Design of a Cow Catcher

Don Snyder

1 Introduction

The St. Louis Woodworkers Guild contributes to the community through a variety of outreach efforts. Among them is an active program in which members make toys and distribute them to children who are in local hospitals. After the beginning the toy program in 1994, a total of 40,000 donated toys will be achieved by the end of 2014. Another outreach effort by members is to help in the restoration of antique trains exhibited at the National Museum of Transportation, which is a popular site within the St. Louis County Parks Department for individuals and their families. A recent challenge confronted by members for one of the trains is to restore its wooden *cow catcher*, seen to be badly damaged in Figure 1. This documents some thoughts motivated by that goal.

I want to thank Guild member Bob Brinkman for bringing this project to my attention. He and another Guild member, John Wetter, are contributing their time and effort in this outreach project at the Museum of Transportation.

Figure 1. Cow catcher to be restored

A *cow catcher* on a locomotive, also called a *pilot*, is a contraption positioned up front and low that is intended to sweep objects out of the way as the train moves forward on the tracks. Catchers do not *catch* anything but, rather, they cause objects encountered on the track to be deflected aside so they do not impede forward progress and so the objects, if they are cows or other living creatures, are perhaps not injured traumatically by a direct, blunt impact. Cow catchers have a shape that sweeps objects to either side, so they have a rather pointed shape, but they are smooth otherwise. Examples of catchers are displayed in Figure 2 and Figure 3.

Figure 2. Example of a cow catcher

Figure 3. Examples exhibiting the variety of cow catcher shapes

As can be seen, cow catchers come in a variety of shapes. Some traditional ones have unusual curved shapes, as evident in Figure 2 and Figure 3. A textbook on analytic geometry (also called descriptive geometry) written in 1910 provides a catcher as an example of a hyperbolic paraboloid [3.1, page 114]. A hyperbolic paraboloid is a three-dimensional surface having a shape involving bidirectional curves (hyperbolas and parabolas) somewhat like a horse-saddle. These surfaces occur not only in old time catchers but nowadays in architectural constructions,

Figure 4. Roof structures based on hyperbolic paraboloids

such as in the roofs shown in Figure 4, commercial products, such as the Pringles potato chips, chair and shades in Figure 5. Hyperbolic paraboloids can also be

Figure 5. Commercial products involving hyperbolic-paraboloids: Pringles potato chips, a chair, a tee-shirt, and a shade covering

found in art works; see Fig 6.

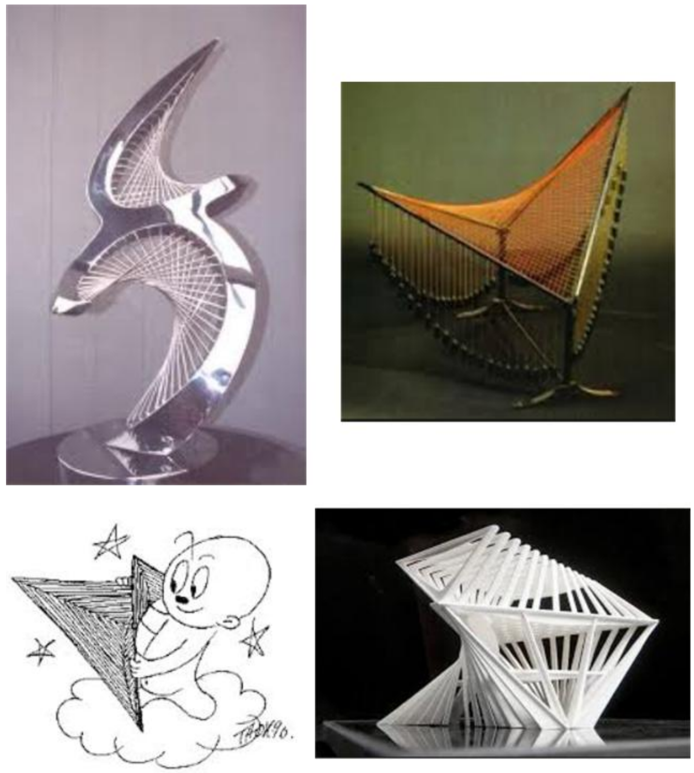

Figure 6. Hyperbolic paraboloids in art objects

2 Descriptions of hyperbolic paraboloids

A hyperbolic-paraboloidal surface is a quadratic surface for which points (x,y,z) on the surface satisfy

$$\frac{z}{c}=\frac{x^2}{a^2}-\frac{y^2}{b^2},$$

where a, b and c are constants that scale the size of the surface, and the sign of c determines the up-or-down orientation of the surface. Figure 7 displays the surface as having a saddle shape for $c=-1$, and $a=b=1$ when graphed for $-1\leq x\leq 1$ and

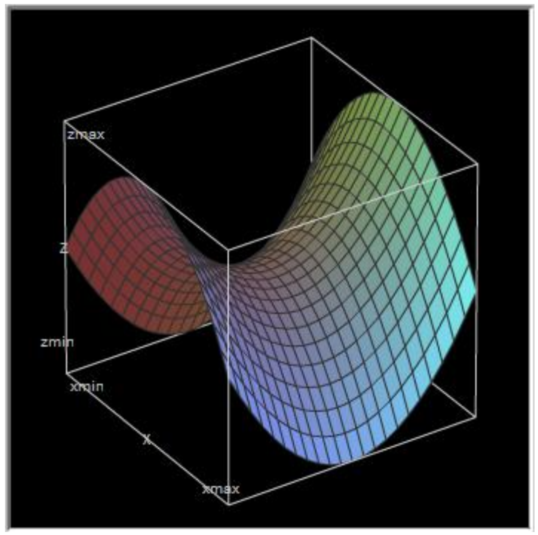

Figure 7. Graph of a hyperbolic paraboloidal surface

$-1 \le y \le 1$. Figure 8 displays a surface for $c = -1$, $a = \sqrt{2}$ and $b = 1$ for $0.5 \le x \le 1$ and $0 \le y \le 0.5$.

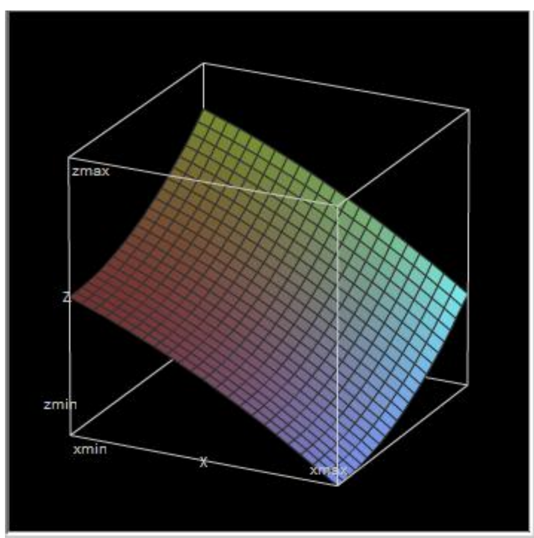

Figure 8. Graph of a hyperbolic-paraboloidal surface

Figure 7 and Figure 8 were produced using an interactive, three-dimensional graphing procedure available on the internet [3.2].

The intersection of a hyperbolic-paraboloidal surface with a plane that is parallel to the X-Z plane is a parabola; the intersection with a plane that is parallel to the X-Y plane is a hyperbola. An interesting characteristic of hyperbolic-paraboloidal surfaces is that they are *doubly ruled*, meaning that they can be constructed with a lattice network of straight elements [3.3]. For every point on the surface of a hyperbolic paraboloid, there are two straight lines that pass through the point, and both lie on the surface. An illustration of this property made by Brian Vincent is in Figure 9. It is this property that makes the surfaces useful in applications.

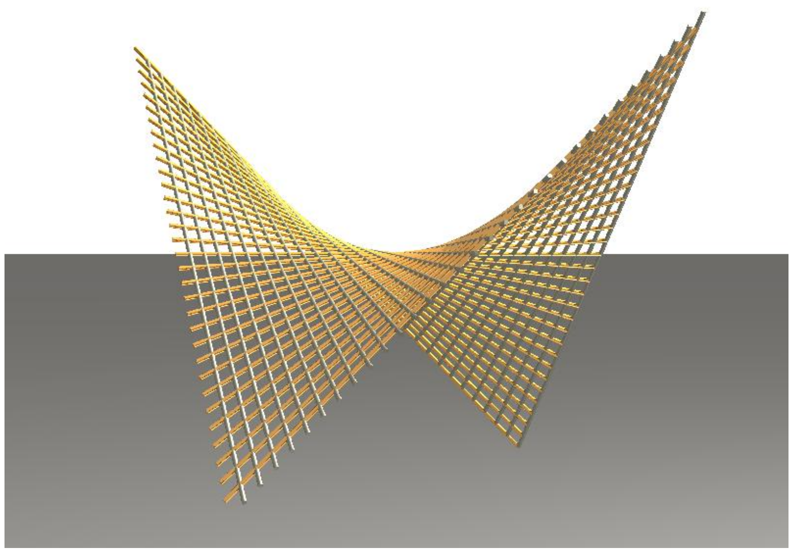

Figure 9. Hyperbolic paraboloidal as a doubly ruled surface [3.4]

3 Use of SketchUp to design and draw a cow catcher and to determine table-saw setup angles to make the parts

A method for drawing a hyperbolic-paraboloidal surface in SketchUp is developed in a YouTube video available on the Internet [3.5]. The method described can be adapted to design and make a drawing of a model of a cow catcher. The drawing can then be used to determine the blade-tilt and miter-gauge angles needed to cut the parts for constructing the catcher.

I will outline the steps to make the preliminary drawing of a cow catcher that is in Figure 10.

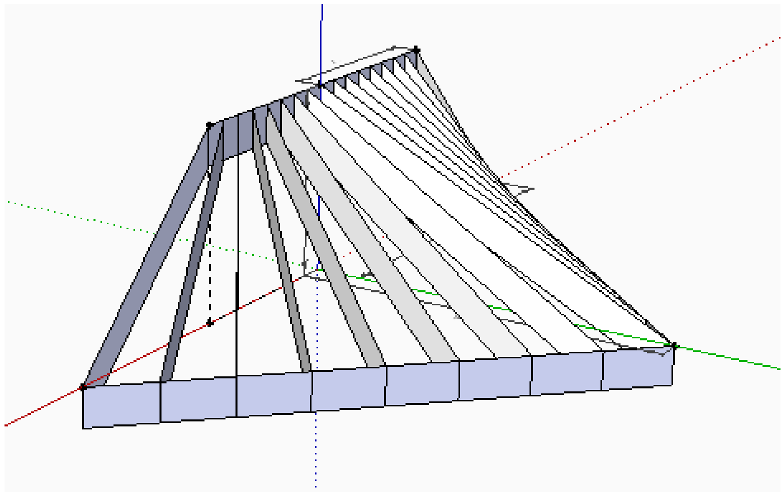

Figure 10. Preliminary SketchUp drawing of a cow catcher

Step 1. Place reference points along the x-y-z axes that indicate the locations of the corners of the catcher. These would be located according to the desired dimensions of the catcher. This step yields Figure 11.

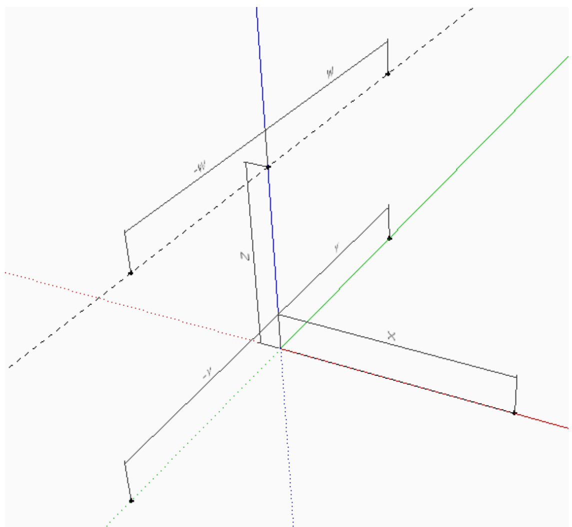

Figure 11. Step 1: locate critical dimensions X, Y, -Y, and Z

Step 2. Draw lines between the critical points. These define the top and base of the catcher. This step yields Figure 12. These lines form edges that meet at six vertices A, B, C, D, E and F.

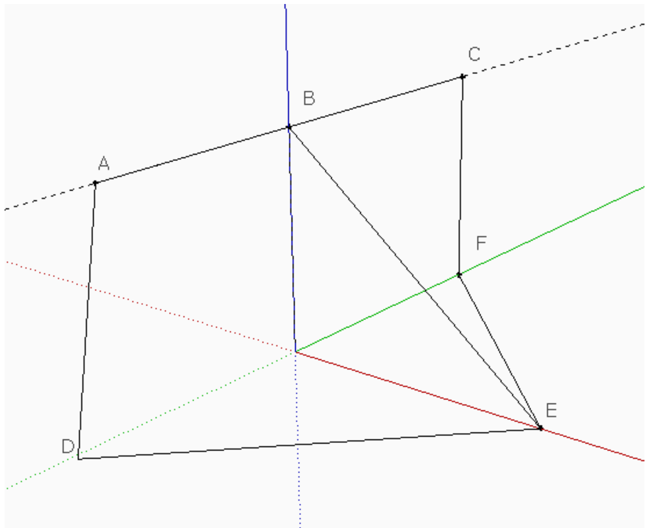

Figure 12. Step 2: draw lines between critical points

Step 3. Now (ruled) lines in the hyperbolic-paraboloidal surface of the catcher are added. Start by drawing a line from the midpoint of edge A-B to the midpoint of edge D-E. Do the same from edge B-C to edge E-F. The result is Figure 13.

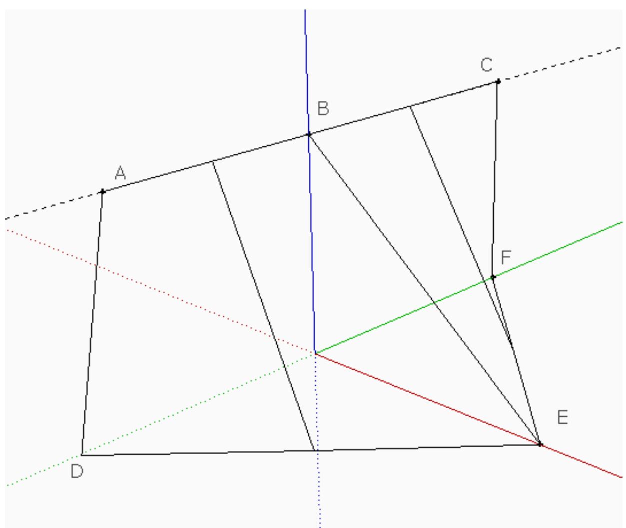

Figure 13. Step 3: begin adding ruled lines

Step 4. Edges A-B, B-C, D-E and E-F are each divided into two equal-length subedges. Repeat Step 3 for each of these eight subedges. The result is in Figure 14.

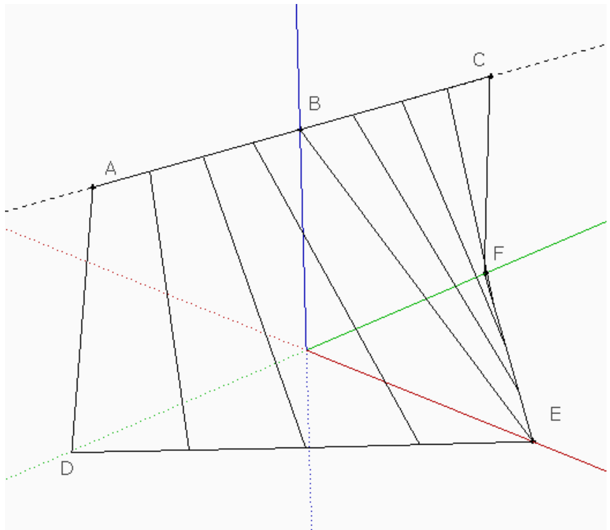

Figure 14. Step 4: add more ruled lines

Step 5. Repeat Steps 3 and 4 until the desired number of staves is obtained. At this point there are nine staves, and we will stop there for now.

Step 6. Add surface planes to the edges and staves. The result is in Figure 10.

Step 7. Orient the cow catcher model to gain view access to measure the required miter-gauge angles using the angular-dimensioning tool of SketchUp. Examples are in Figure 15.

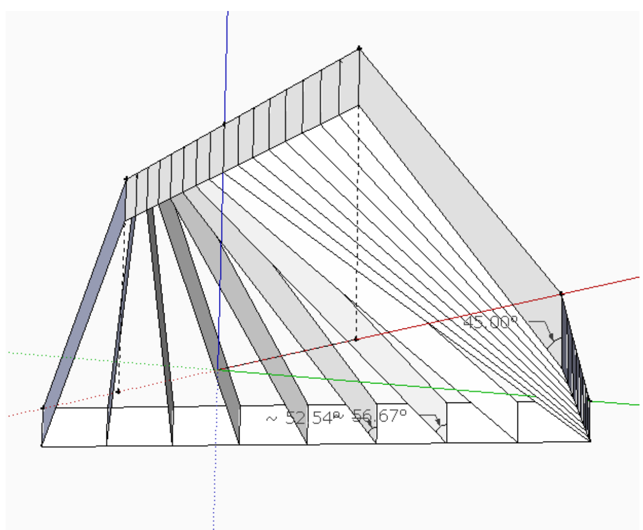

Figure 15. Measure required miter-gauge angles using the angular-dimension tool

Step 8. Orient the cow catcher model to gain view access to measure the dihedral angles between intersecting planes. These are the blade-tilt angles for butt joints. Use the protractor tool to accomplish this. Examples are in Figure 16.

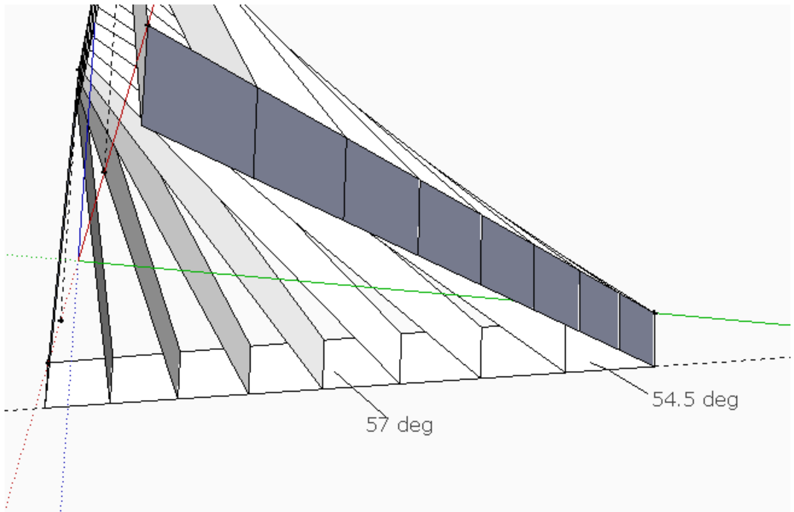

Figure 16. Measurement of dihedral angles for blade-tilt angles

One could go further in developing a model for a cow catcher. For example, each of the planes in Figure 10 could be thickened (using the push tool in SketchUp) to represent the thickness of the material to be used in constructing the catcher. This will show the shaping needed in the top surface of each stave so it conforms approximately to the hyperbolic-paraboloidal surface. Also, a catcher that is to include a cutout area, such as in the catcher shown in the lower left panel of Figure 3 and the catcher to be restored in Figure 1, can be included; this cutout area is for accessing a coupler that is at the front of some locomotives. Pursuing these model variations is left for a future effort.

4 Conclusion

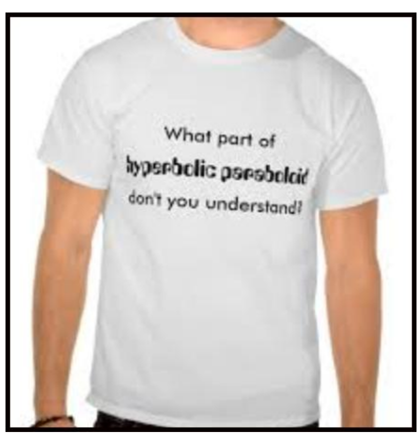

Figure 17. What's left to know about hyperbolic paraboloids?

Much more about hyperbolic paraboloids can be found with a search of the Internet. For example, a search will yield information about the curvature of the surface and its dimensions. Also, there is much more that can be achieved using SketchUp in the design of a cow catcher having the shape of a hyperbolic paraboloid.

3 References

3.1 Gardner C. Anthony and George F. Ashley, *Descriptive Geometry*, Heath & Co., 1910. Available as an e-book at http://books.google.com/.

3.2 http://www.math.uri.edu/~bkaskosz/flashmo/graph3d/

3.3 http://en.wikipedia.org/wiki/Ruled_surface

3.4 Brian Vincent, Ruled Surface, http://www.ms.uky.edu/~lee/visual05/gallery/parab.bmp

3.5 Hyperbolic Paraboloid in SketchUp http://www.youtube.com/watch?v=IzW0eiRSYXY