Creating Four–Strand Braids in TurboCAD®

This article describes a method for modeling four–strand braids such as those illustrated in Figure 1. The technique discussed here requires no mathematics and uses only the tools available in TurboCAD v8.x Professional. Stated very briefly, the procedure is to create four copies of a Pipe, or an extrusion, using a filleted 3D Polyline as the extrusion path.

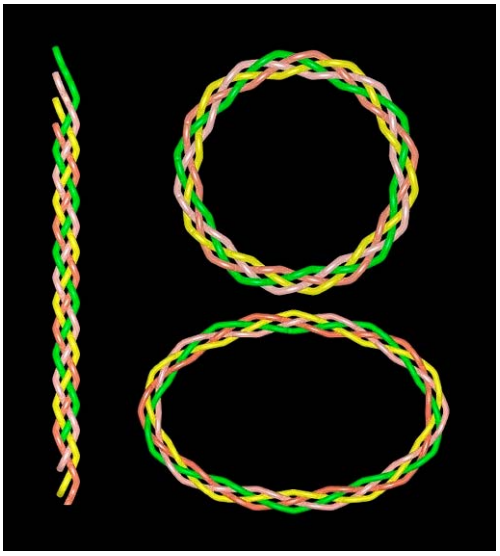

Figure 1
Four-Strand Braids

The extrusion path

We shall begin by learning how to construct that extrusion path. The key to this technique is the 2D *template* illustrated in Figure 2. Make one of these for yourself in a new TurboCAD drawing, using Square "Point" objects with the colors as shown in the illustration. (Don't include the dimensions.) Select the eight Point objects and Group them.

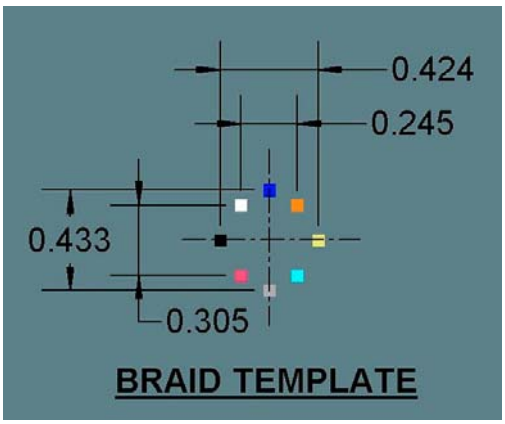

Figure 2
The Braid Template

As I shall explain in greater detail, the extrusion path for a single strand of a straight braid is built by linear–copying the template along the length of the braid and then snapping a 3D Polyline to a particular colored Point on each successive copy of the structure.

Eight copies of the template are needed for one "cycle" of the braid. You'll need at least three or four cycles to make something that looks halfway decent. To begin, copy the template into a new drawing and orient it normal to the World Y axis, with the black square at the left and the blue square at the top when seen in the Front view.

The braid turns out well when copies of the template are spaced 0.25 inch apart. Go ahead and linear–copy this object, using X Step = 0; Y Step = –0.25 inch; Z Step = 0;

Sets = 32. This will produce four cycles of your first strand. I suggest you select the whole collection and place it on its own Layer so you can make it invisible later.

The next part is the most difficult in the entire exercise, requiring care and concentration. To prepare for it (for the straight braid being constructed at this time) I recommend you go to the World Plan view and then press and hold the Ctrl key while you punch the UP arrow key once or twice. This should tilt your viewpoint just enough that you can see each individual square in each copy of the template and still be able to distinguish each template from its neighbors. (Figure 3)

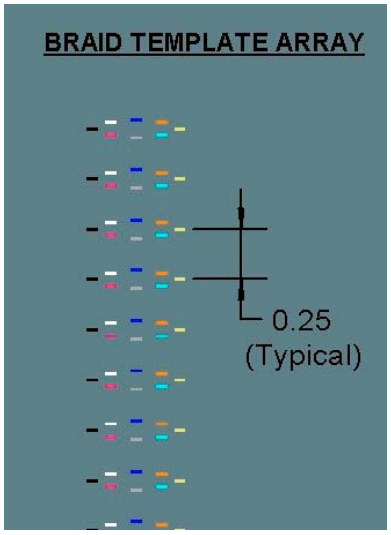

Figure 3
Templates Arrayed for Straight Braid

Now you must construct a 3D Polyline, carefully adhering to the following procedure.

Turn on the Vertex Snap mode only, plus the Magnetic Point option. Select the 3D Polyline tool. Snap to the following colored squares in the order given below. (Figure 4)

1. Black square in Template #1 (the template at the top of Figure TBD);
2. White square in Template #2;
3. Gray square in Template #3;
4. Orange ("Coral") square in Template #4;
5. Yellow ("Goldenrod") square in Template #5;
6. Cyan square in Template #6;
7. Blue square in Template #7;
8. Red ("Orange Red") square in Template #8.
9. Black square in Template #9;
10. Continue this sequence with successive templates, finishing the 3D Polyline on the red square in Template #32.

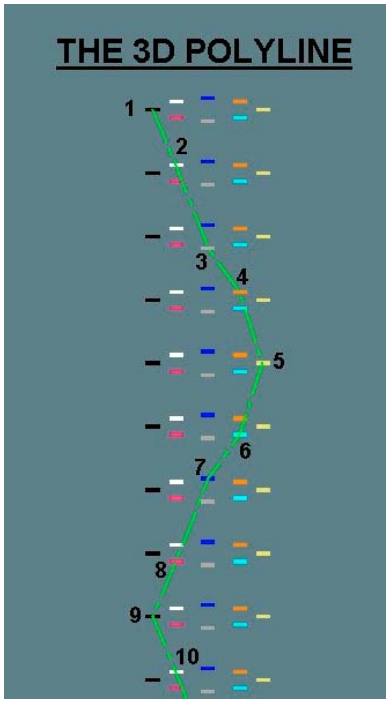

Figure 4
Constructing the 3D Polyline Path for a Straight Braid

I strongly advise you to go back and check your work at this point. Use "Edit Node" to correct any errors. It is very easy to make a mistake when drawing this entity and quite difficult to find and correct it later on. (My own most common error is to snap on a square in the same template as the previous square.)

The rest of the straight braid exercise is easy; all we have to do is to fillet the 3D Polyline and make a "Pipe," which is itself the first strand of the braid. Three additional copies complete the object. You may find the following instructions helpful…

Making the straight braid

Be sure the 3D Polyline is on a different layer from the 32 templates, then make the latter invisible. Make a copy of the 3D Polyline and move it aside for safekeeping.

Open the AddOns|Special Tools|Modify menu and select "Fillet 3D." Click on the 3D Polyline, whereupon the "Fillet3D options" dialog will open. Select the *All segments* option and the *Delete source polyline* option. In the Fillet3D radius window you'll probably see "0.209212" or something pretty close. That is the maximum fillet radius which can be applied to all intersections of the 3D Polyline's straight segments IF all the radii are equal. Accept this, because if you try for larger radii you'll find that the resulting arcs are not always connected smoothly.

To make a braid strand with a circular cross section, open Add Ons|Special Tools|Modify|Pipe and select the filleted 3D Polyline. In the resulting dialog, specify *Delete source Fillet 3D* (to get it out of the way) and enter "0.07 in" in the *Pipe radius* window. Feel free to experiment with this later on, but you'll find 0.07 is close to the largest you can use without interference between adjacent braid strands. Click OK and there's your braid strand. It'll be a strongly faceted Surface object; to improve its appearance, double–click on it and set the "Smooth" option in the *Extrusion Shape* tab.

Make the remaining four strands by linear–copying this first one. Use zero Step values in the X and Z directions. In the Y direction the correct spacing is *two times* the distance between adjacent templates; i.e., set Y Step = 0.5" if you spaced the templates at 0.25" intervals as I recommended earlier.

Render the result in Draft mode and examine it critically. If the weaving is wrong, you'll have to delete the strands and correct the original 3D Polyline.

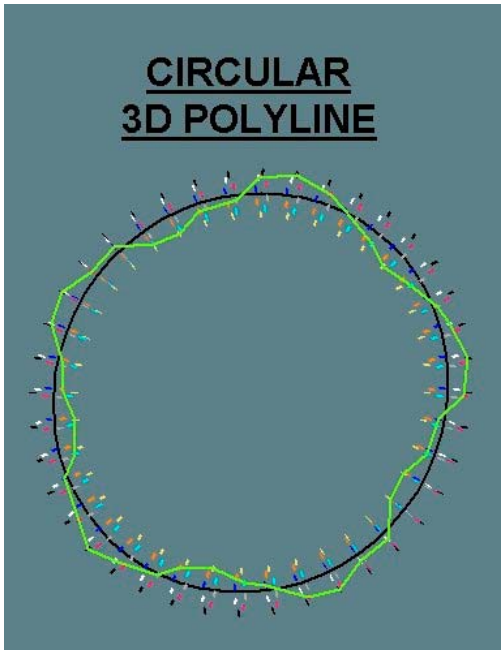

Figure 5
The Template Array
And the Extrusion Path
For a Circular Braid

A circular braid

Making a circular shape rather than a simple straight braid is a little more difficult because it's easier to make a mistake when constructing the 3D Polyline. The procedure I recommend (Figure 5) is to draw a circle about 4 inches in diameter on the World plane and radial–copy the template around

the circle. (The circle itself will prove useful later on.) Be sure to use a multiple of *eight* for the number of copies; I suggest 40, at 9–degree intervals.

Construct the 3D Polyline just as for a straight braid, following the same sequence of colored squares. Fillet it and make a "Pipe"; then radial–copy the pipe around the center of the circle, *not* around the object's Center of Extents, because the latter is not its center of symmetry. Make 4 copies altogether, at *eighteen*–degree intervals.

Elliptical braid

An elliptical shape requires a lot more work, because for best results you must create four individual templates since radial–copying won't work. Furthermore, while it is possible to make an elliptical shape by differentially rescaling a circular braid, it won't look quite right because its width will not be constant. For a good–looking finished product, you must arrange the templates in an elliptical array at the very beginning of the exercise.

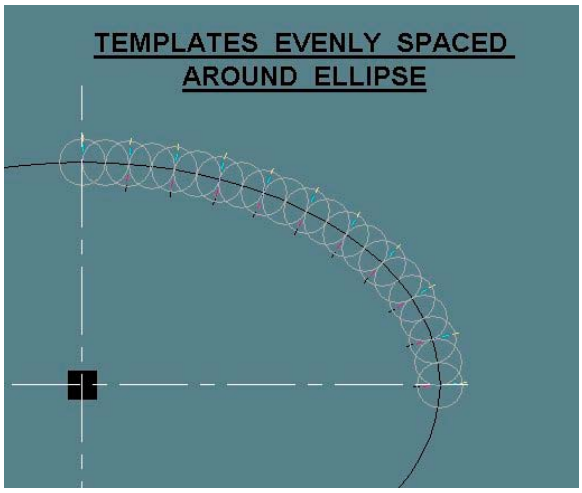

Figure 6
Braid Templates Evenly Spaced
Around One Quarter of an Ellipse

That in itself is fairly easy to do, by drawing an ellipse and using AddOns|Special Tools|Insert|Profile Along Path to place copies of the template around the ellipse. Populate one quarter of the ellipse and use Mirror Copy to complete the array. Here's one way to space 40 templates uniformly around an ellipse:

1. Draw a circle with a diameter equal to 1/40 of the ellipse's circumference (which you can read from the Selection Info Palette).
2. Snap the circle to one of the ellipse's Quadrant Points.
3. Rubber–stamp copies of the circle, placing each copy at the intersection of the ellipse and the previous copy. Work your way around one quarter of the ellipse. Figure 6 shows the work at this stage.

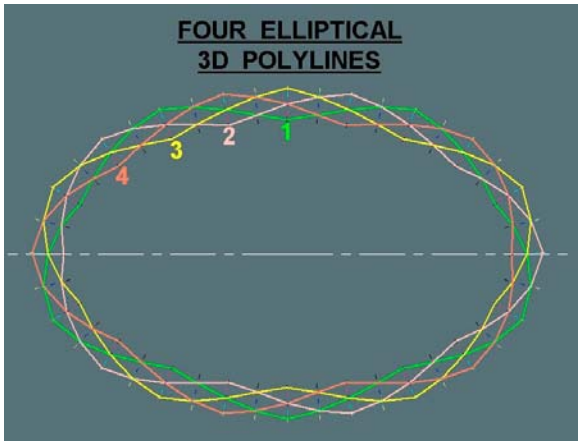

Figure 7
Four Extrusion Paths for Elliptical Braid

4. Use the Profile Along Path tool to place copies of the template at the intersection of the ellipse and every second copy of the circle.
5. Mirror–copy twice to populate the entire ellipse (remembering not to make copies of the templates located at the quadrant points).

Having arrayed the templates, go ahead and construct a 3D Polyline in the usual manner. Begin with the black square in any template and continue around the entire array, finishing at the starting point.

Now construct a second 3D Polyline, then a third, and finally a fourth. Begin each new one on a different template—not the copy right next to the one where you began the previous Polyline, but the one next to that. Figure 7 shows these four 3D Polylines.

Fillet the Polylines, then apply the Pipe tool as usual to each of them.

Fancy braids

You can create braids with multiple profiles and non-circular profiles as illustrated in Figure 8, but there are pitfalls to be avoided. One problem is that the profile twists as it progresses along the extrusion path if you use "Normal" extrusion. This isn't usually noticeable with a compact profile such as a regular polygon, but it's quite obvious with a wide rectangular profile, for example. If you choose "Rigid" extrusion to avoid this problem, you'll seed that the resulting braid is not smooth. (This could be quite acceptable. The blue and white braid in Figure 8 was made using the "Rigid" extrusion mode.)

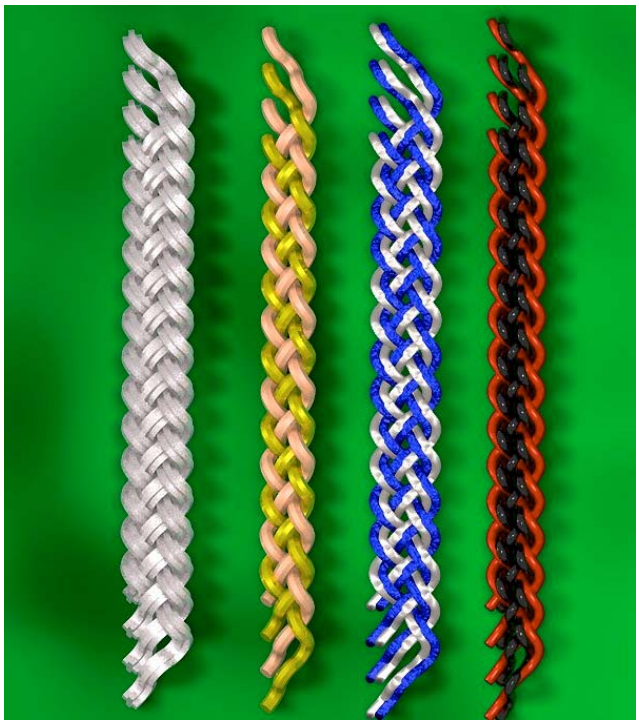

Figure 8
Fancy Braids

To use a filleted 3D Polyline as an extrusion path, you must explode it and then weld the pieces back together with "Join Polyline." To use this tool on a 3D Polyline, select all the fragments; activate "Join Polyline": right–click and select "3D Polyline"; then pick "Finish Join Polyline."

Note that you can scale the original un-filleted 3D Polyline along any or all axes and then fillet it. After doing this and exploding the result, you may find it necessary to use "Join Polyline" *twice* to put it all back together.