Multi-axis Turning

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Terms

(In some case, I could find no established term, so I took the liberty of making them up.)

Single-axis turning: Single-axis turning is regular turning. In the context of Multi-axis turning, this term can be useful to emphasize the singular axis of regular turning when comparing to Multi-axis turning.

Multi-axis turning: Multi-axis starts out as a Single-axis turning, but is then remounted and re-turned one or more times on an additional axis/axes.

Original axis: The initial axis used to turn square stock round. In Multi-axis turning, the original axis could be skipped in many cases, but often it is easier to proceed with round stock. The original axis can also serve as a reference for other axes.

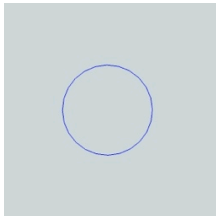
Bias: When a new axis is chosen, the work will be off balance at most or all of the length, such that one side of the workpiece will be cut before the opposite side. I refer to this effect as bias. The further offset the new axis is, the more bias there will be, that is to say, a deeper cut will be required to begin cutting the opposite side of the work.

Shadow: Bias and shadow are closely related. As the work spins on a new axis, the bias will produce a shadow, since there is wood present only part time. The shadow is invaluable as a reference while turning on multiple axes.

Multi-axis Fundamentals

There are two elements that set multi-axis turning apart from single-axis turning: **cross-section** and **axes relationship**.

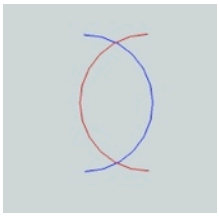
Cross-section



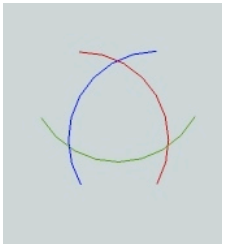
Circular cross-section

In "regular," single-axis turning, the cross-section is always circular. In multi-axis turning, the cross-section can be either circular OR it can be two or more intersecting arcs.

A new circular cross-section is created when cutting completely through the "shadow." An intersecting arc cross-section is created when cutting only part way through the shadow.



2 intersecting arcs

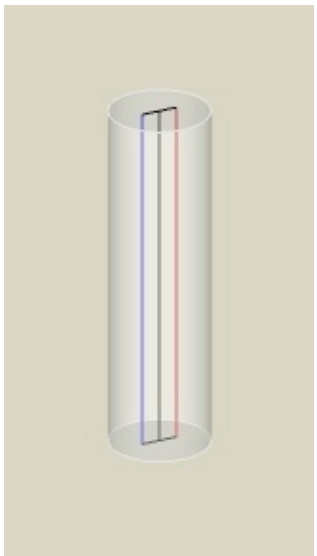


3 intersecting arcs

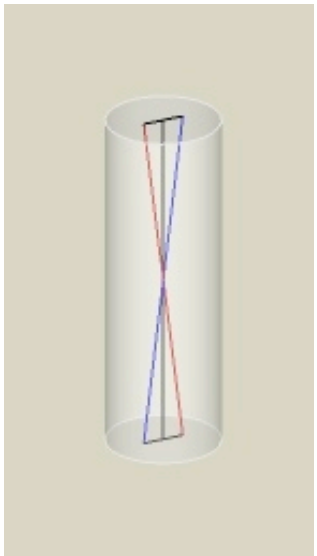
Axes Relationship

Since there are more than one axes in Multi-axis turning, we can consider the relationship between pairs of axes. Since an axis is essentially a line, we can borrow from mathematics to describe axes relationships. In mathematics, there are only three possible relationships between lines: If the lines are in the same plane, then the lines are either **parallel** or **intersecting**. If the lines are not in the same plane, then they are **skew**.

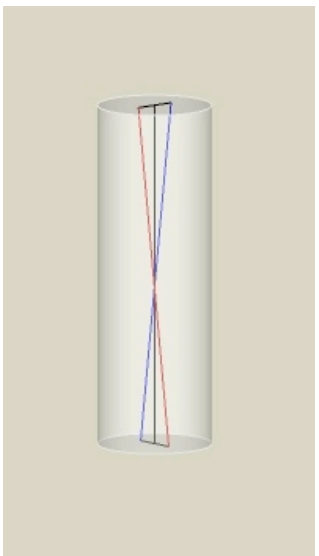
Each relationship, parallel, intersecting, and skew, have a specific effect on form in Multi-axis turning.



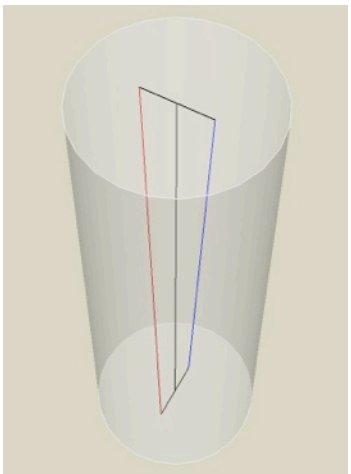
Three parallel axes: the original plus two offset.



Three intersecting axes: the original plus two offset.



Three skewed axes: the original plus two offset.



At first glance, skewed axis (left) may look intersecting, but this perspective show that they are not.

Parallel Axes

Parallel axes are, perhaps, the easies to grasp, and is perhaps the most versatile axis relationship. Abstract human forms are possible with just three axes! Parallel axes produce a uniform bias across the length of the work. This effect can be used to make "sided" forms, with each side being based on a arc.

Parallel forms with 2, 3, 4, and 5 axes are quite useful. Two axes are useful for adding features to only one side of a workpiece. Three, four, and five axes are useful for making 2, 3, and 4 sided figures, respectively.

Abstract human forms, made on parallel axes, by Mark Sfirri

This "Bad Luck" rolling pin was made on just 2 axes.

Prototype of a 4-sided, curved stretcher, made on 5 parallel axes.

The bias created by an axis parallel to the original axis produces a uniform shadow across the work.

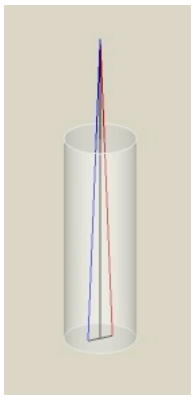
Intersecting Axes

Lid handle on just 2 axes, intersection at end.

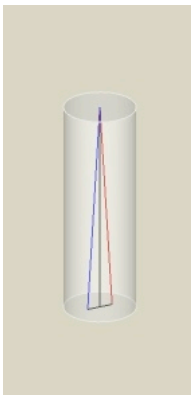
Intersecting axes share a similar effect as parallel axes, except that the bias diminishes as the two axes get closer to the intersection. At the furthest point away from the intersection, the bias (and shadow) are the largest, and a the point of intersection, the bias/shadow disappear. Depending on where the intersection is in relation to the work, different diminishing effects can be achieved. Having the intersection at the end of the work is convenient since it only requires moving only one center (when working between centers). Having the intersection inside the work has a mirroring effect.

I find intersecting axes particularly useful for asymmetric goblet stems and for making furniture parts, but there are many other possibilities, including abstract human forms.

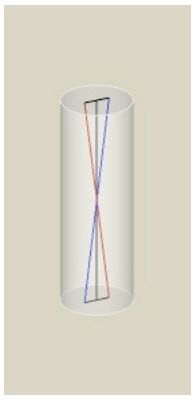
The legs on the stool are made on 2 intersecting axes, and the stretchers on 4 intersecting axes.



intersection outside of the work

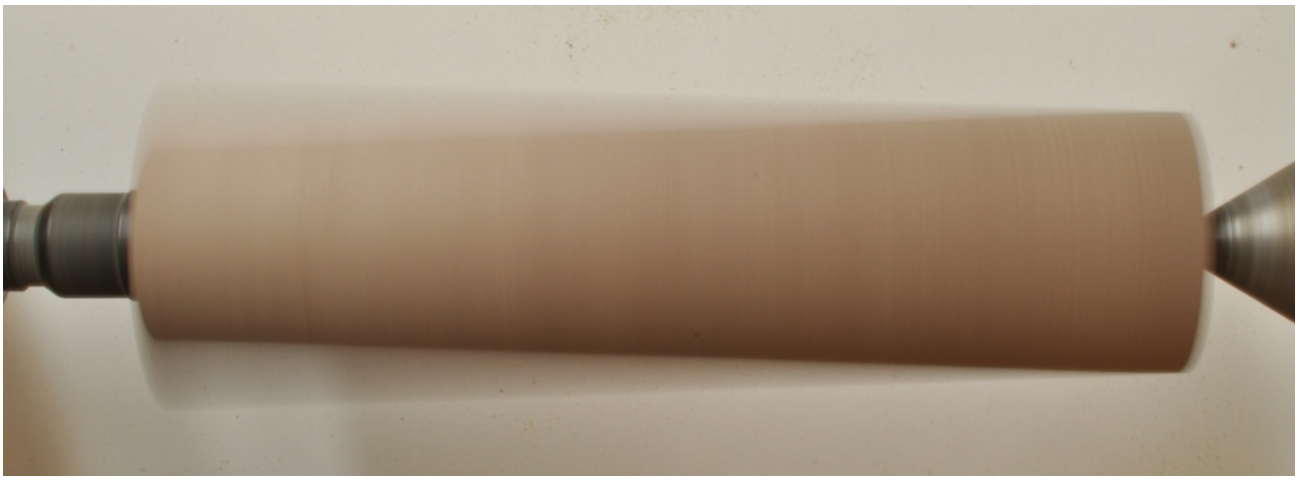


intersection at end of the work



intersection inside of the work

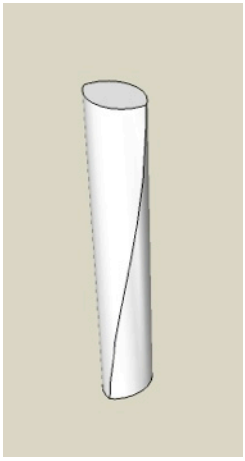
"Music note" (or "Gold Club", depending on you fancy) stemmed goblet, on 2 axes.



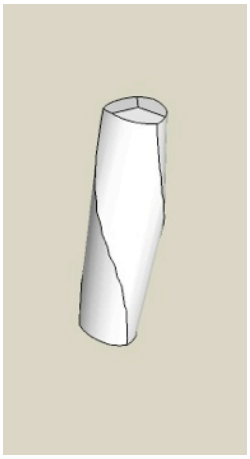
The bias created by an axis intersecting the original axis will produce a diminishing shadow along the work. The second axis on this work was effected by shifting (only) the center on the headstock (left), such that the intersection of the axes is at the end of the work (at the tailstock).

Skewed Axes

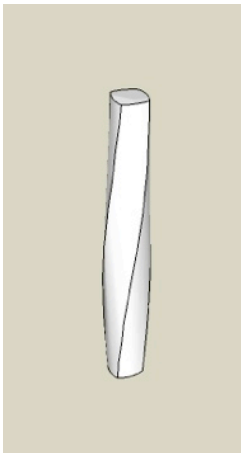
Skewed axes are also similar to parallel axes, in that they produce sided forms, but in the case of skewed axes, the sides are twisted. These twisted surfaces can be used to add a subtle aesthetic where a straight cylinder would normally be used, such as in furniture parts, candlesticks, goblet stems, lidded boxes.



two-sided, twisted form (3 axes)

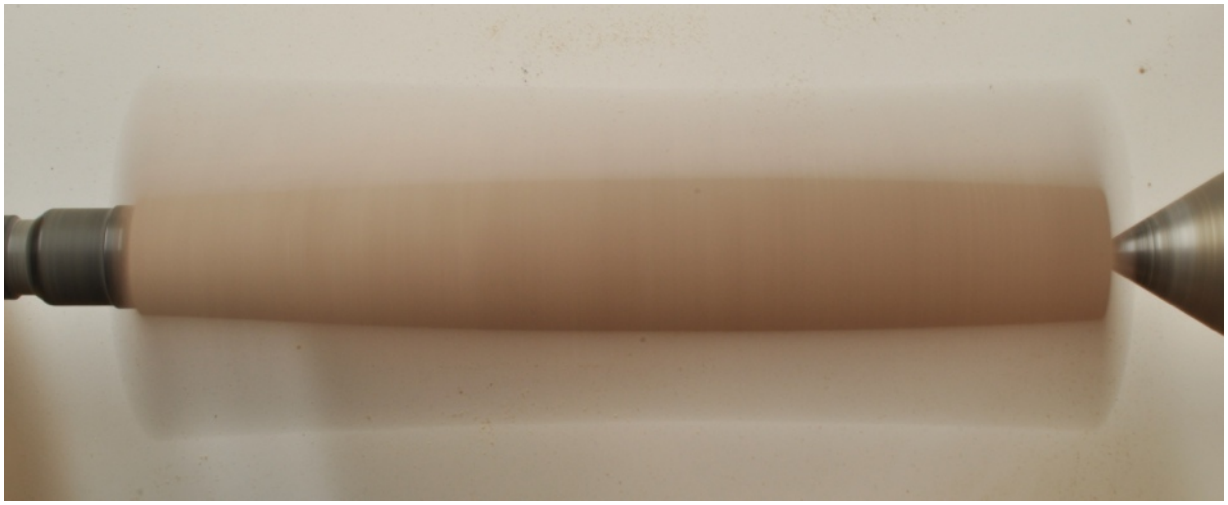


three-sided, twisted form (4 axes)



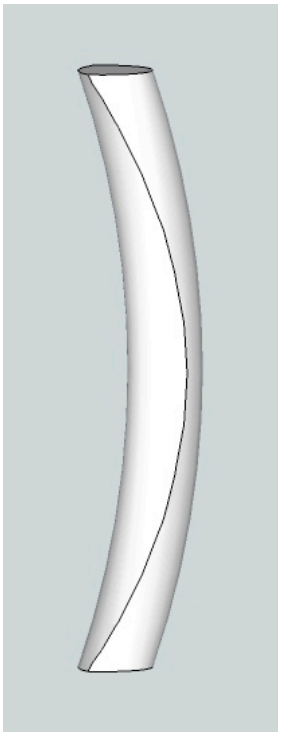
four-sided, twisted form (5 axes)

three-sided, Twisted, Lidded box, turned on 4 axes: One axis for each side, and hollowed on the original axis.



The bias of a skew axis produces a shadow that has a slight cove. Notice also that the solid wood looks like a slight bead that is a mirror image of the shadow's cove.

Parallel Axes Example

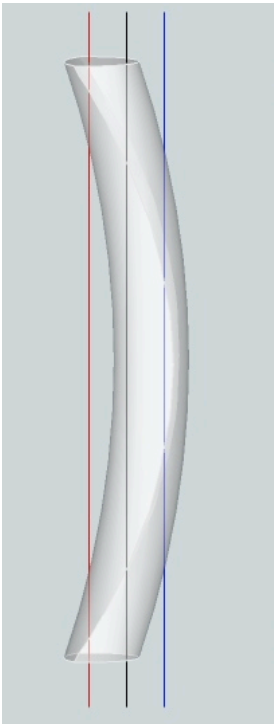


basic parallel-axis form

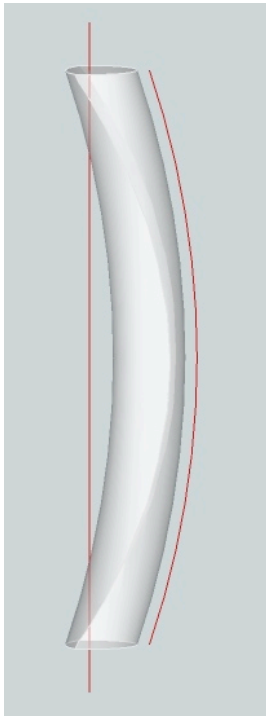
How To: This is a basic 3 axis turning, with the original axis (black), and two additional axes (red and blue). It is essentially the intersection of a long bead and a long cove.

- The original axis (black) is used simply to turn square stock into a cylinder. Since the initial cylinder will be completely cut away, this step could theoretically be skipped, but in practice it is usually easier to start with a cylinder.
- After turning the initial cylinder, both centers are shifted in the same direction to effect a second (red), axis, which will be parallel to the original axis. On this second axis, I cut a long bead.
- For the third axis, shift the centers to the opposite side of the original axis, the same distance, to effect the third (blue) axis, also parallel to the original axis.

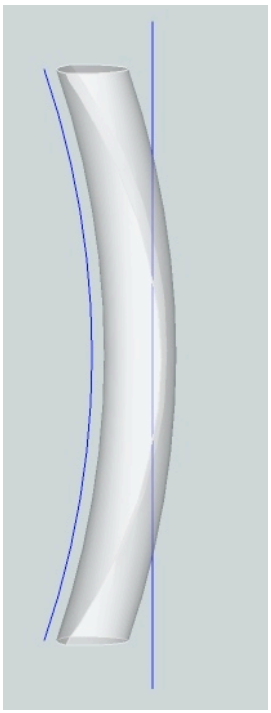
Possible Uses: mug handle; door handle, drawer handle; tray handle; curved candlestick.



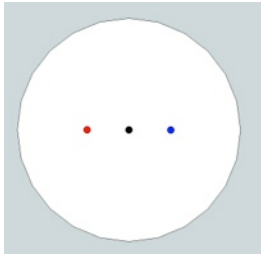
3 axes: original plus 2 parallel offset axes



The second axis is used to cut the bead.



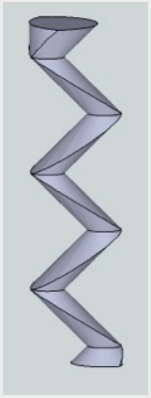
The third axis is used to cut the cove.



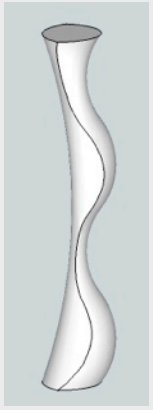
Mark the endpoints for the second and third axes the same distance from the original.

Other profiles: Many other profiles can be used with this same multi-axis configuration to effect varied results.

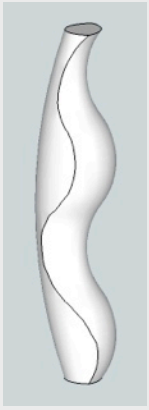
alternating beads and coves



alternating v-grooves

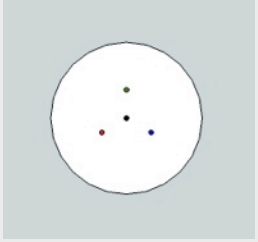


beads/coves intersected with a long cove

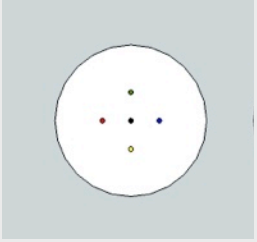


beads/coves intersected with a long bead

Also Try: More than three axes



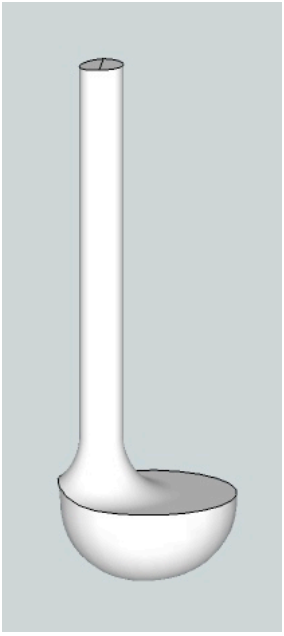
4 axes



5 axes

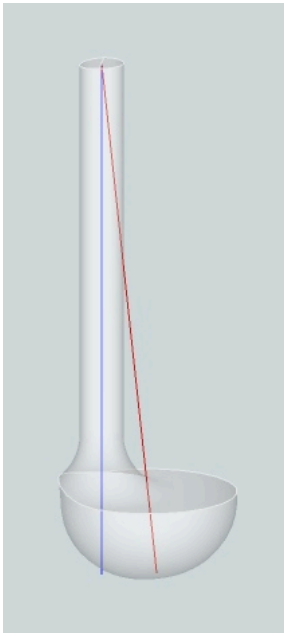
Intersecting Axes Example

The “Golf Club” form is one of the easiest forms to make in Multi-axis turning, and is also one of the most useful. It can be used as a foot for furniture legs or on a footed turning, as an asymmetric lid handle on a lidded box, as a drawer or door pull, etc. One of the most clever uses I have seen with this form is to make toy ducks.

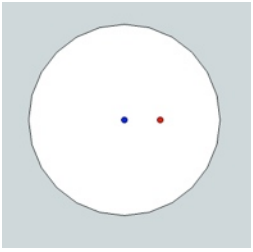


How To: This is a basic 2 axis turning, with the original axis (red), and and additional axis (blue). It is essentially the intersection of a half bead and a half cove.

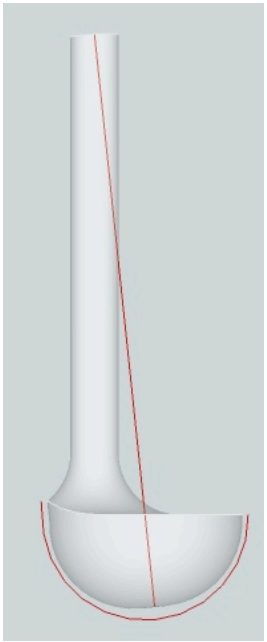
- The original axis (red) is used to turn square stock into a cylinder, and to begin forming a half bead. Note that some extra material must exist beyond the bead to accommodate remounting on the second axis.
- Next, move the center at the bead end to a new center to establish the second axis (blue), and cut the half cove. Since the intersection is at the end of the work, only one center needs to be reset for the new axis.
- Return to the original axis to finish the bead and part off the work.



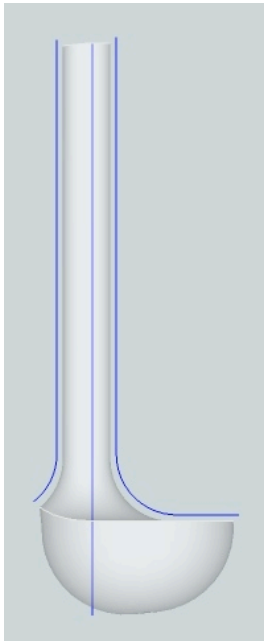
Only two axes are needed for a golf club.



The golf club is easy to layout, since only one center needs to be reset. Only the distance from the original axis’s center needs to be accurate.



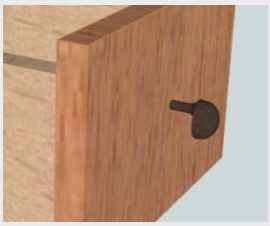
Cut the half bead on the red axis.



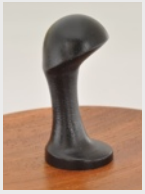
Cut the half cove and stem on the blue axis.

Try: Varying the stem for different purposes

Leg



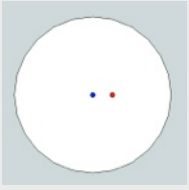
Drawer pull

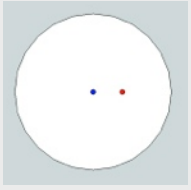


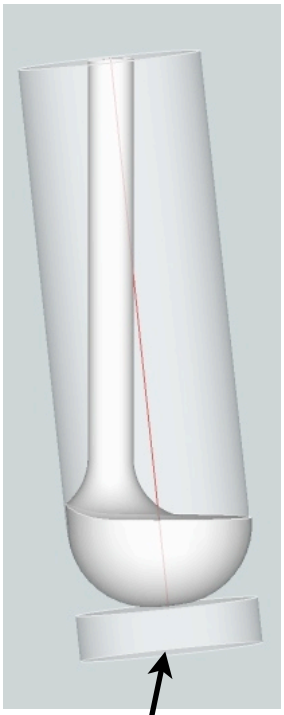
lid handle

Duck toy concept

Also Try: Varying the distance of the second axis



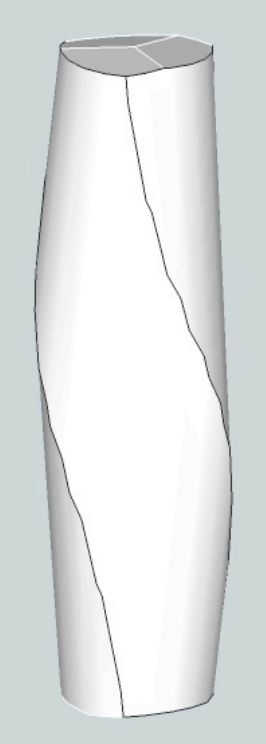




Leave extra material for reseting the center

Skew Axes Example

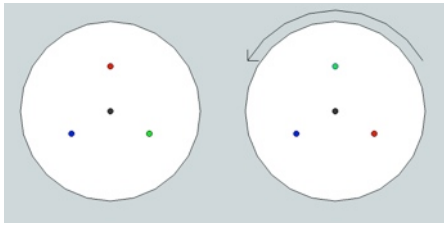
This is a typical three-sided “twisted cylinder”, useful for adding interest to an otherwise mundane dowel, or for making twisted lidded boxes.



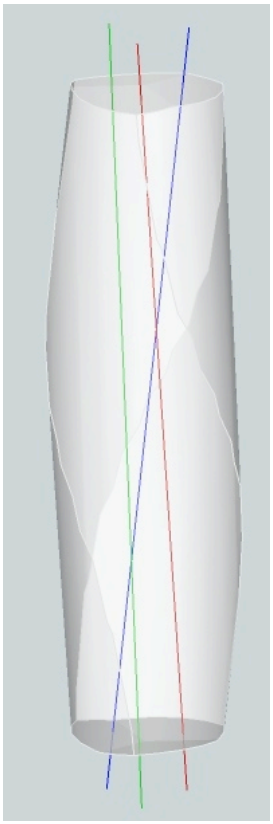
Three-sided “twisted cylinder”

How-To: The most difficult part of a skew axes turing is grasping and keeping track of the layout of the axes. The turning part is straight forward.

- Layout the endpoints at one end as points equidistant from the original axis, at 120 degree intervals. Layout these endpoints in a clockwise direction, red, green, then blue.
- At the other end, layout the points counter-clockwise, but NOT opposite the respective endpoints. In other words, start with the red endpoint opposite the green endpoint, and mark counter-clockwise, red, green, blue.
- After reducing the work to a cylinder on the original axis, turn the three twists using matching endpoints, red/red, green/green, and blue/blue. Each time, the shadow will be a slight cove. Remove a consistent amount of the shadow each time to produce a straight twisted cylinder.

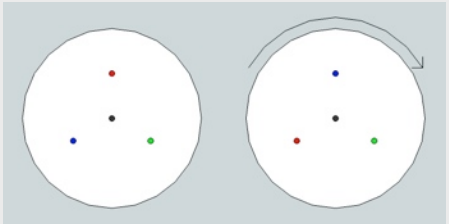


Rotate the second end before laying out the endpoints counter-clockwise

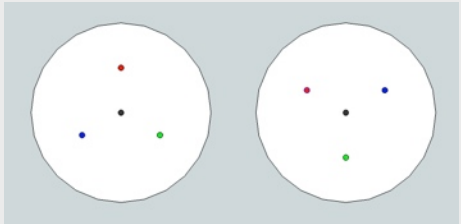


Although the axes look like they are intersecting when viewed in 2-D, the axes are at different depths at that point.

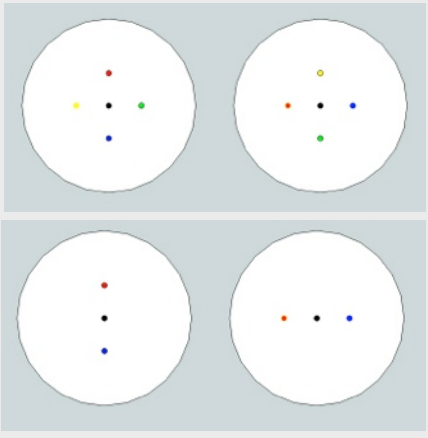
Also try: Rotating the second set of endpoints in the opposite to reverse the twist.



Also try: A partial rotation for a more subtle twist.



Also try: Two and four sided twisted cylinders.



Reference

Multi-axis woodturners:

Mark Sfirri: http://www.youtube.com/watch?v=7uZNmvwHHIY&list=PL5C042A45F57C1D01&index=2

Barbara Dill: http://www.barbaradill.com

Barbara Crocket: http://www.bcwoodturning.com

Jean-François Escoulen: http://www.escoulen.com/joomla/index.php/en/woodturning

Practice and prototyping wood:

I often tryout new multi-axis ideas and turn prototypes of designs on less expensive woods before turing my good stock into sawdust. For this purpose I usually use fir 2x2's and Poplar.

Fir

Fir 2x2's are dirt cheap and a good size for playing around and experimenting with various forms, and since it already comes in 1-1/2" x 1-1/2", there is no milling involved; just cut them up into 6" to 8" blanks. The downside of fir is that it tends to splinter easily and is too flexible for more serious prototyping.

Poplar

Poplar is stronger than Fir, making it better for more serious prototyping of longer work. It is still relatively inexpensive but requires milling to make turning blanks.