Modeling and Patterning Developable Hull Surfaces with Pro/Engineer Creo 2

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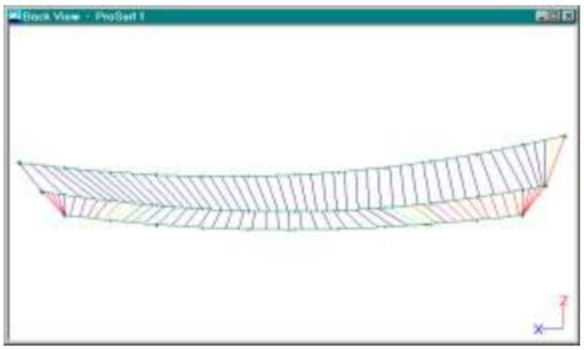
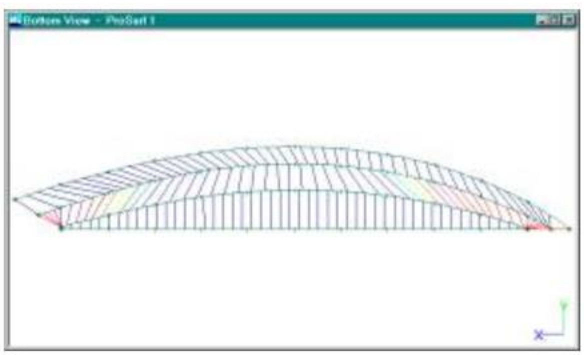
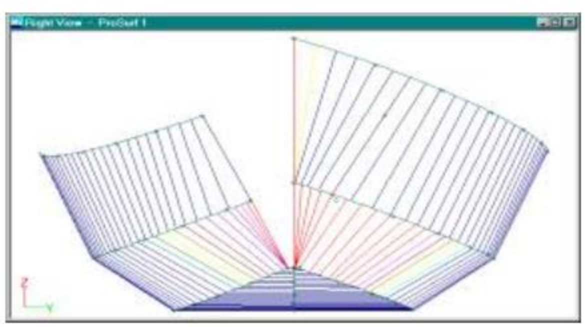
Project: Use PTC Creo 2.0 software to derive a method to accurately model the lower side panel surface and create a dimensioned flat pattern for the lower side panel of the dory hull model shown:







The three views above are taken from the tutorial "Developable Plate Ruling Line Example" by Stephen Hollister of New Wave Systems, Inc. at www.newavesys.com

The model used is from *Skene's Elements of Yacht Design,* by Francis S. Kinney (Dodd, Mead & Co., Eighth Edition, 1973, pg. 47).

The designer of a hull intended for construction with sheet material such as plywood, aluminum or steel typically provides a table of offset dimensions defining the sheer, chine, and/or bottom curves. The offsets tabulate the x, y and z coordinates of points on the curves. Three dimensional spline curves connect through these points. The spline curves define unique developable surfaces which connect the pairs of curves. Designers in other industries such as those involving textile, sheet metal or sheet plastic products use similar types of curves to create similar types of developable surfaces.

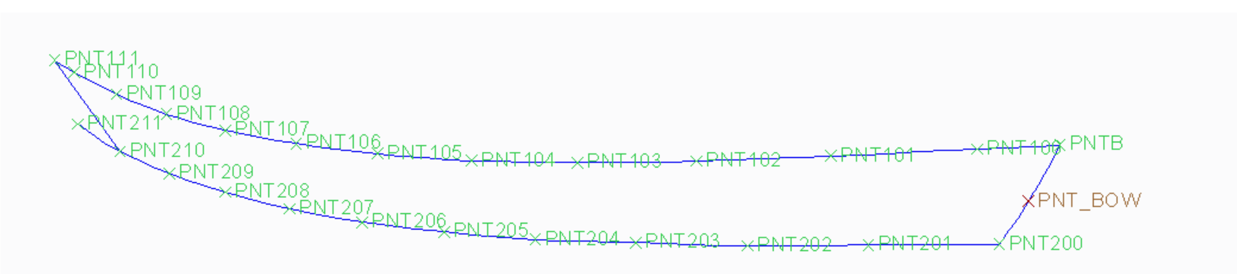
Project Statement:

Given two curves that define a developable surface:

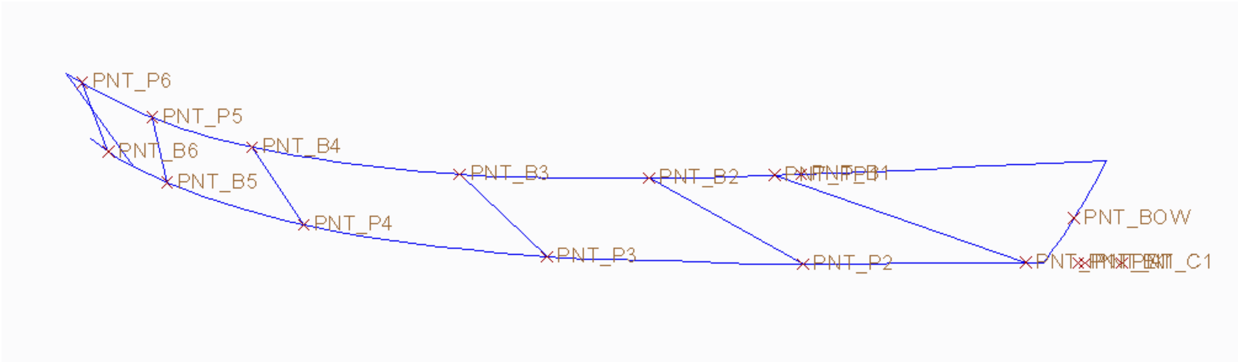
- How to accurately model that surface?

-How to generate the flat pattern of that surface?

The surface of the lower side panel of the dory is used as the example in this project. This surface is defined by the chine curve and the bottom curve. The bottom curve is where the bottom panel joins the lower side panel. The chine curve is where the lower side panel joins the upper side panel. (The top edge of the upper side panel is the sheer):

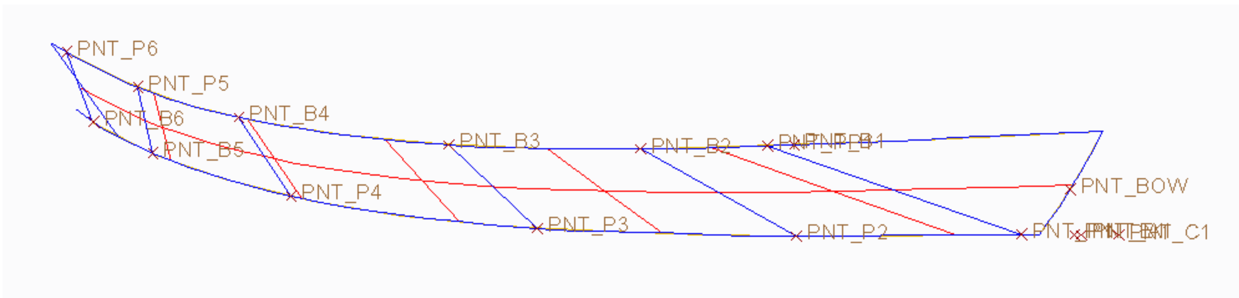


First: a set of rulings (ruled surface rulings) is found:

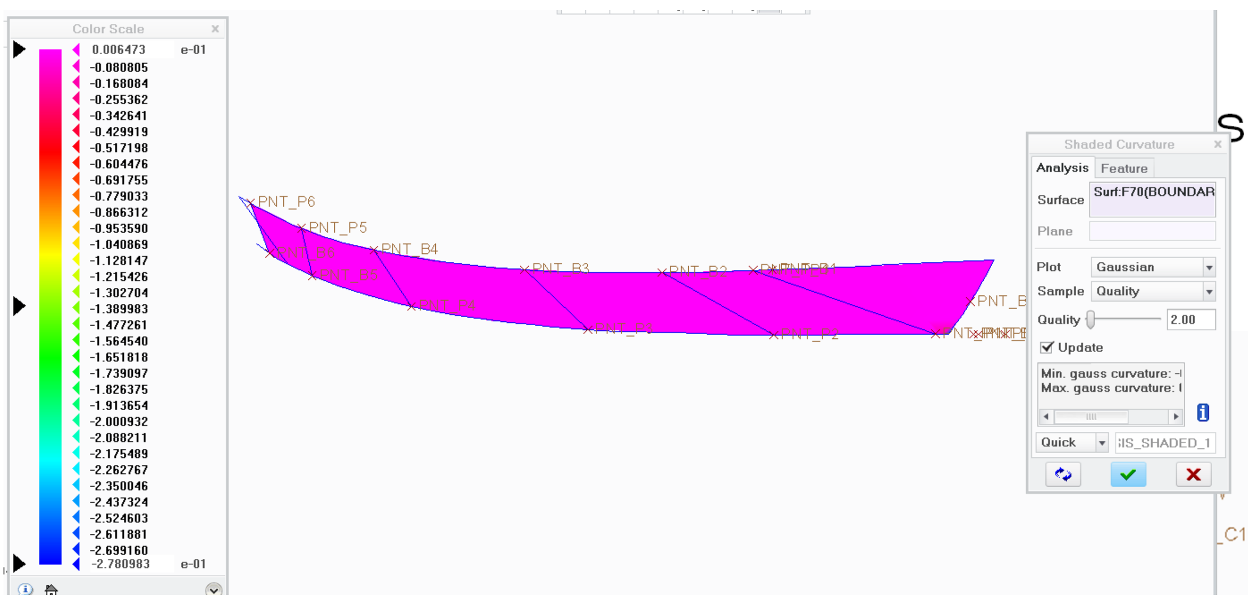


Each of the rulings of the set is found by trial and error; pick, say, as an arbitrary example point PNT_P2 on the bottom curve, and guess the location of the corresponding point PNT_B2 on the chine curve. Then create a tangent axis to the respective curve through each of the two points. The longitudinal (fore and aft) location of point PNT_B2 is adjusted incrementally until the tangent axes through PNT_B2 and point PNT_P2 are co-planar. The co-planar condition is determined when the measured distance between the two axes is minimized. The ruling is then drawn connecting the two points. Additional rulings are found in a similar manner.

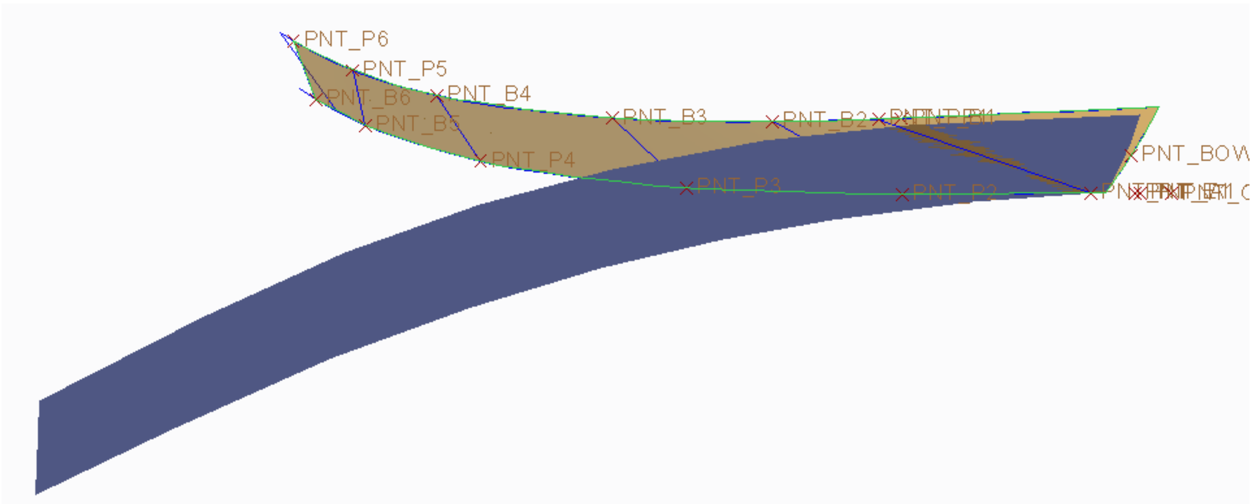
The rulings are straight line elements of the surface. Using Creo, a boundary blend is created that uses the chine curve and the bottom curve as primary curves and the rulings as secondary guide curves:

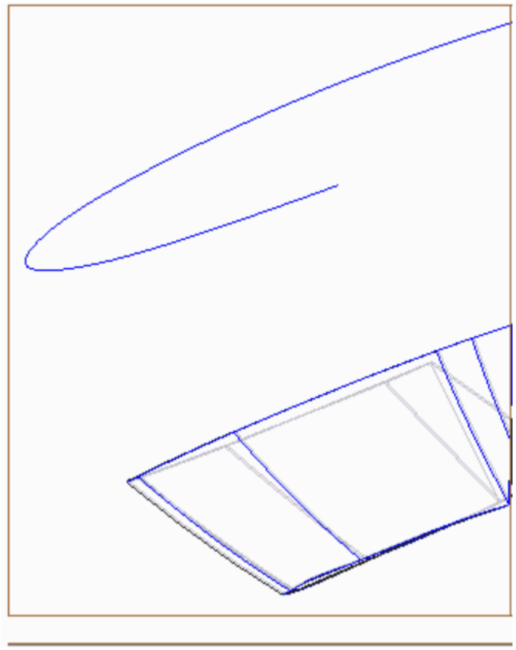


Absence of curvature indicates that the surface is developable:

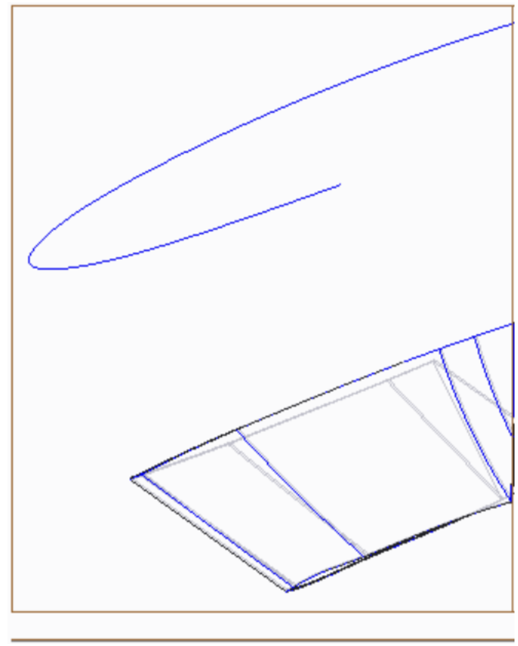


The quilt is flattened:



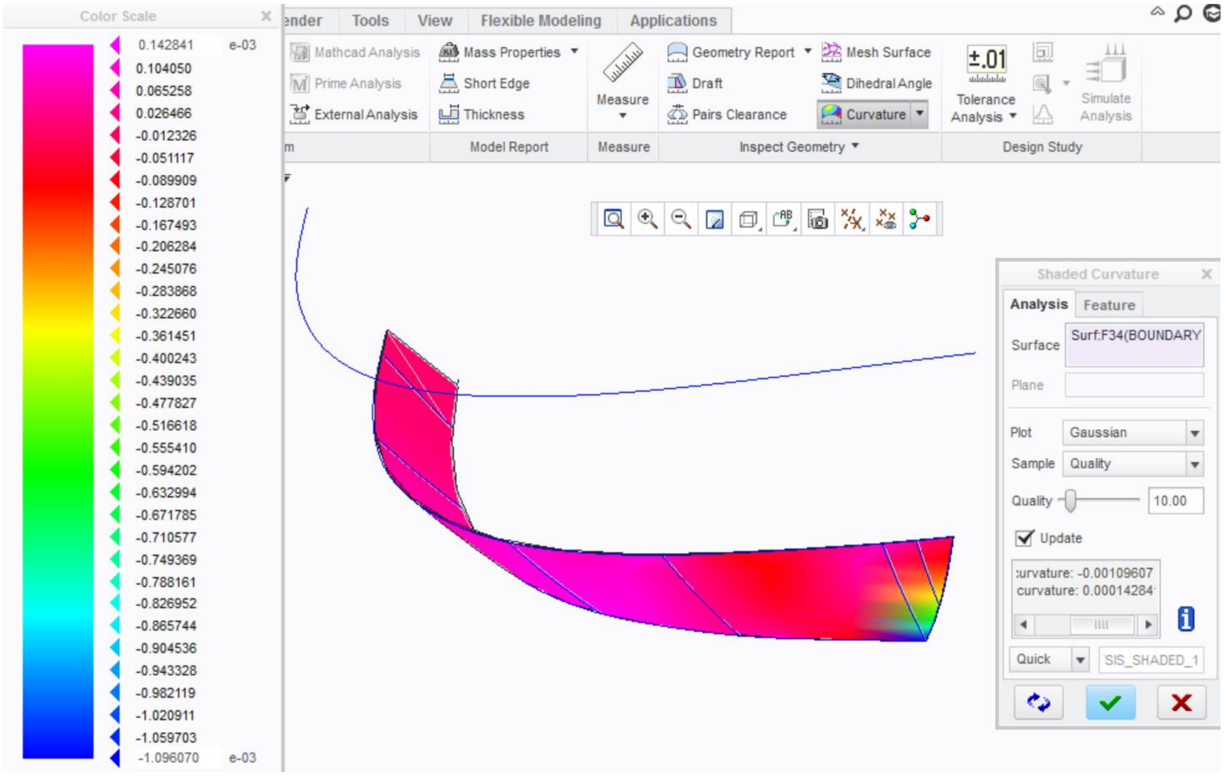


RULINGS NOT USED

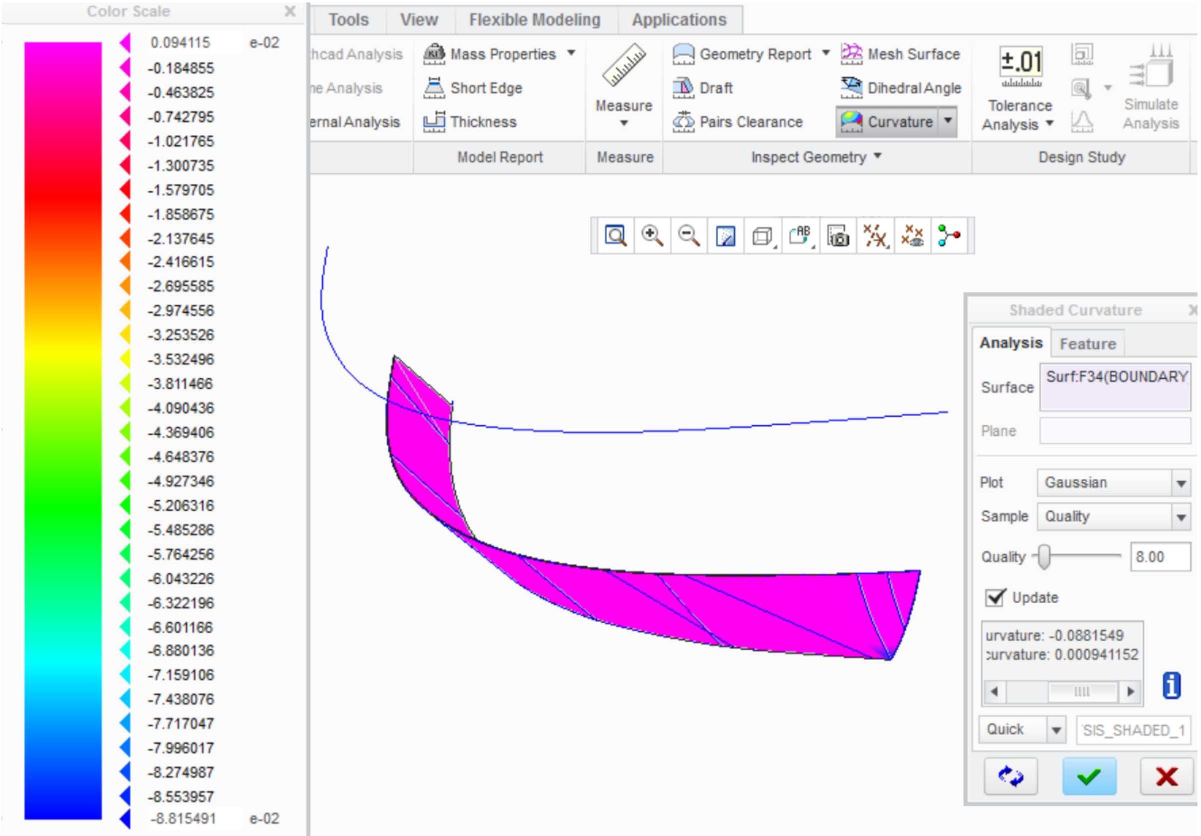


RULINGS INCLUDED

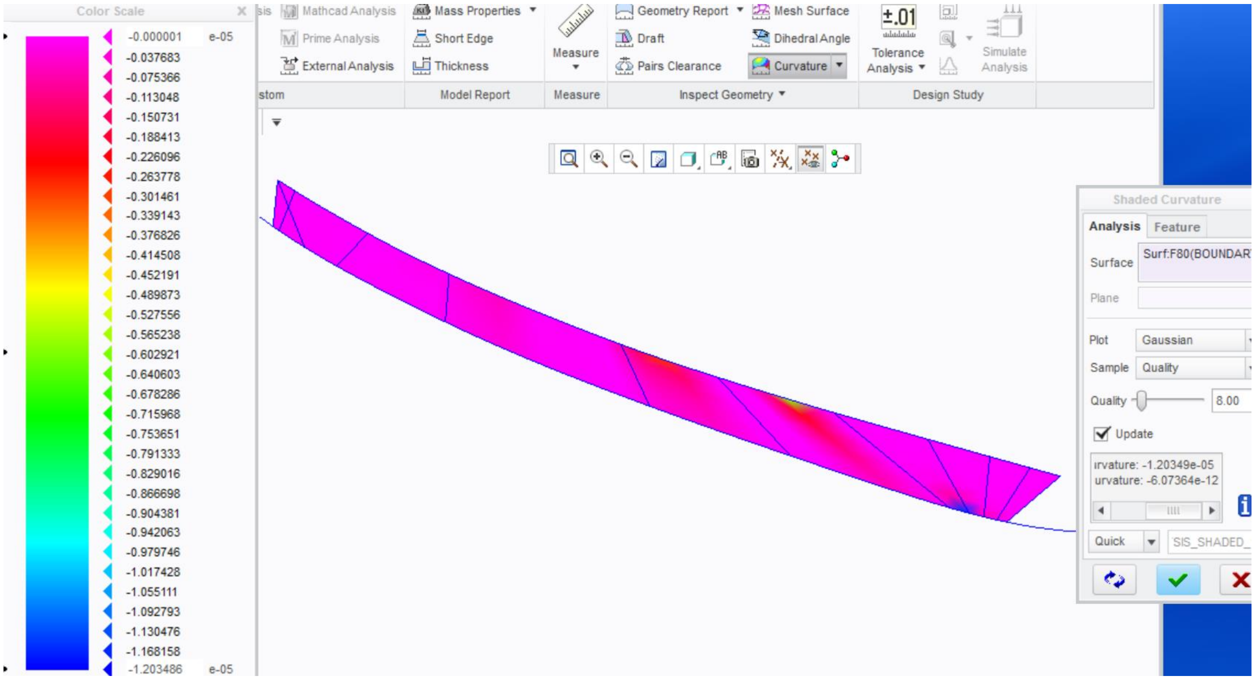
Above is a side by side comparison of two versions of the starboard half of the front view of the hull (shown as if the hull was cut in half down the centerline with the centerline at the right in each view). The sheer line curve is shown above the lower side panel surface in both views to provide context. The lower side panel surface shown in each view is a boundary blend surface which was created using the bottom edge curve and the chine edge curve. Rung-like vertical station frame curves are shown. These vertical curves were created from parallel vertical planar sections by the use of the "create-curve-from-section" command. The view at the left is of the boundary blend which was created using only the endings as secondary guide curves. The view at the right is of the boundary blend created with the rulings and the endings used as secondary guide curves (the rulings are not shown in this view). The view at the left shows straighter sections forward, near the bow, than the view at the right. The view at the left also shows more curvature amidships.



The view above shows the Gaussian curvature of the boundary blend which was created with only the ending curves used as second direction curves -- one at each end –-rulings were not used. The vertical rung-like station curves are visible. The maximum curvature is -.1096 e-3 in^{-2}.



The view above shows the Gaussian curvature of the boundary blend which was created using the rulings as secondary curves. Also shown are the vertical rung-like station frame curves that were added after the boundary blend was created. The longer, more diagonal curves are the rulings which were used as secondary curves when this boundary blend was created. The maximum Gaussian curvature, -8.815e-2 in^{-2}, is greater in this case than in the case where only the two secondary curves were used, but only at the one small blue spot shown by the bow.



To reduce the total Gaussian curvature, the bottom curve is extended and additional (minor) curve faring adjustment is done. The boundary blend surface with 9 rulings selected as second direction curve chains, above, shows much less Gaussian curvature than in the previous cases. Note the maximum curvature value of only -1.203e-5 in^{-2}.

Although a flat pattern may be created from a boundary blend surface that has been created using two primary curves and only two secondary (end) curves, that surface will not likely conform to the actual shape that the real physical sheet material will conform to. Without including the rulings the manner in which the sheet material conforms to the curves will not be accurately modeled. The method presented here is effective because by including the rulings in the boundary blend the true developable surface connecting the two curves is closely approximated.

Showing the Rulings on the Flat Pattern

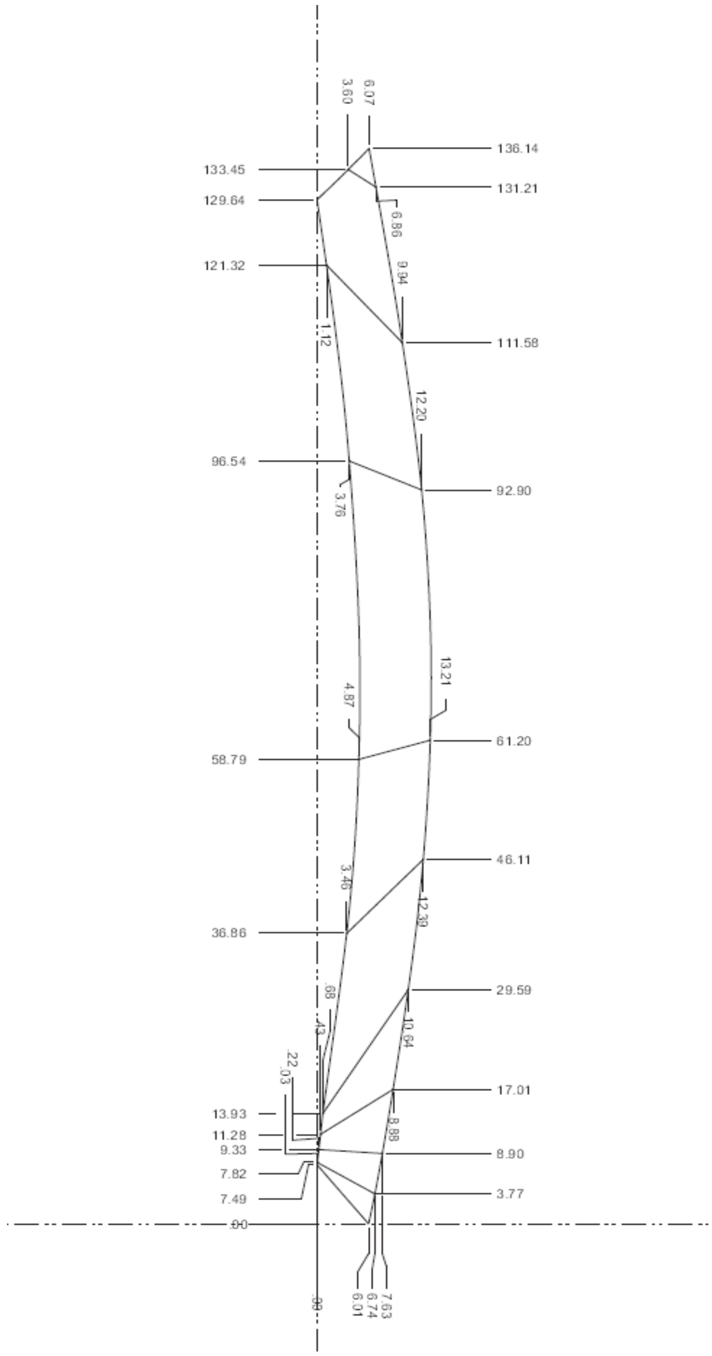
To transform the rulings from the boundary blend surface to the flattened quilt, diameter 0.1" holes are extruded from the vertical center plane to penetrate the boundary blend surface before it is flattened. From the side elevation view, the holes are located at the apparent intersection of the ruling with the chine and bottom. The boundary blend surface is then flattened using the "flatten quilt" command, and the holes on the flat pattern are used to locate the rulings and the dimensioning points for the flat pattern.

The steps above yield the flat pattern with rulings and an accurate sectional representation of the internal and external curvature of the hull surface for the lower panel.

The accurate sectional representation of the hull is important because in order to accurately design and pattern the internal structural components that mate to the internal surface of the hull, the representation of the internal curvature is necessary. The accurate characterization of the curvature of the external surface is important in analyzing the predicted hydrodynamic behavior of the hull.

To create a Creo Sheetmetal part representation of the lower side panel, the boundary blend surface is offset by the thickness of the sheet. Four boundary blend surfaces are created, one to enclose each of the four edge gaps. Then the surfaces are merged and the result solidified. Then the merged volume is converted to Sheetmetal.

Although I could not create a flat pattern from this Sheetmetal representation because there was no flat fixed wall to reference, the Sheetmetal lower side panel I created was an appropriate component for inclusion in a dimensionally accurate solid assembly model of the dory hull.



The dimensioned flat pattern with rulings is shown above.

Appendix:

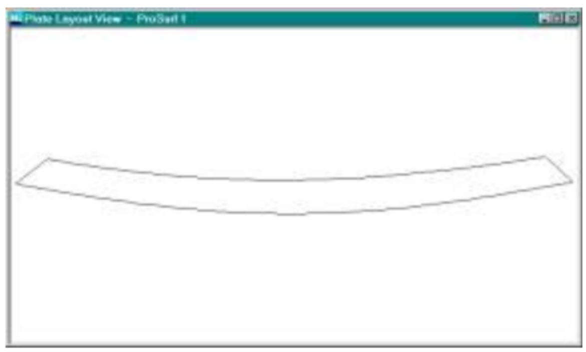
Example and Views below are taken from the tutorial “Developable Plate Ruling Line Example” by Stephen Hollister of New Wave Systems, Inc.

Dory.txt - Notepad

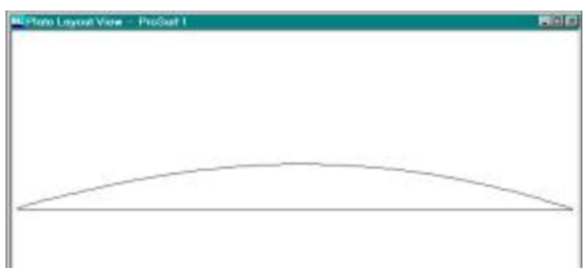
File Edit Search Help

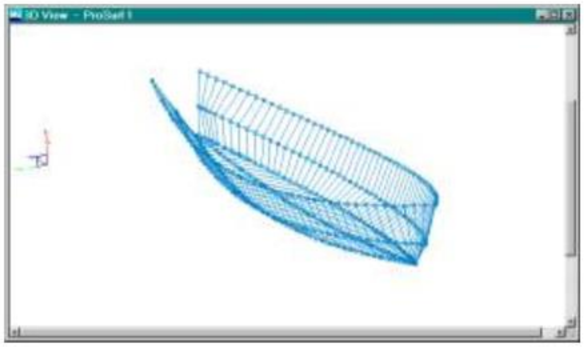
```
PLINE3D
Npts=13
  -0.9167  0.0     2.229
   0.0     0.573   2.031
   1.0     1.024   1.836
   2.0     1.365   1.671
   3.0     1.586   1.539
   4.0     1.709   1.441
   5.0     1.750   1.376
   6.0     1.718   1.344
   7.0     1.617   1.344
   8.0     1.452   1.375
   9.0     1.225   1.438
  10.0     0.948   1.531
  11.0     0.625   1.645
PLINE3D
Npts=13
  -0.51    0.0     1.146
   0.0     0.271   1.052
   1.0     0.677   0.896
   2.0     0.998   0.760
   3.0     1.219   0.658
   4.0     1.346   0.596
   5.0     1.387   0.574
   6.0     1.346   0.588
   7.0     1.226   0.634
   8.0     1.031   0.710
```

the developed 2D pattern for the upper side

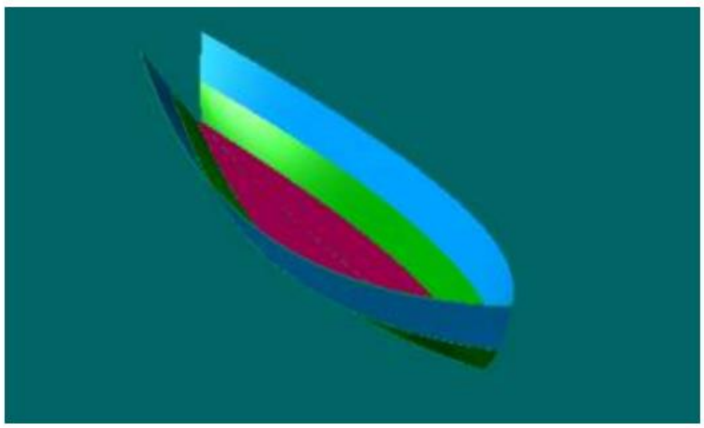


the developed 2D pattern for the lower side





3D Wireframe View of the Hull

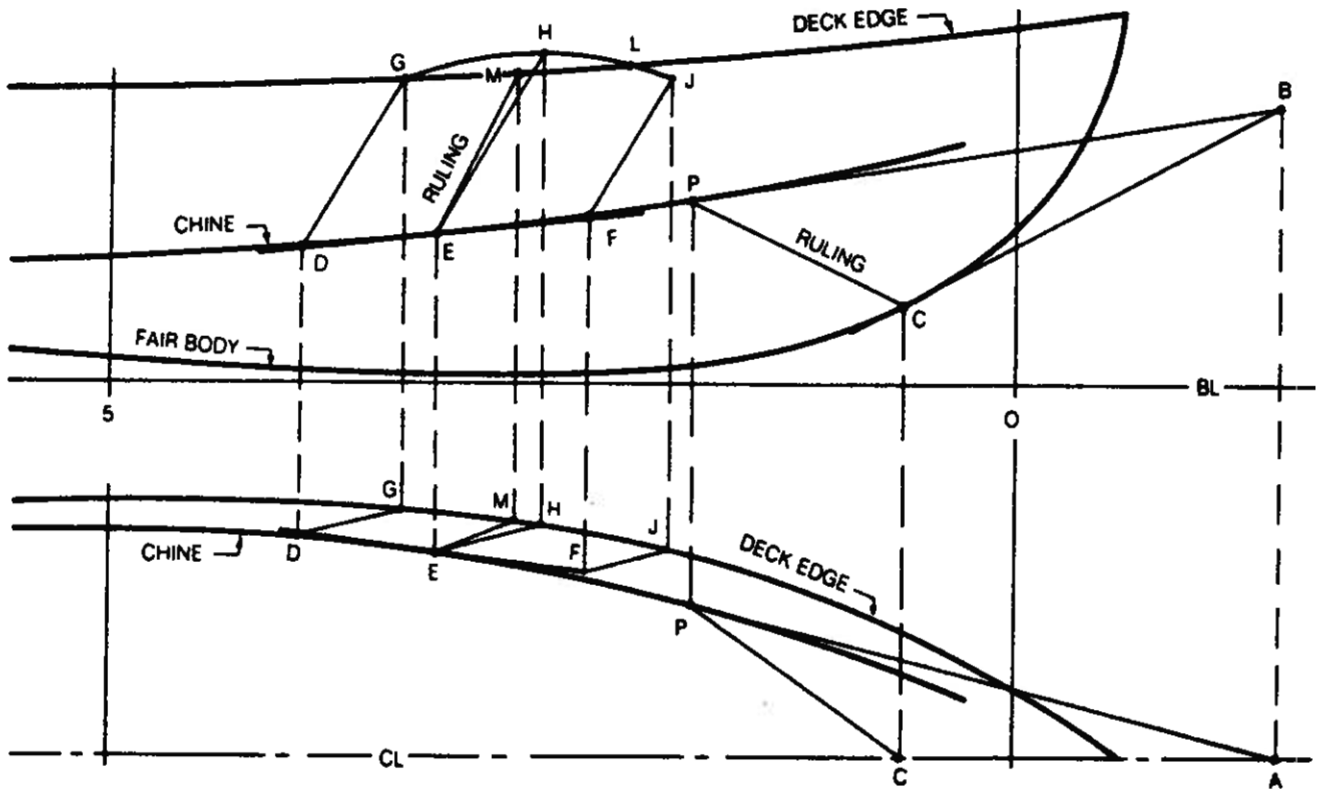


3D Render View of the Hull

The views shown above are taken from the tutorial “Developable Plate Ruling Line Example” by Stephen Hollister of New Wave Systems, Inc. They are shown here for reference and clarity.

My observation: the rulings I present here do not appear to match those generated by Mr. Hollister’s software as illustrated in his article.

The diagram below presents the graphic method of finding rulings from a two dimensional drawing showing a set of orthographic views of the chine and deck. This is the classic method presented by Ullmann Kilgore in "Developable Hull Surfaces," *Fishing Boats of the World*, Fishing News (Books) Ltd V. 3, 1967.



To find ruling between deck edge and chine:

1. Draw $\overline{DF}$, tangent to chine at E.
2. Draw $\overline{DG}$, $\overline{EH}$ and $\overline{FJ}$ in half-breadth plan parallel to each other at arbitrary angle.
3. Project G to deck edge in profile.
4. Find points M and J in profile as projections from half-breadth where $\overline{DG}$, $\overline{EH}$ and $\overline{FJ}$ are parallel.
5. Draw curve GHJ in profile cutting deck edge at L.
6. M is midpoint of GL and is end of ruling $\overline{EM}$
   Plane DGJF is tangent to chine at E.

   Curve GHLJ is the intersection of plane DGJF with a cylindical surface with vertical elements through deck edge.

To find ruling between stem profile and chine:

1. Draw $\overline{PA}$ and $\overline{PB}$ tangent to chine at P.
2. Project point A in half breadth at CL, to point B in profile.
3. Draw $\overline{BC}$ tangent to stem profile at C, giving end C of ruling $\overline{PC}$.

Figure 1.6: Kilgore's Manual Graphical Solution