Creating Woodturnings that incorporate Slanted Staves

This article is about creating woodturnings incorporating slanted stave elements. Since this is an extension of the segmented vessel process let's start by comparing three methods of creating segmented vessels used by turners to create pieces of art using multiple pieces of wood in combination. There other forms of the segmented art, but the three we'll discuss are:

1. Rings of staves
2. Rings of segments
3. Slanted stave rings

Rings of Simple staves – those with straight sides – are a simple construction in which the key to success is to accurately make the two key elements – angle and width of the stave – close into a stave ring with no gap. The angle is derived by a simple formula dividing 360° by the number of staves. Then for convenience to divide that by 2 to set your saw's bevel angle for two cuts. Hence, a stave construction of 8 staves would require dividing 360 by 8 to get 45° and then dividing that by 2 to get two equal cuts of 22.5°. Once you know what you're accomplishing you can use the short form of this to divide 180° by the number of staves.

The width of the stave can be ***roughly*** determined by dividing the circumference by the number of staves in the ring. For example: A ring of 8 staves with a circumference of 24" would seem to require 8 staves of 3" width. Actually due to the geometry of the ring and the flat cut staves, if you were to follow the above formula the finished circumference of your ring would be less than 24" – in fact close to 22 ¾". A more accurate calculation would be to use the formula:

X = 2 x R x Tan Ca

- Where: X is the width of each stave; R is the radius of the ring; and Ca is the cut angle defined above.

In this process you would have calculated the width of the stave to be about 3.16 to get the ring you wanted.

You could have made your staves by ripping a board at the proper angles, width, and length and cutting off equal sections along its length representing the height of your ring. The grain in that case would be running parallel to the axis of the resulting ring. The other method would be to cut your staves from a four square board by cutting them across the grain; thus, the grain would run perpendicular to the ring's axis. In the first case the end grain would be exposed at the top and bottom of the ring and would need to be dealt with in attaching that ring to adjacent rings. In the second case, the end grain would be exposed at the sides of the staves and measures of attachment would need to be considered to account for the resulting weak glue joints.

The key to success here is to make sure that the bevel angle is actually 22.5° (or what you've calculated based on the number of staves in your ring) and then to pay close attention to your technique.

Rings of segments use the same math described above but with different names for the parameters. The key elements in a ring of segments are the segment length and cut angle. Cut angle is calculated the same by dividing 180 by the number of segments. Again 8 segments would have a cut angle of 180 divided by 8 or 22.5°. What was the width of our stave is now called the length of our segment (S_L) and is calculated:

$$S_L = 2 \times R \times \text{Tan Ca}$$

All this is pretty straight forward because there is little difference in the math between the stave and the segment approach and the key to success is to make sure your bevel angle and segment length are cut precisely so that the ring closes on itself leaving no gaps. Once again you need to pay close attention to your technique.

Slanted Stave Rings are the third method and have a lot of the same elements as the simple rings of staves namely that they are made up of a ring of staves cut at precise widths and angles. The difference is that, due to the fact that the sides of the staves aren't parallel to the center axis of the ring (i.e., meaning that the stave is tilted in or out from the center of the ring), the angles are more complex and indeed are called compound angles. While the math is a little complex – to reflect the fact that the sides aren't parallel to the axis of the ring – it's relatively easy to run the calculations with a pretty elementary calculator (one with trig functions) once the formulae are available. There are also published charts with the angles given once you know the basic elements which you'll get from your design drawing. The primary element is the slope of the side of the stave referenced to the base. If you picture a vessel sitting on a table, the base will be on the table and the slope you're after is the one that the side of the vessel makes with the table top. In the case of a vanilla stave bowl that angle would be 90° (i.e., straight up and down). As you tilt the side of your stave inward or outward the angle becomes less; for example: 75°, 60°, etc. This is the only real measurement necessary because your number of staves is that which you've planned for in your design. The angle can be read using a protractor right off of your sketch.

The first difficult part comes once you know the angles you have to set them precisely in both the blade angle (bevel) and miter angle (setting the miter gauge at some angle other than the 90° you would for a square cut). That's two angles to deal with and they must be precise since one affects the other. Grasp the meaning of that statement. While you can tweak one of the angles a little if you find a gap in your fit, you can only do that to a pretty small degree because changing one angle affects the other. What you hope to be doing with your tweak is taking out error in the angle you're tweaking not compensating for an error in the other angle. If you have error is the miter setting and trying to tweak the bevel angle of the blade you could be making things worse. Of course, you might get lucky and hit on a viable combination that just modifies the tilt angle a little. Good luck with that.

Without doubt the best way to approach this situation is to have a means of setting both angles precisely to start with, but such isn't going to be the case often. However, there are things you can do to help by having a means of setting one of the angles to a known good angle and sneaking up on the other. I'll give you a scenario that I've used. This is just one way and there are probably a lot more.

This is an example of the method I've used employing an Incra 5000 table saw jig with which I can dial in angles to one half degree. The first step using this technique is to make sure the table is square with the blade and then square the jig with the table. Once you can cut exact 90° angles with the jig you can then dial in the angle you wish to within 1/2° using the jig's protractor. But 1/2° accuracy isn't close enough for most compound angle cuts. The solution is to pick a tilt angle close to your desired one but one which comes as close to a 1/2° setting of the miter angle as possible. If you're using a chart as described above you'll likely find one without much deviation from the tilt angle you're after.

Once you have a miter angle in which you're confident, the bevel angle is next. I use a Wixie[i] angle measuring device (about a $40 investment worth its price) to set my blade to within 0.1° of the desired angle with good results, but you could make a template from stiff cardboard and a protractor to set your blade pretty close and, knowing you can count on the precision of the miter angle previously set, tweak the blade angle to close any gaps by using enough lumber to make trial cuts.

This is just one example and I'm anxious to hear others should you wish to share your secrets.

Incidentally, there are different formulae from different sources that can be used but the set I find easiest to use are as shown below since they deal directly with the terms with which you're likely to be familiar.

You first calculate the flat miter angle (FMA) – what the angle would be if the stave was not slanted. That's just the familiar formula dividing 180 by the number of staves.

FMA = 180/N

With FMA known, you calculate the miter angle (MA) by the formula:

MA = Arctan[Tan FMA x Cos S]

And then the bevel Angle with the formula:

Bev = 1 – [Arcsin(Sin FMA x Sin S)]

- FMA is the flat miter angle
- MA is the miter angle to correct for tilt of the stave
- N is the number of staves
- S is the angle of the stave relative to the base (e.g., if you tilt the stave 15° off vertical S would be 75°

Unless you really like to play games with calculators you can download a chart with the angles you'll need at http://woodgears.ca/miter/ . There's also a tutorial there.

So now you've mastered the theory and you're ready to do something with the numbers you get. These formulas will tell you what angles to set on your miter gauge and your blade. The above example will tell you how I accomplished the angles to get my staves cut. We'll discuss that in a little more depth but you'll need to come up with a scheme that works for you and fits your tools and techniques.

Figure 1 Incra sled with Aux fence. Note saw fence used as stop.

We've already pointed out that it's very important to set your angles precisely, but it's equally important to cut the staves to the proper length consistently. Otherwise, they will not close in your ring precisely. For a simple analogy, think of a rectangular box with mitered corners. If the opposing sides of your box aren't precisely the same length the corner miter joints will not close properly leaving gaps somewhere along the way. The same holds true for a stave vessel (or any one of the segmented ring structures). In my set-up, I used the table saw fence to set the width of the stave by butting the end of the stave against it. See figure 1 and note that, to make sure that the stave segment won't get caught between the fence and the rotating blade and kick back, the fence is pulled back so that the cut workpiece is clear of the fence before the cut begins. The Incra protractor is set to the correct miter angle as computed and the blade is tilted to the right. The workpiece is nestled in the auxiliary fence and, after the initial cut is made, it's flipped over and pushed against the table saw fence to set the width of the first stave. In this way the segment is cut and falls to the right of the blade and is pulled away with an unsharpened pencil (eraser end) after which the workpiece is flipped and pushed against the table saw fence to cut the second stave. This technique results in the face sides of alternate staves coming from the opposite face of the board. This may or may not meet your design goals but there are ways around it if it does. One way is to continuously re-trim the board so that succeeding staves come from the same face. That process would waste a good part of your lumber. An alternate approach would be to make double the number of staves and sort them so that the faces of each set come from the same face. The latter approach isn't too off the mark since you probably will want to make more than one vessel once you've gone through the process of precisely setting your angles.

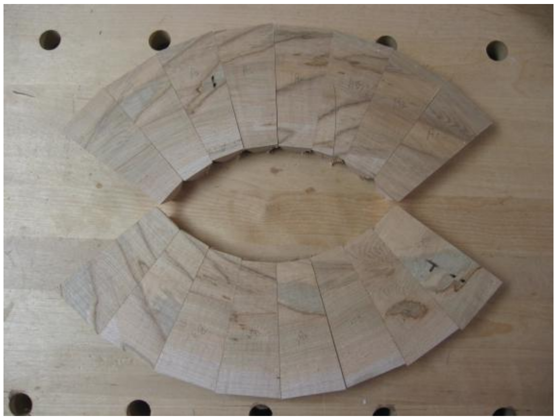 Figure 2 Two sets of staves from opposite sides of board

Figure 2 shows the effect of this sorting technique. While the grain will not align precisely the coloration and general figure effects will be more consistent.

A discussion of technique is in order at this point since almost any slip up could undo your careful alignment efforts. Once you've set you angles correctly and adjusted your stop blocks so that the stave widths are consistent, you must pay close attention to how you approach the cuts you're going to make. Is your blade sharp and clean? A dull or gum encrusted blade puts force on the workpiece as you make the cut. If, by pushing the blade through the cut you cause the workpiece off of its reference points (the sled's fence in my case), you will get a miss formed stave which could be difficult to identify. Your goal is to keep the workpiece securely pressed down against the sled and back against the sled fence to ensure that your reference for the cut is consistent. If you slip up in any of these areas, the result, after all your efforts, would be a ring that refuses to close on itself.

Now that you have your staves cut you need to glue them into a ring.

Once you get all your staves cut you need to make sure the ring does indeed close on itself before committing to a glue up. This can be done using masking tape on each joint and closing the form for inspection as shown in figure 3.

Figure 3 Segements dry fit for inspection

My approach is to try real hard to get the angles set so that the glue up goes in one operation. That's not always possible so the alternative would be to glue the segments in combinations until you have two halves. Once glue has cured on the halves they can be sanded to the point that the joints match.   One technique for this is to use spare staves as cauls and glue up halves in that way. Figure 4 shows how this can be done.

Figure 4 Glue up of halves using cauls

Getting cauls for this method is done by simply making extras as you cut your main staves or taking a scrap piece and cutting the required number of cauls using the same setup you used for the staves. Clamping the cauls to a convenient surface as shown in the figure will enable the glue up operation.

Figure 5 shows the completed halves ready for sanding if necessary. Careful sanding should permit a fully closed ring but care should be taken not to burn or burnish the surfaces so that the joint becomes too slick for the glue to adhere or becomes unsightly due to charring. In addition, it's important to apply even pressure to the surfaces being sanded so as not to round over the edges thus compromising your closure.

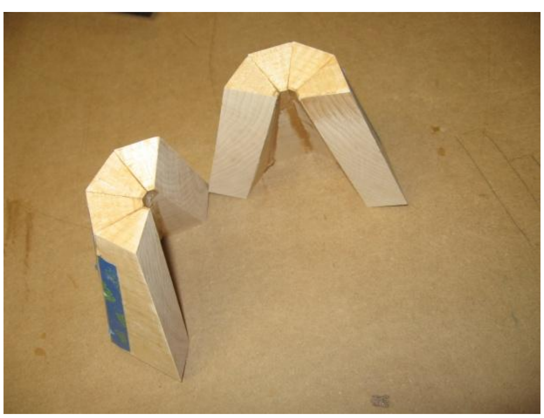

Figure5 Half rings ready for sanding

However you choose to do your glue ups your goal is to have the ring close perfectly so there are no gaps.

To get your staves ready for final gluing you need a way to hold them in place and apply the required force. Malcolm Tibbetts[ii] shows a clamping mechanism that works pretty well for this. My version of the device is shown in figure 6. The clamp uses a lathe faceplate on the large end of the staves and a series of rings with successively smaller diameter cutouts along its length. Tibbitts laments the need for precise bevel cuts in the rings that compose the clamping mechanism, but my version ignores that and uses the edges of the rings to bite into the stave facets instead. This gets a good grip on the stave and causes no harm since the facets will be turned away later anyway. Using the faceplate enables alignment of the overall vessel and truing its end on the lathe. A cone center is used for alignment during glue up and, as shown in the figure, a Forstner bit can be used for truing the small end after the glue has cured so that a sacrificial block can be added.

Using the sacrificial tenon you can turn the facets off inside and out and inspect the assembly for opens. Figure 7 shows the assembly of staves after preliminary turning. The finish turning will occur after the stave assembly is attached to more of the rings so that shape can be determined in a larger context. The purpose of the preliminary turning is to inspect the ring for failure of the closure before committing the rest of the assembly – just for insurance.

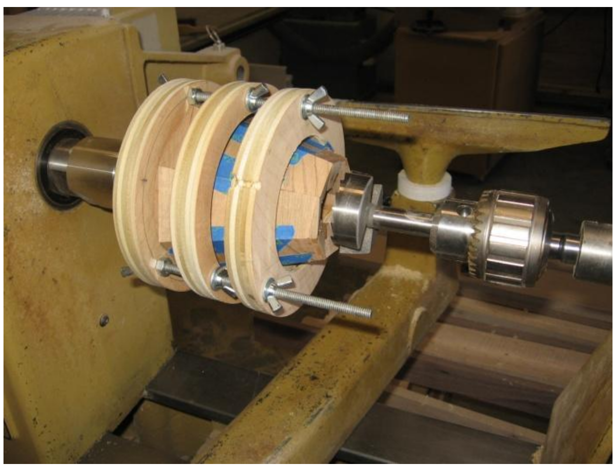

Figure 6 Clamping mechanism with stave assembly inclosed

Figure 7 The stave assembly following preliminary turning. A rabbit was added to enable turning of the opposite end of the assembly.

Let's elaborate on a point made earlier relating to grain orientation. Note in Figure 7 that the end of the stave is actually the side grain face. This is due to the way we cut our staves from the board. By using a four square board and cutting across the grain as each segment is removed, the ends of the staves are side grain. The end grain faces to the cut edges. The strength in our structure will be from gluing the ends of our staves to other side grain structures like the top or bottom of a ring of segments. If, on the other hand, we had cut our staves from segments of a board in which the grain ran generally in the same direction as the cut – meaning that the grain will run along the length rather than the width of our stave – we would have end grain at the end of the staves and would need to deal with the weak glue joint by employing a mechanical connection such as a mortise and tenon joint. You might wish to have your grain pattern running vertically rather than around the vessel for design considerations, so this is something you may run into as you go further into stave turnings.

So there is a rundown on slanted stave structures. They can be used independently or in combination with other structures such as rings of segments. In a vessel with staves in place of segments it's possible to cover more vertical space with much less lumber than with rings of segments. Staves can also be of value when a surface cuts too sharply over the glue joint between rings sometimes resulting in an irregular glue line. There may be other advantages of staves over segments but it's up to you as the designer to decide where that occurs.

The primary disadvantage is that the complex angle combinations once determined can still be difficult to achieve physically.

As you create your own vessels using staves, segments, and slanted staves, share your experience with others in our workgroup. We're all in the learning mode and can use all the experience the group has to offer.

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[i] Wixie – Digital angle gauge available from woodworking suppliers for under $40

[ii] Malcolm Tibbets "The Art of Segmented Wood Turning …"