with a 45° guide and a stop set for 11/16", I cut diagonal slices. (Figure 11.) I kept the pieces in the same order that they were cut from the stock.

After the pieces were cut and arranged (alternate pieces flipped over), I glued them together into sets of four or eight. The saw cuts were very smooth, with no saw marks, etc., but I sanded them by rubbing them against 100 grit sandpaper on a flat surface. If I had glued them into larger sets, e.g., sets of 24, it might have been easier to trim them. When arranging the pieces, I focused on the appearance of the zig-zag line, trying to make it line up as well as possible. Any tiny error in the cutting angle will tend to make a long string of pieces wander off at an angle, but this can be corrected in the next step.

To trim the pieces, I marked guidelines along the points of the pattern and then ¼" on each side, for a border. The outer lines were the guidelines showing where I wanted to cut the pieces. I cut a small strip of Masonite to act as a sled. I put a piece of double-sided tape on the Masonite and carefully arranged the rows of segments on the sled, aligning the guidelines so that the pattern would be uniformly centered along all of the pieces. Then, I lined up the row on the table saw, using an angle guide against the rip fence when necessary, and trimmed the pieces to the same size. (Fig 12.) The small chips that were removed are shown in the picture to underline the point that a zero-clearance throat plate is necessary for this operation; otherwise, the pieces may jam in the throat of the saw.

**Figure 17**. Segmented Bowl with Zig-Zag Feature Ring. Note irregularities in the zig-zag design

When cutting the segments on the miter sled, the joint has to exactly bisect the saw kerf. That is, sawing has to remove equal amounts from each side. Otherwise, the “zig” will not line up with the “zag” when the rings are glued together. This was, for me, the most difficult part of making a zig-zag feature ring. (See Figure 13) Alternatively, you could wait to trim the segments until the rings were made. Then you could glue the segments into the rings so that the zig-zags lined up, but the rings might be very difficult to flatten.

I also tried cutting laminations across the layers, to produce alternating rings , sort of a ring segment effect in a staved bowl. The light and dark layers have to line up perfectly, but, despite my best efforts, the staves slipped while the glue was setting. If I want ring effects in the future, I will use ring segments.

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***Appendix: Compound Miter Calculation***

The following formula will give the miter gauge setting, and the head (tilt) angle for any number of sides on any angle you choose.

1. Calculate (or choose) the vertical angle of the side pieces, ***measured from the horizontal***. (For example, if the sides were vertical the angle would be 90°.) Call this angle ***b***. Suppose, that you have drawn a bowl. The bottom diameter is 2½", the top diameter is 6" (rise= 3½") and the bowl is 4" high. The tangent of the angle is rise/run = 3.5/4= .875. Then b= arc tan (.875) = 41.19°

2. Choose the number of sides, s.

a=360/s
x=arctan((cos b)*tan(a/2))
y=arcsin((sin b)*sin(a/2))

The "x" value will be the desired angle of the miter (cross cut), as it would read on a miter gauge. (Blade track would be 90°).

The "y" value will be the desired (tilt) angle of the saw blade relative to the normal perpendicular position of the saw blade (vertical). For example, to make a octagonal barrel with parallel sides the angle has to be 22.5°

In the example, given 12 sides, with a slope of 41.19° from the horizontal,
a = 360/12 = 30°
x = arctan((cos(41.19)*tan(30/2)) = arctan((.753)*(.268)) = arctan(.202)
= 11.41°

y = arcsin((sin(41.19)*sin(30/2)) = arcsin (.659*.259) = arcsin(.171)
9.83°

By the way, for a 45° vertical angle and 12 sides x= 10.7 and y = 10.5. For a bowl with 12 straight sides, x=0° and y=15°

Trig formulas from Robert Smith, http://groups.google.com/group/rec.woodworking/msg/ebffc02b598816cd, accessed September 5, 2010

Calculator available at http://www.delorie.com/wood/compound-cuts.html and many other sites on the web. Table available in Tibbetts, pp 176-7