

Automation of Propeller Blade Design Process

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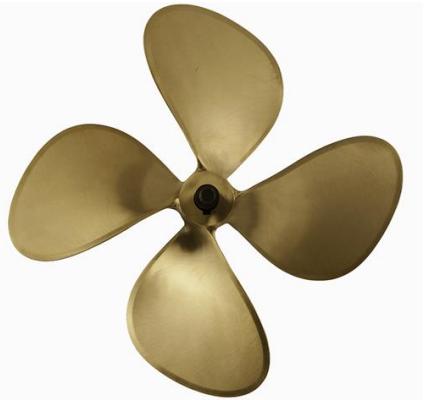
Presenter Type: Graduate

Mentor: Dr. Lothar Birk

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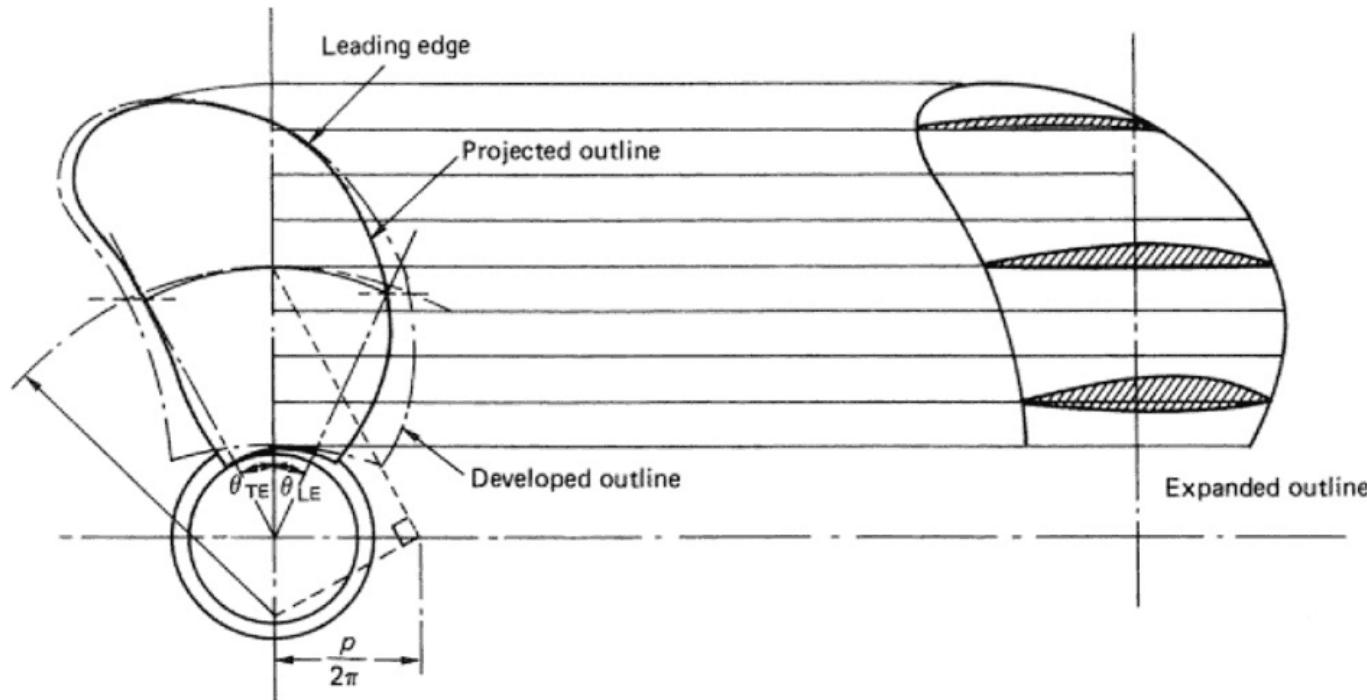
- A. Brief Introduction
- B. Design Process
- C. Discussion
- D. Demonstration





Propellers

Brief Introduction

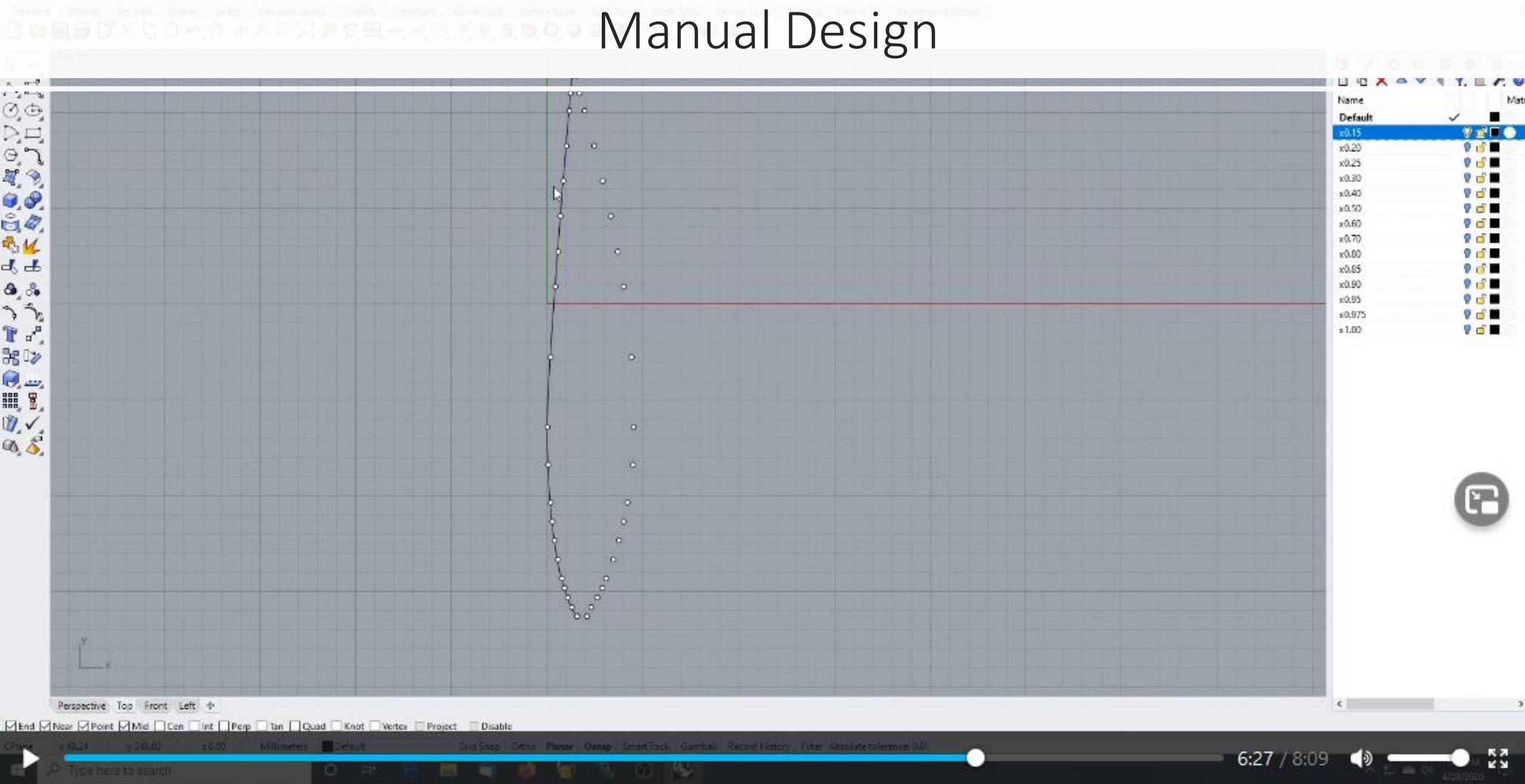


Manual Design

Process of creating Face & Back

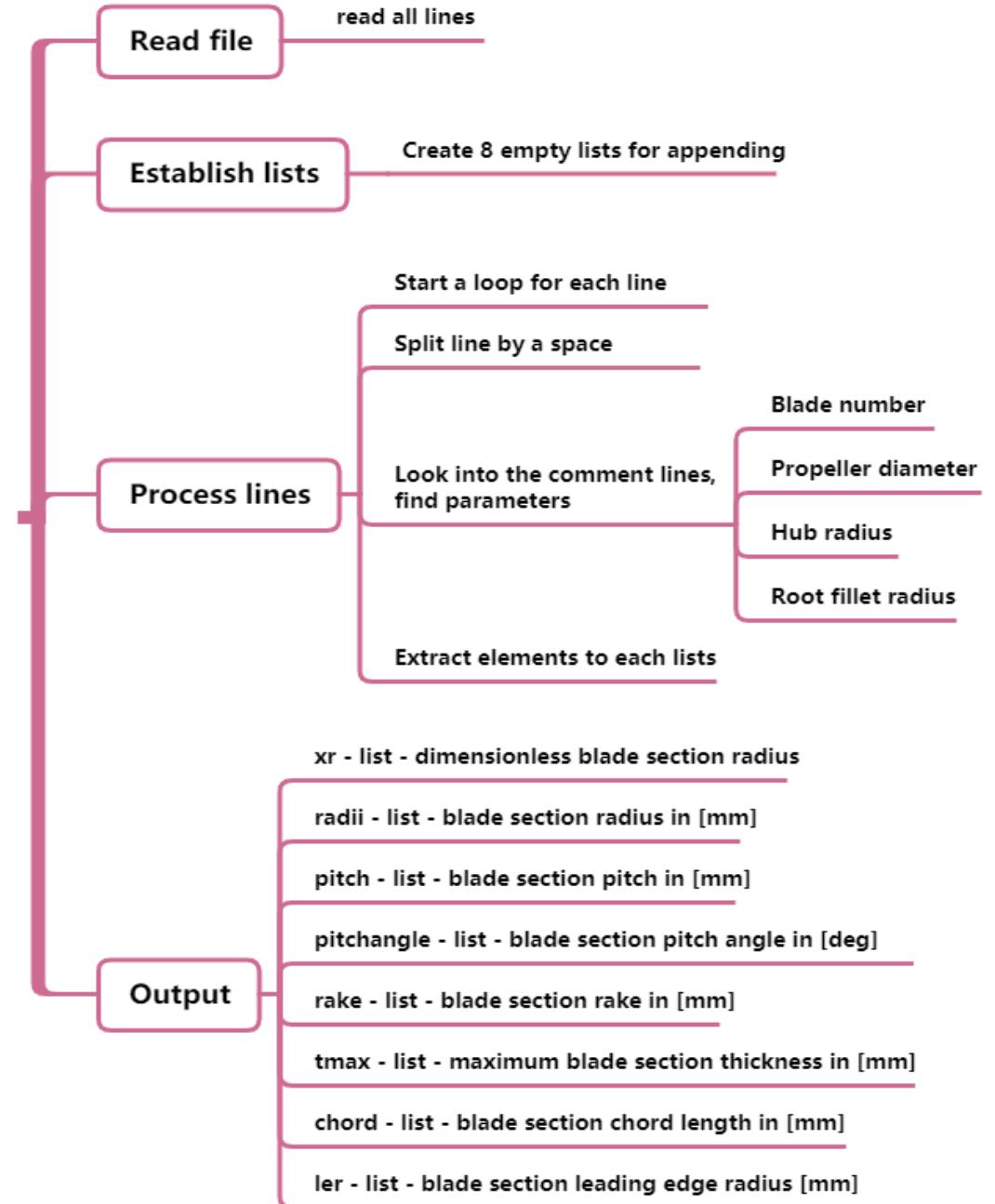
- 1) Import offsets points from CSV file.
- 2) Switch view: "Right" -> "Left".
- 3) Establish corresponding layers.
 - Create layers and name them by its radius.
 - Move offset points to their own layers.
- 4) Interpolate Face & Back.
 - Hide other layers while activate the working layer.
 - Interpolate points for face and back separately and leave the vacancies.
- 5) Go back to step 4) except for the top layer "x1.00".

Fig 3.1.1 Process summary of creating Face & Back

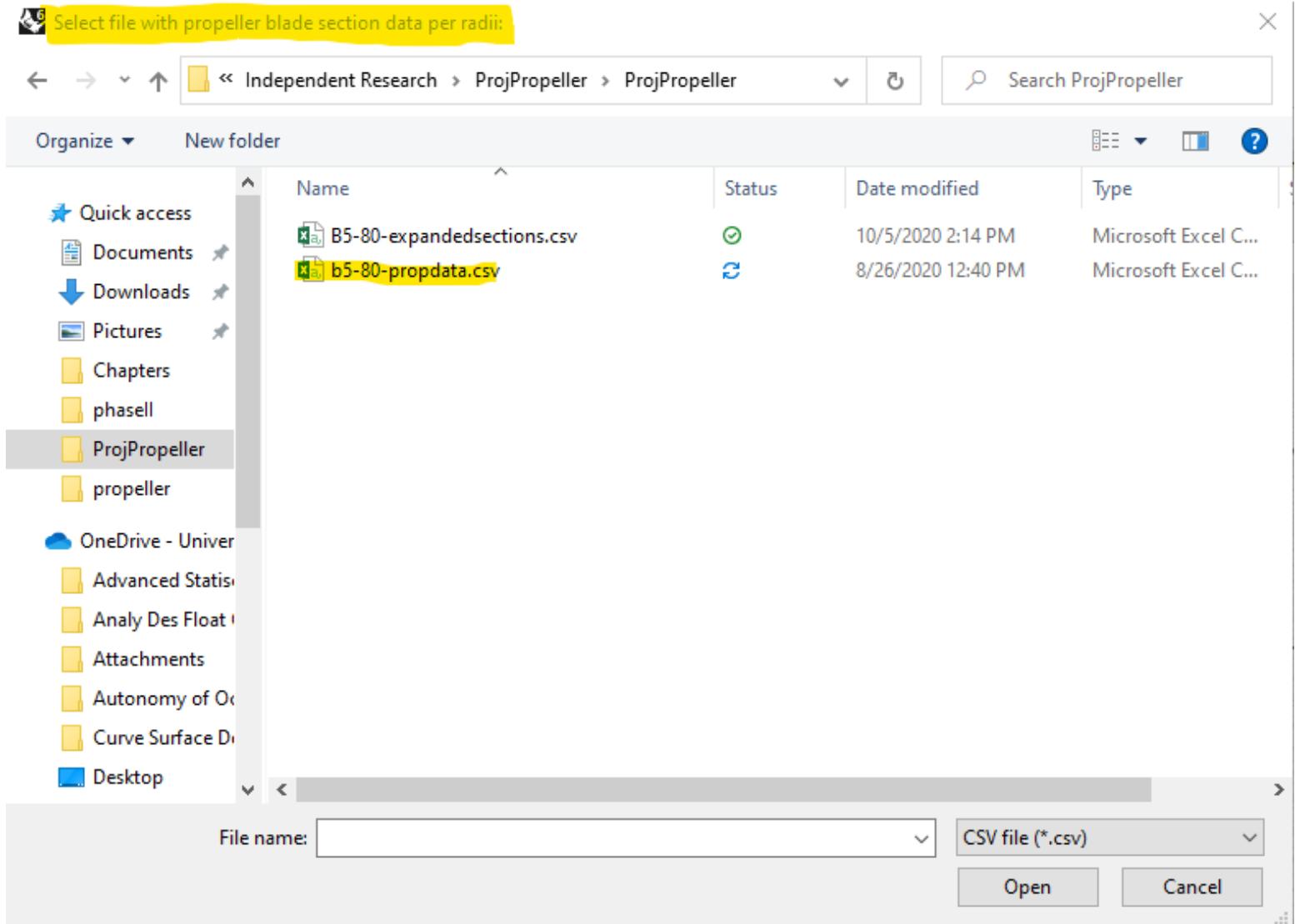


Automation Data Import

Import Propeller Data

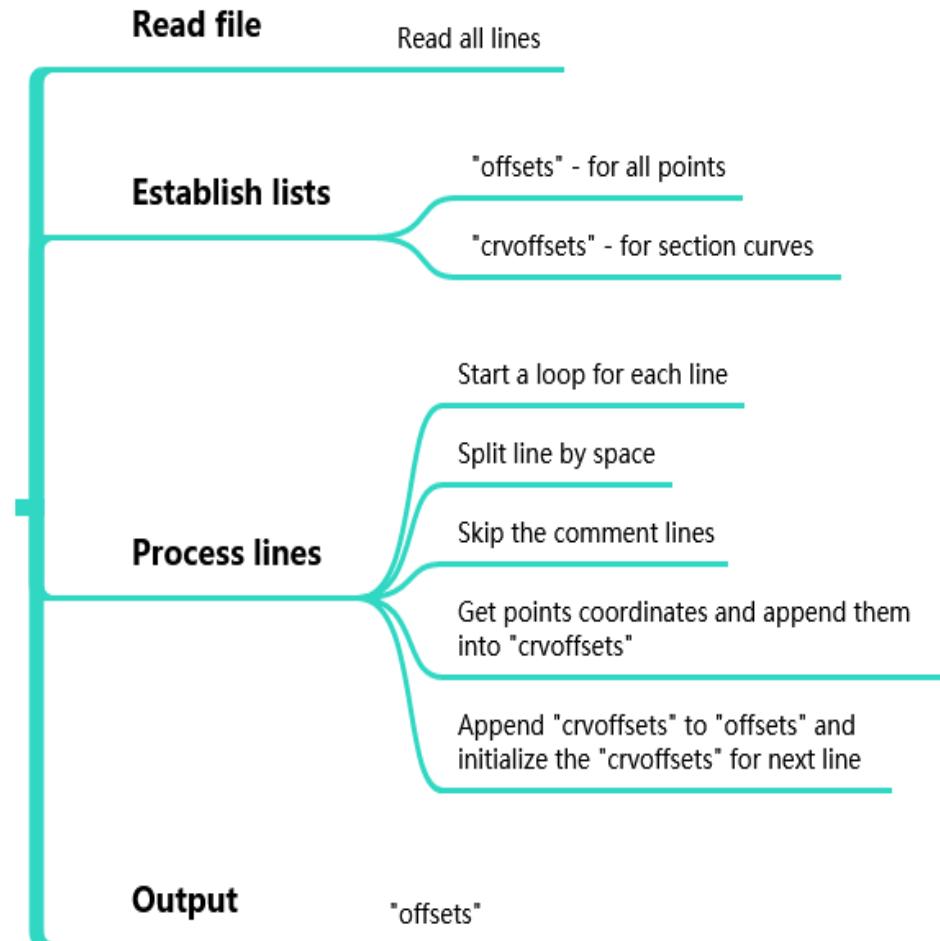


Automation Data Import

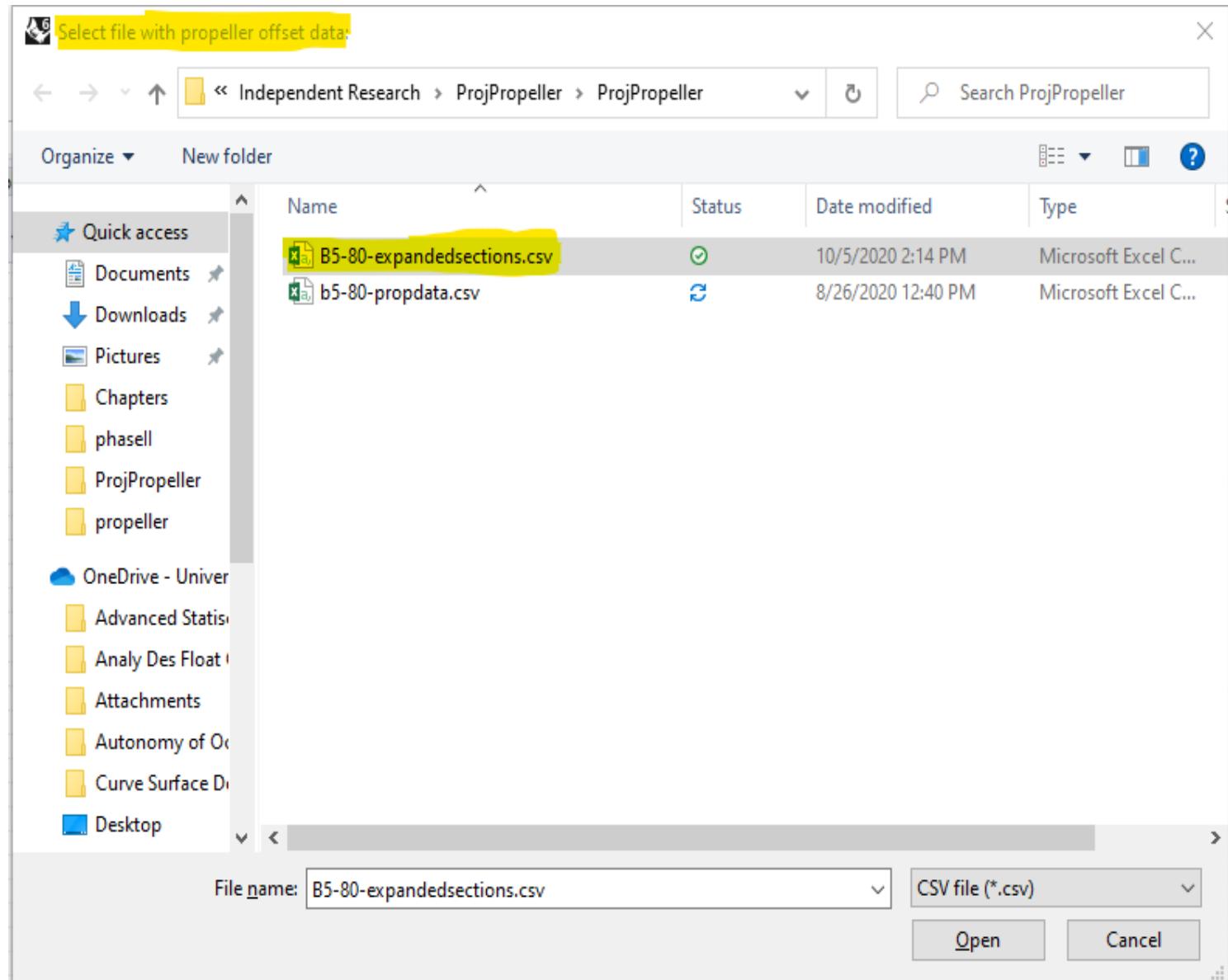


Automation Data Import

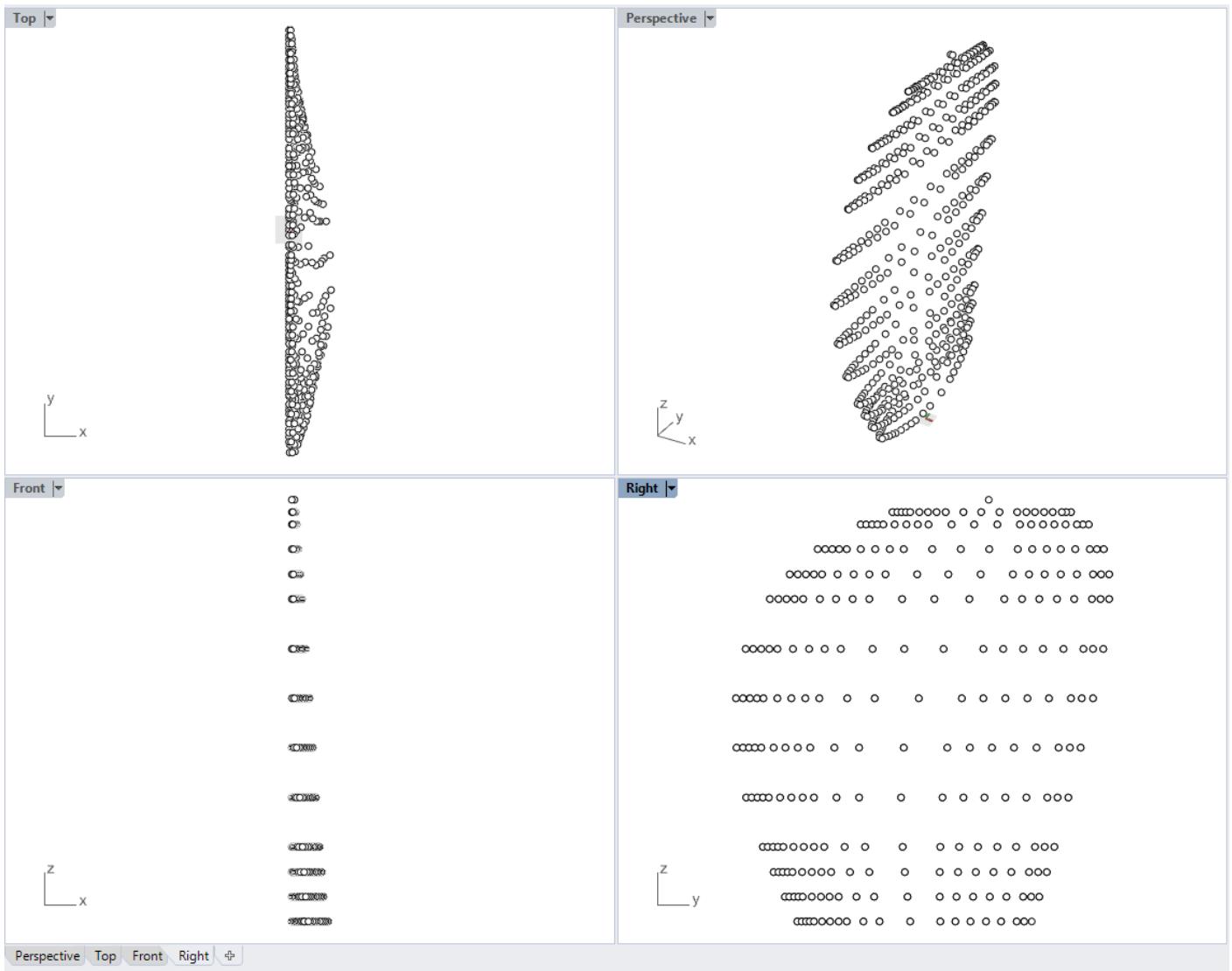
Import Offsets Points



Automation Data Import



Automation Offsets Import

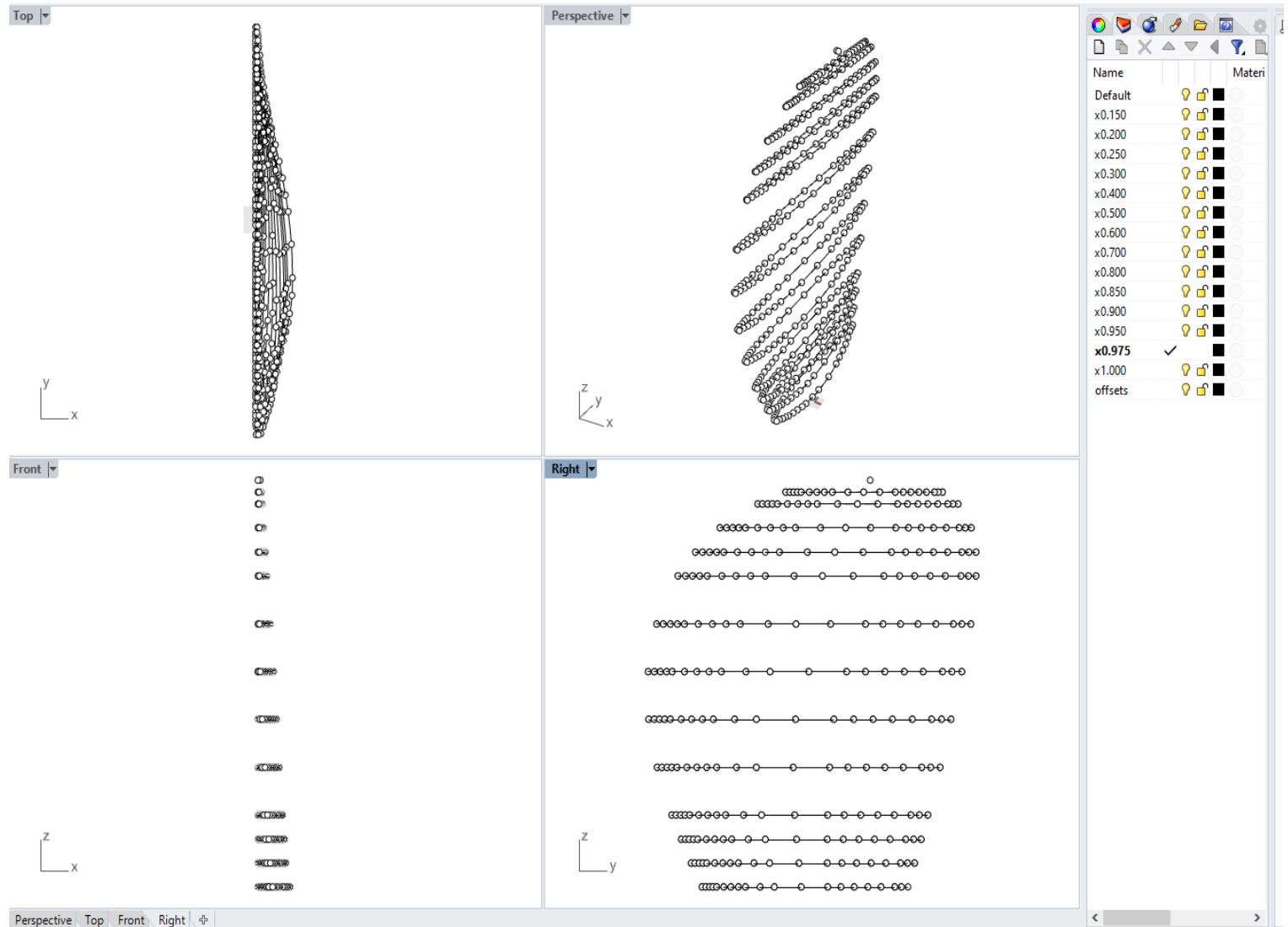


Automation Section Curves

Create Section Curves

- 1) Establish two empty lists for return
- 2) Create a loop for layer
- 3) Make radius layer active
- 4) Create back & face section curves

Automation Section Curves



Manual Design

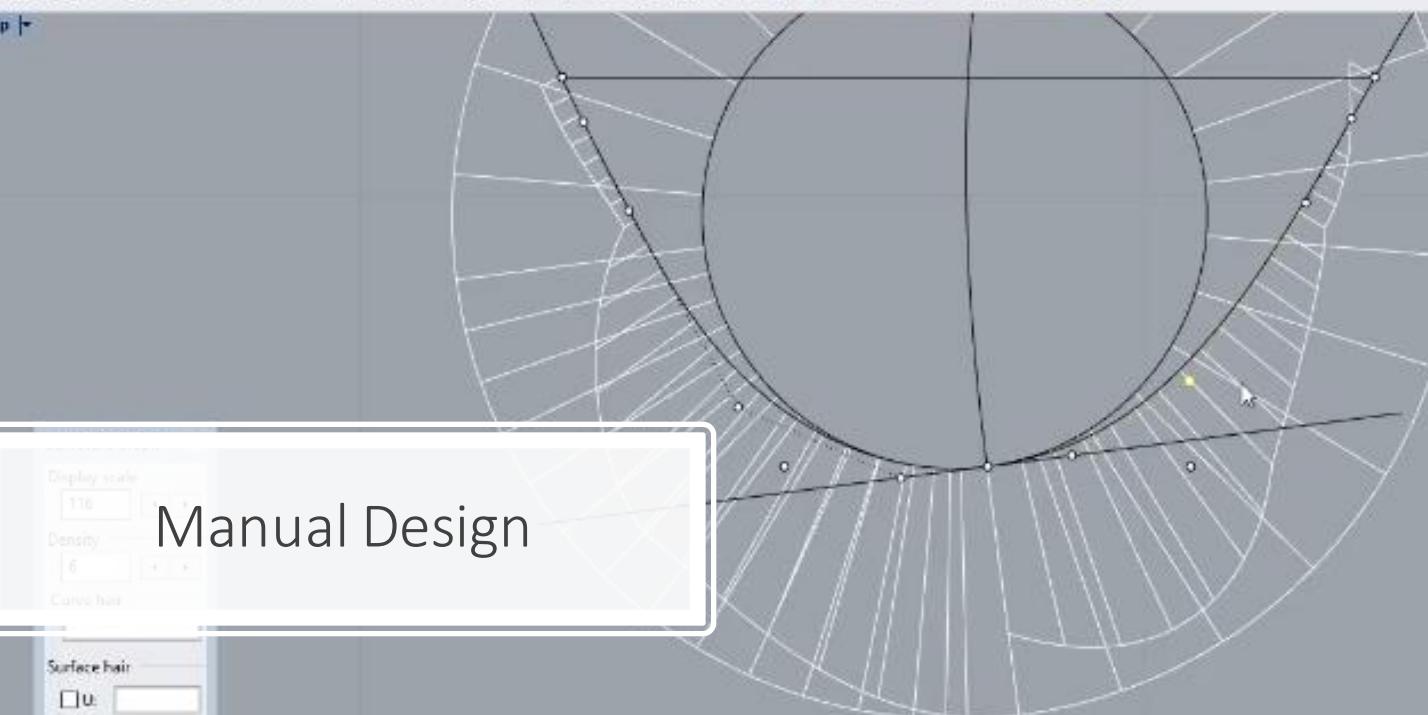
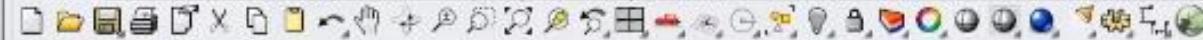
Process of creating Leading Edge

- 1) Select layer "x0.15" and hide others.
- 2) Create four pairs of simple polylines for the last four pairs of points.
- 3) Create the camber line by interpolating the middle points of four polylines.
- 4) Create a curve perpendicular to the camber line from the end toward both directions.
- 5) Create a circle tangent to the camber line from the end of the camber line, and type the radius we need from the IE rad.
- 6) Adjust the two sides
 - "Split" the curve with the intersection of the first polyline.
 - "Rebuild" the curves by 6 vertices and 3 degrees.
 - Open the curvature graph of the circle and the two split curves and move the last two control vertices into the lowest point on the circle.
 - Move the second last pairs of points to the tangent line and move the third last pairs of points until the curves look fair which means the curvature distributions graphs look as ideal and smooth as possible.
- 7) Delete all the auxiliary curves and join 2 pieces.
- 8) Create a new layer "Offsets" and select all points and move them to the "Offsets" layer.
- 9) Choose another layer and repeat all the mentioned steps above to all layers except for "x0.975".
- 10) For "x0.975" leave the middle two points and move other points to "Offsets"

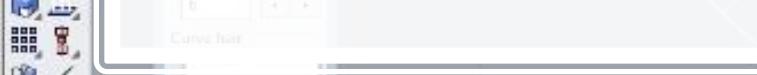
Nudge 0.02, Cumulative 0.54
Nudge 0.02, Cumulative 0.02

Command:

Standard CPlanes Set View Display Select Viewport Layout Visibility Transform Curve Tools Surface Tools Solid Tools Mesh Tools Render Tools Drafting New in V6 Background Bitmap



Manual Design



Surface hair

 U: [] V: [] Add Objects Remove Objects

Perspective Top Front Left

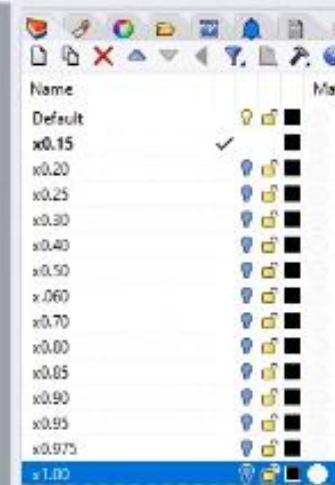
 End Near Point Mid Cen Int Perp Tan Quad Knot Vertex Project Disable

Change

Type here to search

GridSnap Ortho Planar Snap SmartTrack Gumball Record History Filter Memory used 179 MB

8:00 / 19:03



Rhinoceros

Notes

B5-B0 9-Series Propeller - Stage 03
Leading edge shape

With the process below we establish the shape of the leading edge for each section. This is of hydrodynamic importance.

Blade section data

x	R	P	phi	rake	tmax	c	LF rad
[-]	[mm]	[mm]	[deg]	[mm]	[mm]	[mm]	[mm]
0.150	450.00	6000.00	64.7584	79.35	225.30	1414.08	16.08
0.200	600.00	6000.00	57.0501	105.00	195.60	1536.00	11.16
0.250	750.00	6000.00	51.8540	132.25	184.50	1650.24	9.24
0.300	900.00	6000.00	46.6963	158.69	173.40	1758.72	7.66
0.400	1200.00	6000.00	38.5119	211.59	131.20	1942.08	5.27
0.500	1500.00	6000.00	32.4818	264.49	129.00	2076.49	3.59
0.600	1800.00	6000.00	27.9467	317.39	106.80	2153.28	2.42
0.700	2100.00	6000.00	24.4526	370.29	84.60	2157.12	2.35
0.800	2400.00	6000.00	21.6970	423.18	62.40	2046.72	2.29
0.850	2550.00	6000.00	20.5300	449.63	51.30	1924.80	2.16
0.900	2700.00	6000.00	19.4775	476.03	40.20	1726.00	1.93
0.950	2850.00	6000.00	18.5241	502.53	29.10	1376.64	1.54
0.975	2925.00	6000.00	18.0804	515.76	23.55	1077.12	1.21
1.000	3000.00	6000.00	17.6568	528.98	18.00	0.00	0.00



Automation Leading Edge

Create Leading Edge

1) Create partial camber curves

2) Split off and rebuild part
for leading edge curves

3) Form leading edge curves

4) Complete leading edge curves

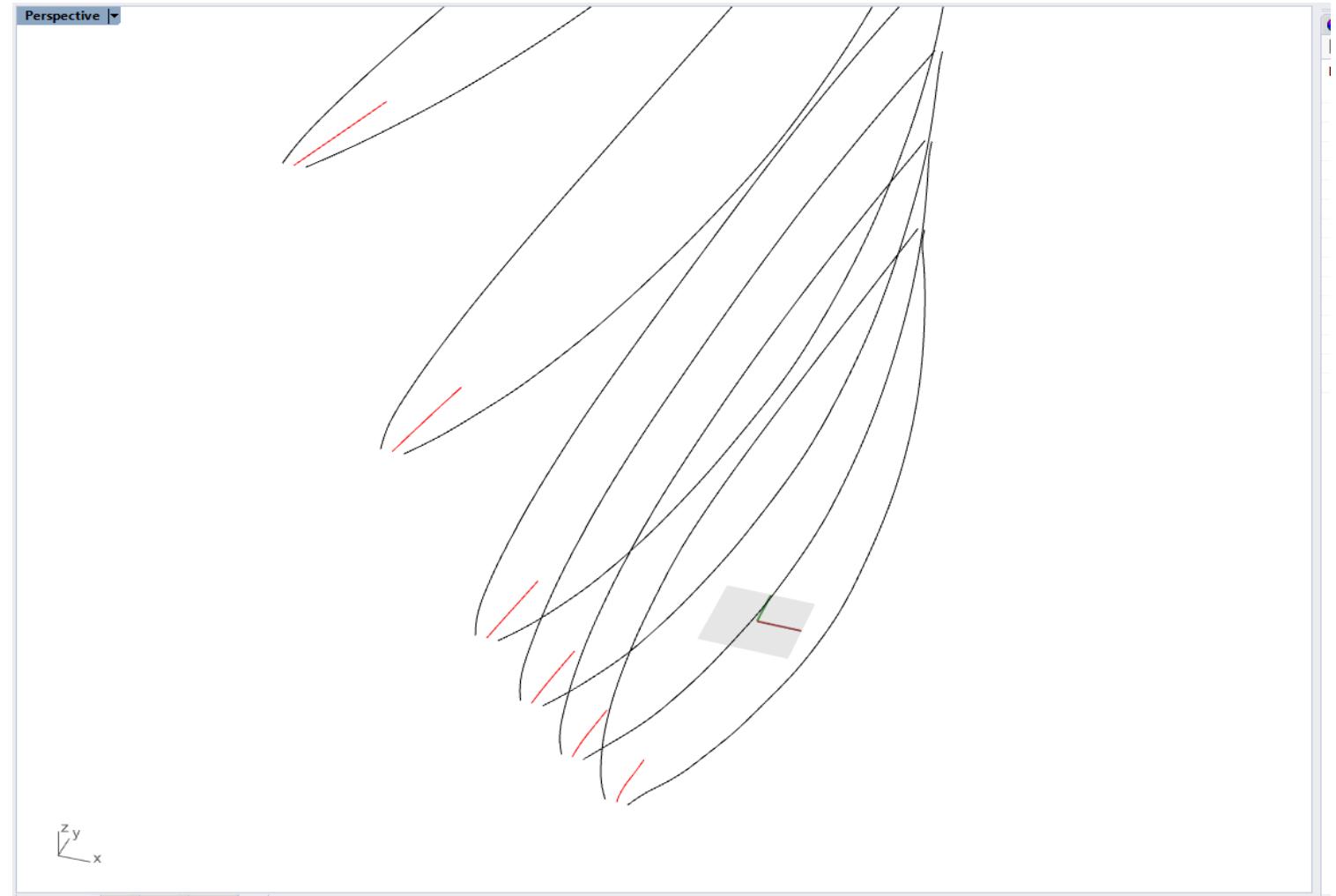
Curves

Leading edge curves

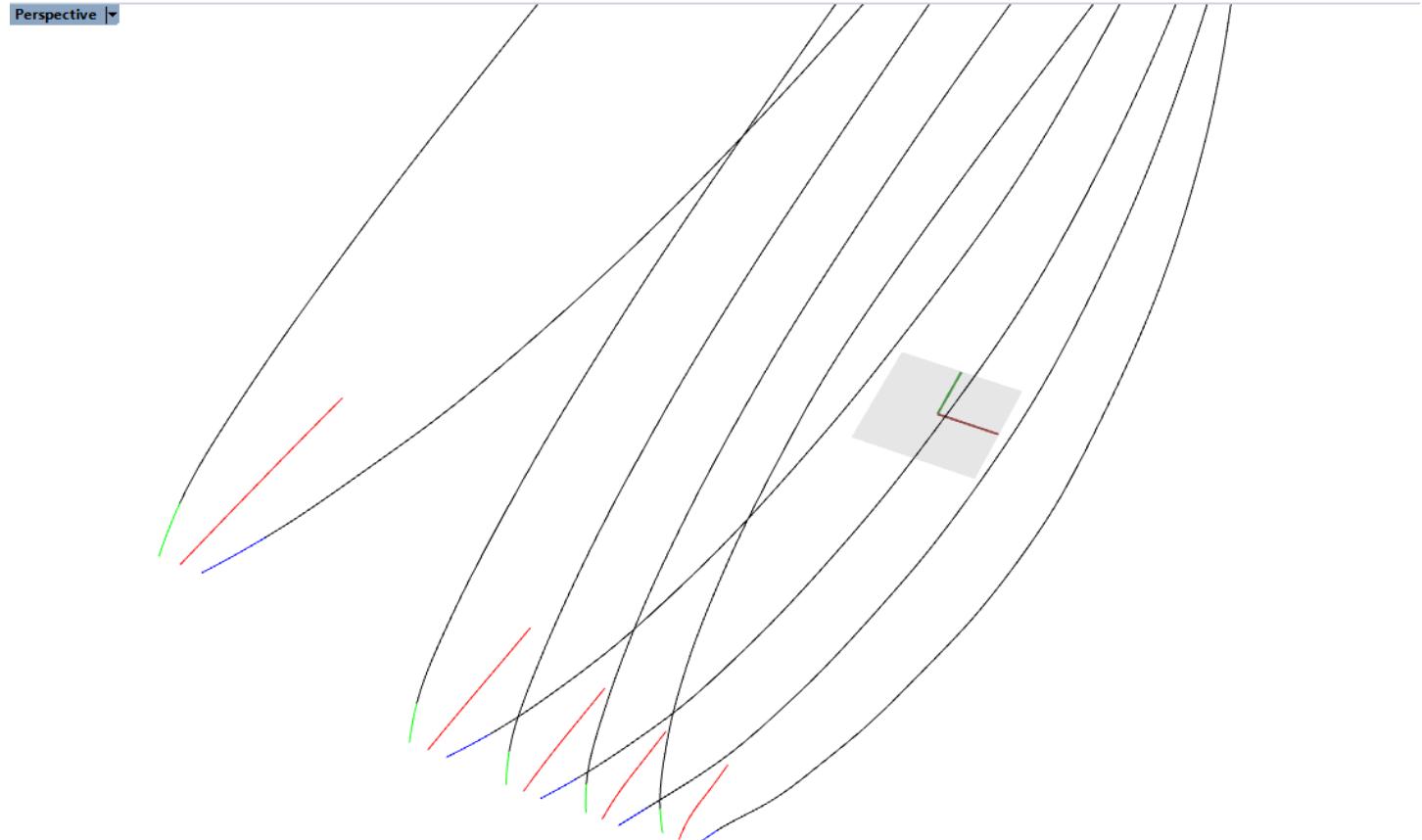
Move the last three control vertices

Automation Leading Edge

1) Camber lines



Automation Leading Edge

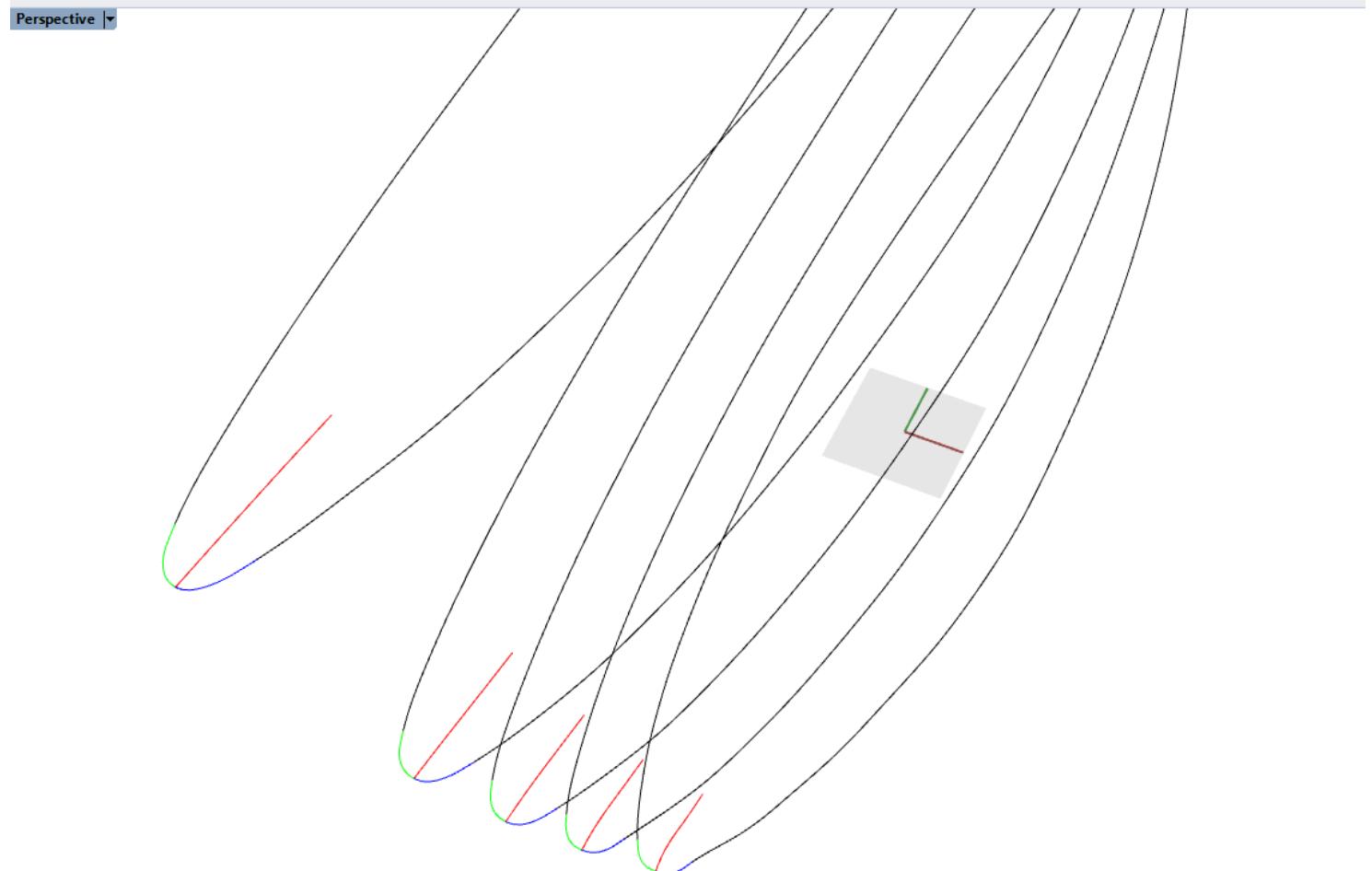


2) Split curve



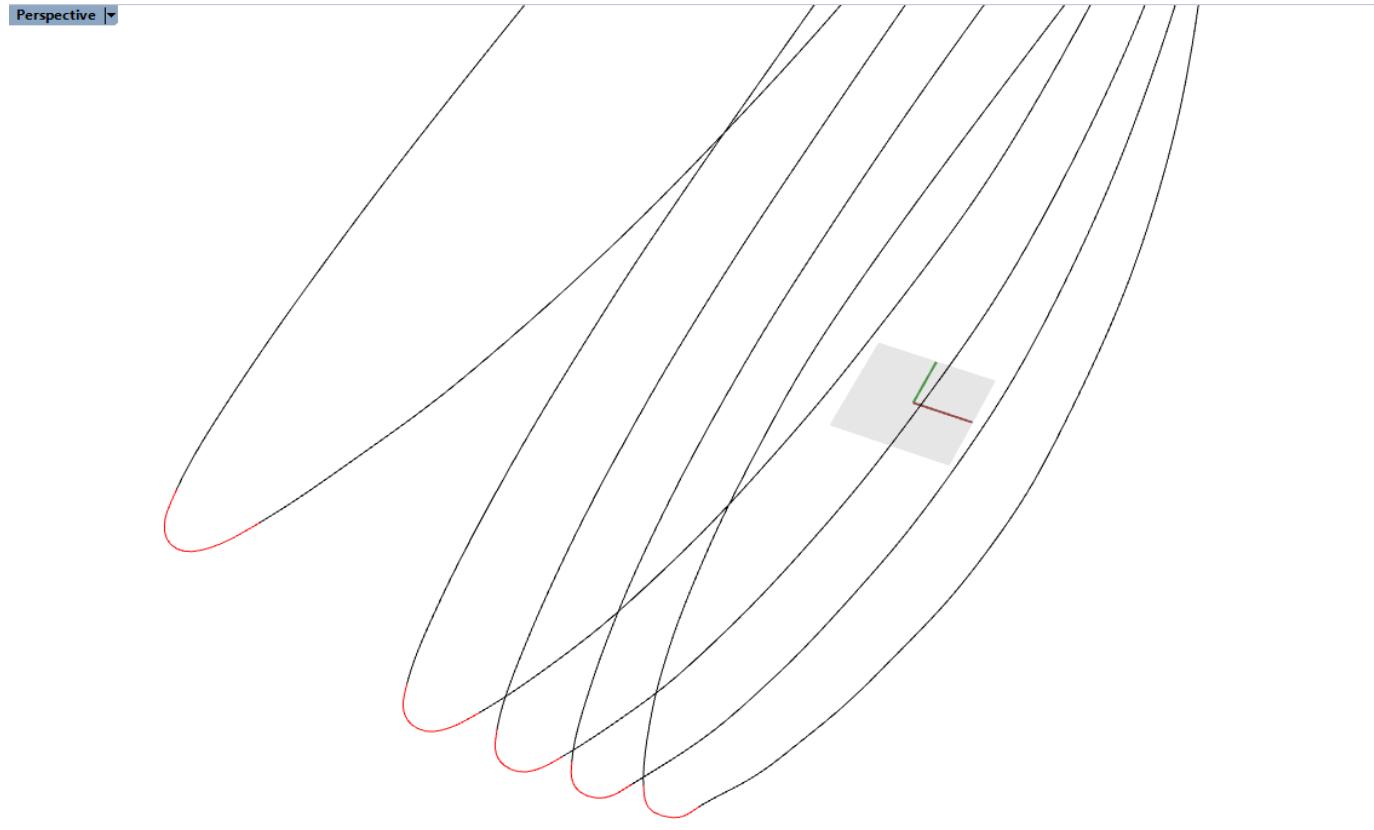
Automation Leading Edge

3) Form leading edges



Automation Leading Edge

4) Finish leading edges



x
y
z

Manual Design

Process of creating Trailing Edge

1) Choose the "Top" view and select the layer 'x0.15' and hide other layers.

2) Create polylines on each beginning of Face and Back.

3) Create a circle that tangent to three curves.

4) "Trim" : select a circle as a cutting object.

5) Repeat step 1) to 4) for layer "x0.25" .

6) For layer "x0.30" , "Fillet curves" for radius equals 3 and then join the two pieces.

7) For layers from "x0.50" to "x0.95" , "Fillet curves" for radius as 1, and join the three parts.

Select cutting objects. Press Enter when done (ExtendCuttingLines=No ApparentIntersections=Yes Line)

Select cutting objects. Press Enter when done (ExtendCuttingLines=No ApparentIntersections=Yes Line)

Select object to trim, select pressing Shift to extend (ExtendCuttingLines=No ApparentIntersections=Yes):



Name	Default	Mate
x0.15		
x0.20		
x0.25		
x0.30		
x0.40		
x0.50		
x0.60		
x0.70		
x0.00		
x0.05		
x0.90		
x0.95		
x0.975		
x1.00		
Offsets		

Manual Design



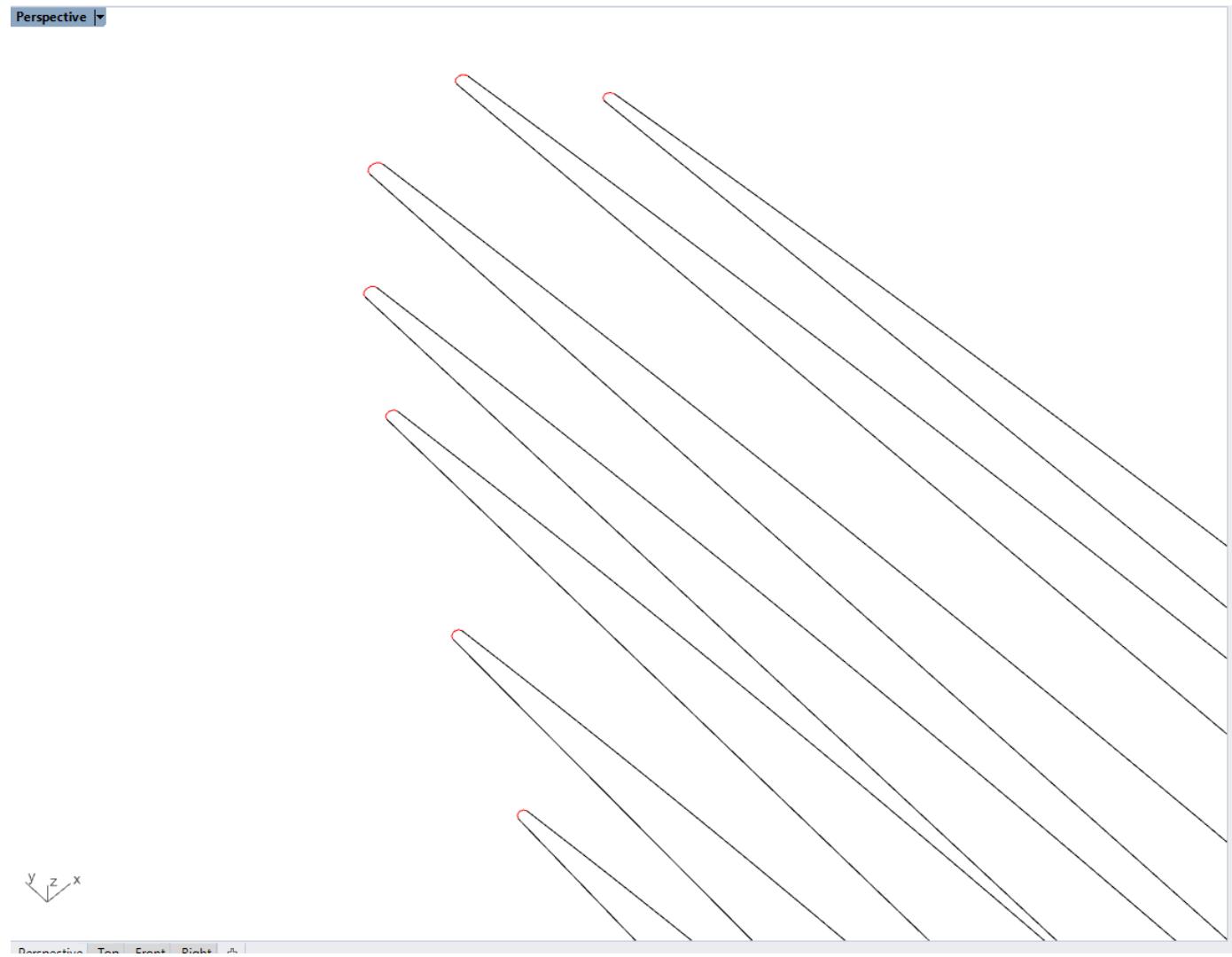
Automation Trailing Edge

Create Trailing Edge

- 1) Activate current layer
- 2) Find start points of face and back curves
mark the trailing edge
- 3) Connect end points by polyline
- 4) Define fillet radius
- 5) Split auxiliary curve and delete
overhanging part
- 6) Add fillet curves to list for trailing
edge curve
- 7) Join fillet curves

The factor 0.45 should become radius
dependent input

Automation Trailing Edge



Manual Design

Process of establishing Pitch Angles and Rakes

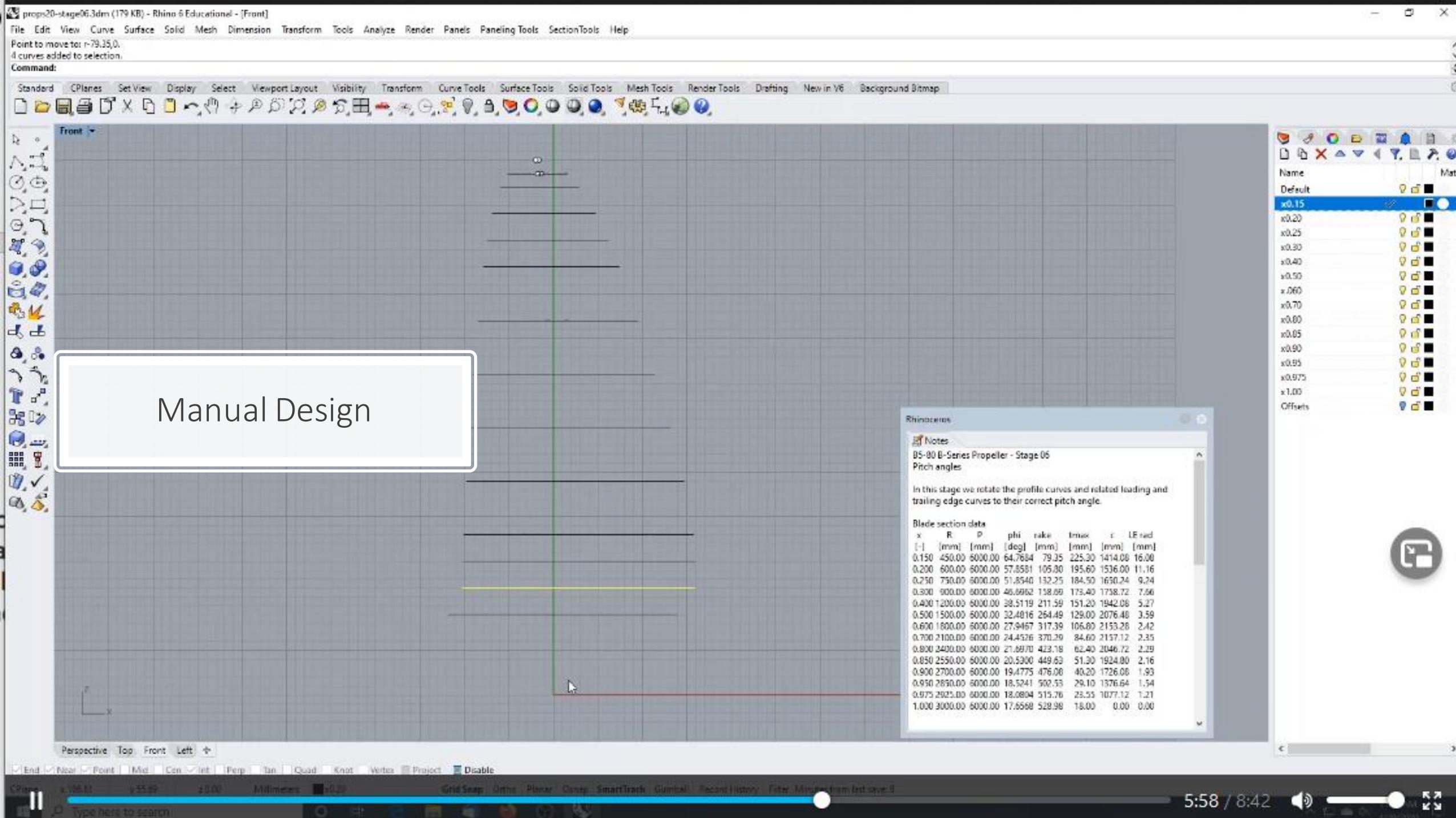
1) Select the layer 'x0.15' and hide other layers.

2) Rotate around the center and use the [phi] from the previously prepared data file as the pitch angle degree.

3) Move all items from the center where uses the [rake] from the previously prepared data file as the rake.

4) Repeat steps 1) to 3) for all other layers.





Manual Design

Process of Developing Blade Sections on Cylindrical Surfaces

1) Hide all layers except the "x0.15" and draw a circle on the active layer in the "Left" view,

2) Switch to the "Front" view, move the circle to somewhere behind the profile.

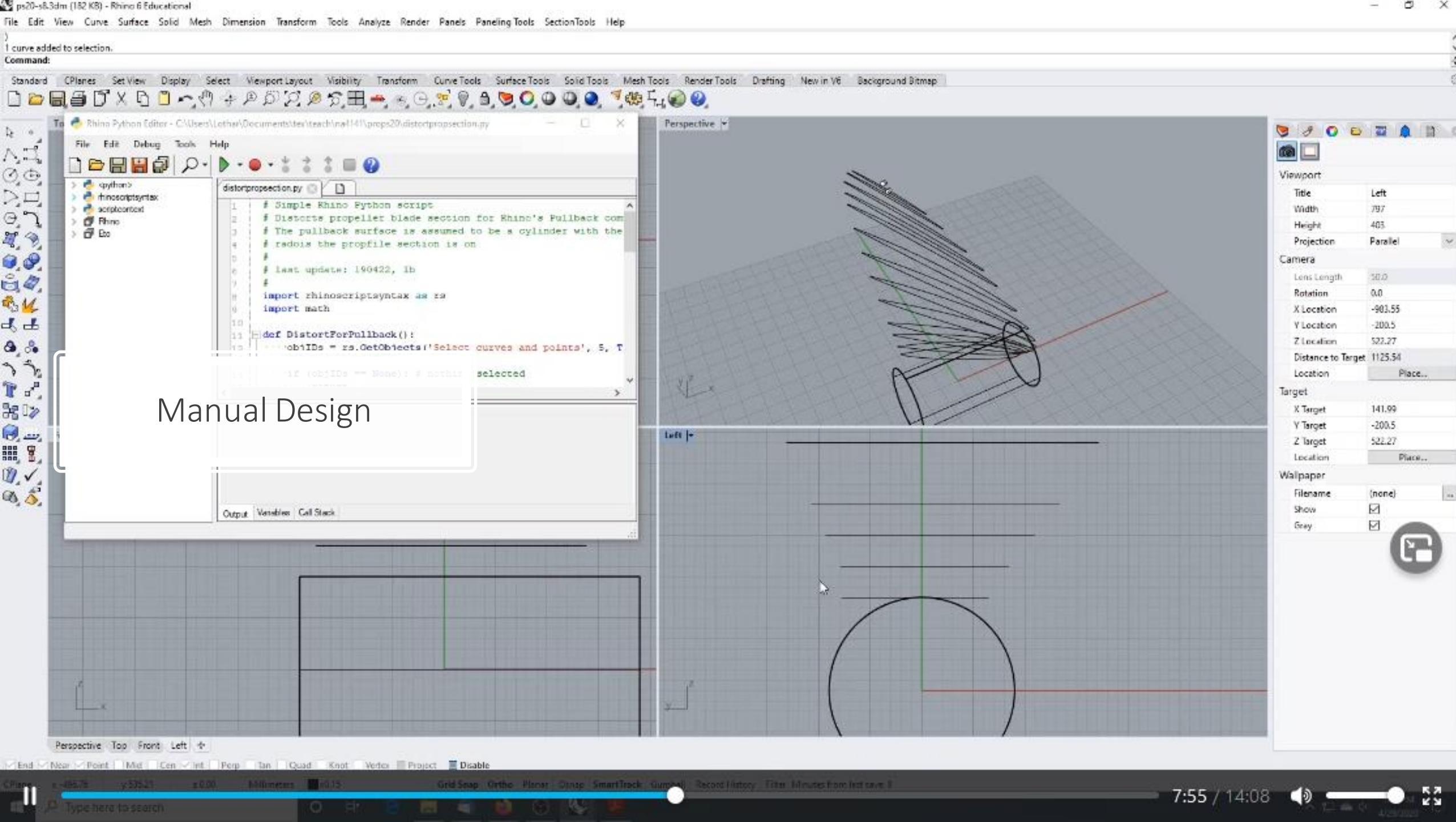
3) Extrude the circle into a cylinder.

4) Open and run the "distortpropsection.py" file.

5) Using the "Pullback" command to pull back both curves and points onto the cylinder

6) Delete the cylinder.

7) Repeat step 1) to 6) above for the rest layers



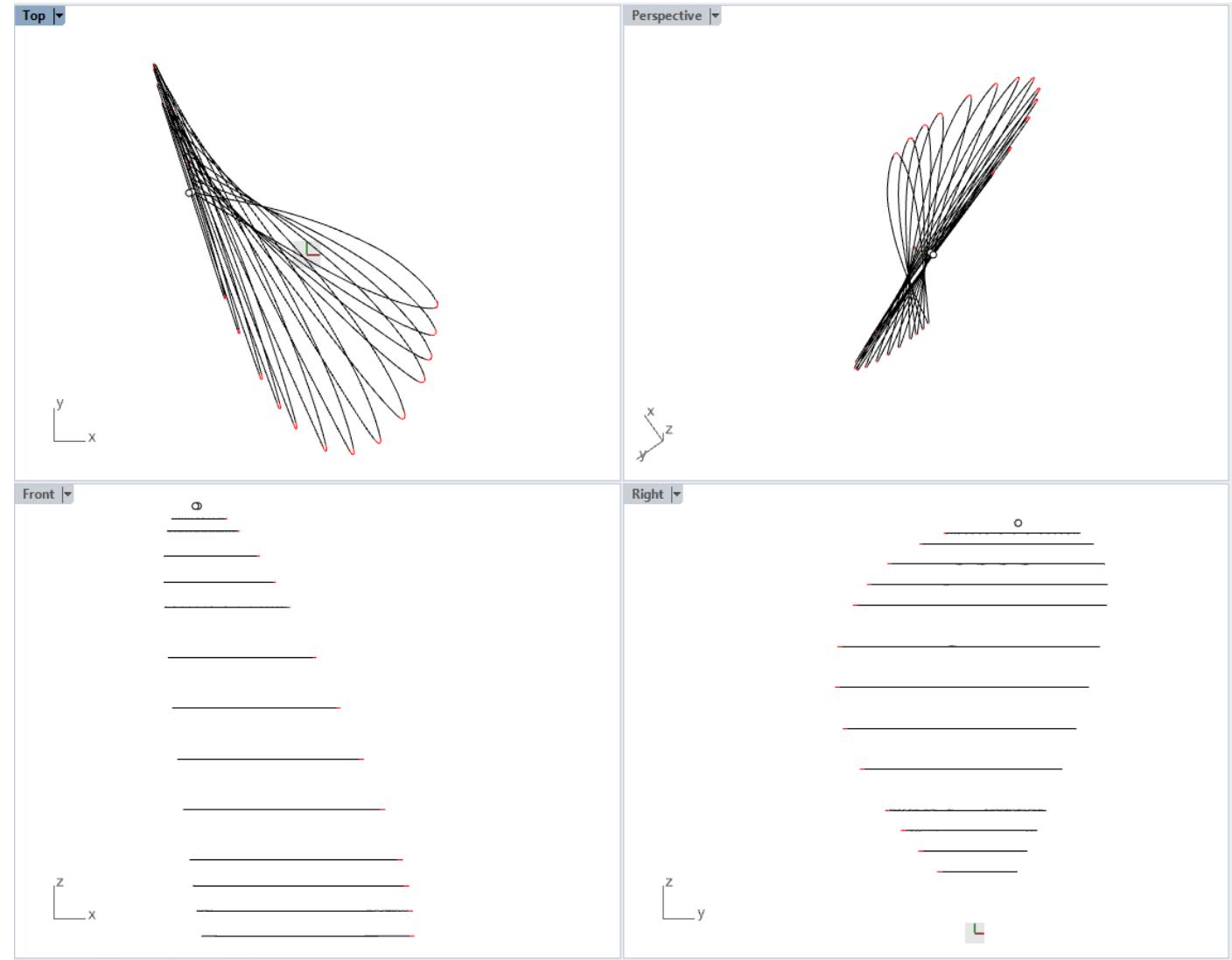
Automation Transformations

Transformations

- 1) Pitch sections
- 2) Rake sections
- 3) Create a loop over radii (layer) except the last layer
- 4) Create pull back cylinder
- 5) Distort for pull back
- 6) Pull back sections

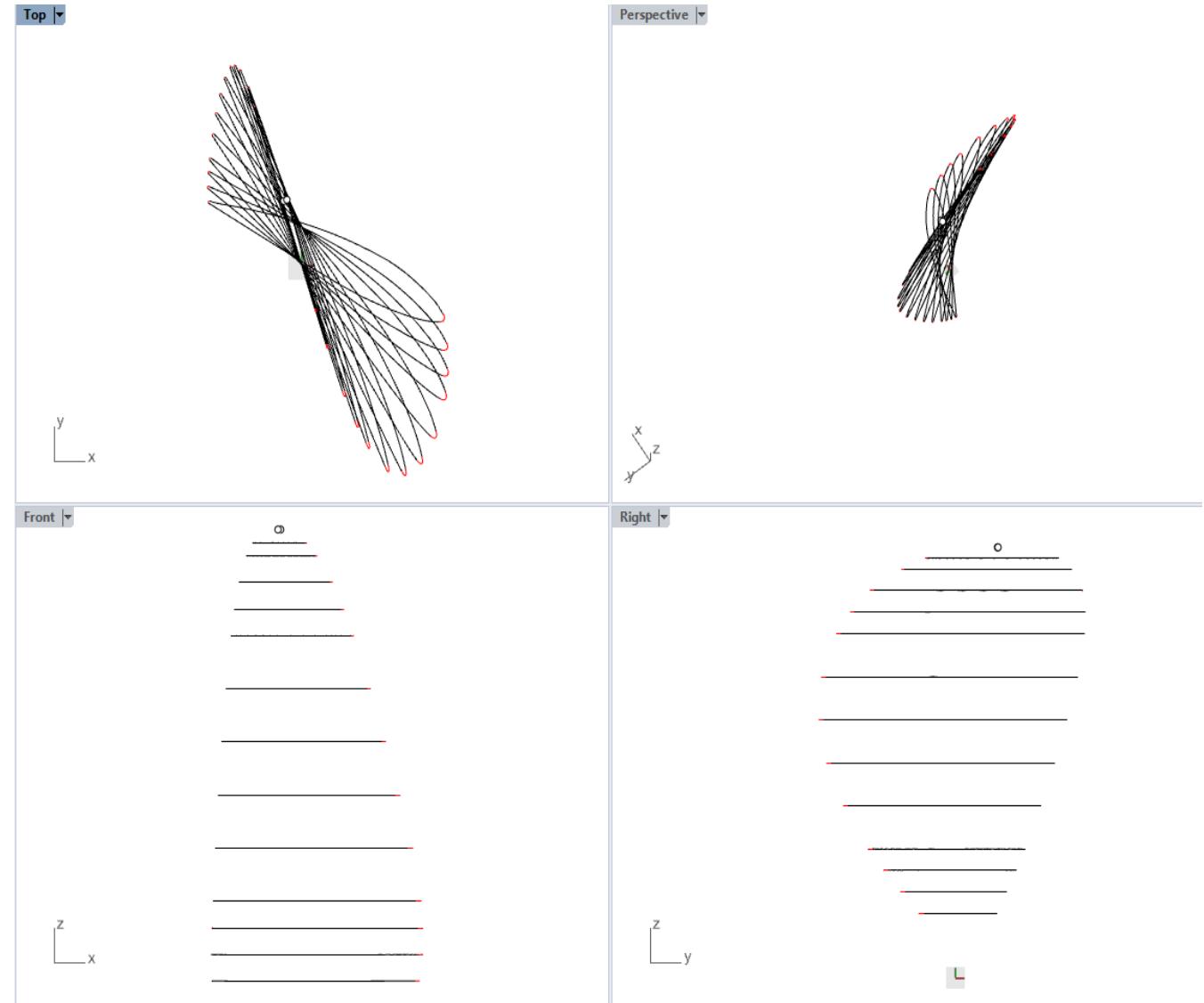
Automation Transformations

1) Pitch sections



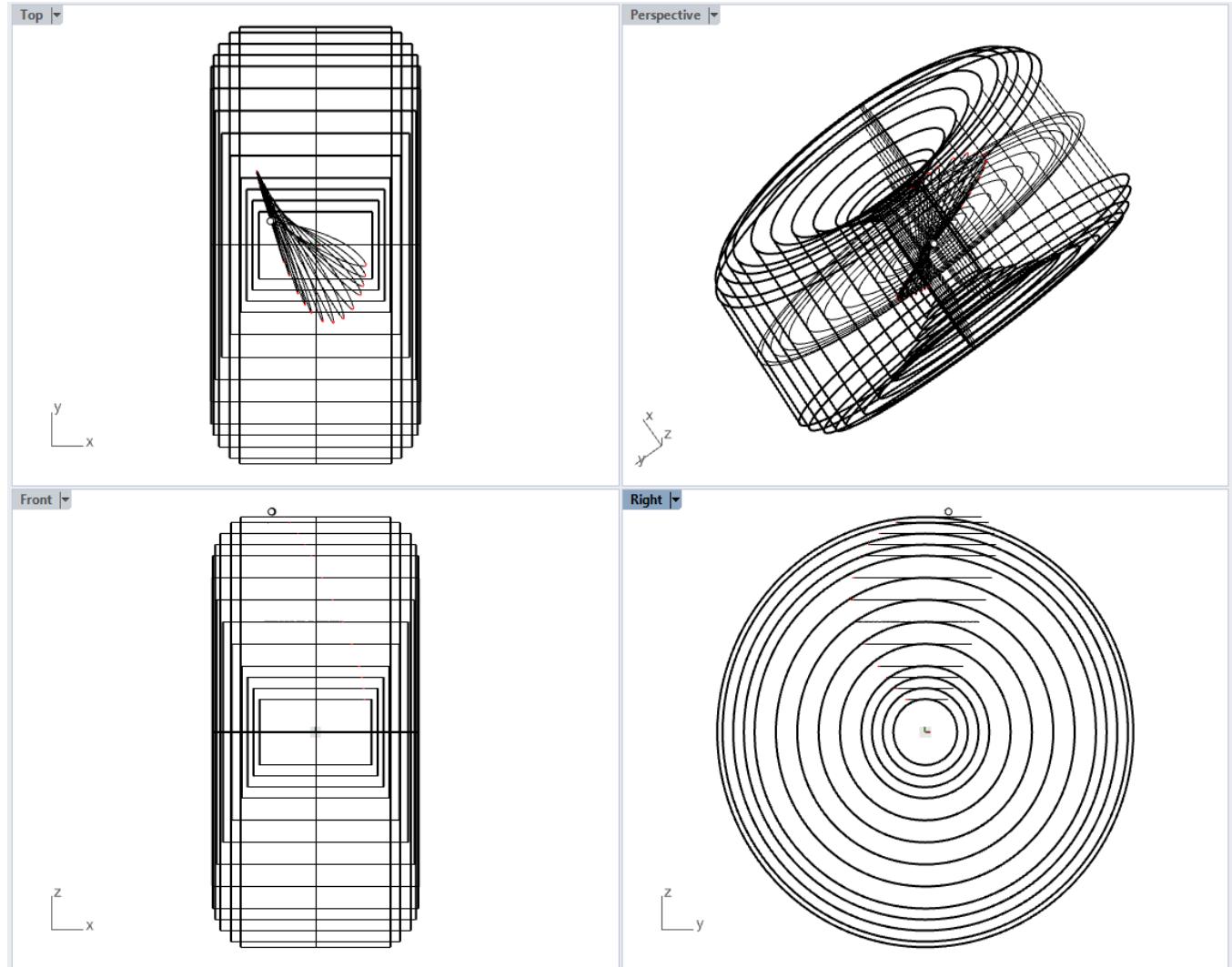
Automation Transformations

2) Rake sections



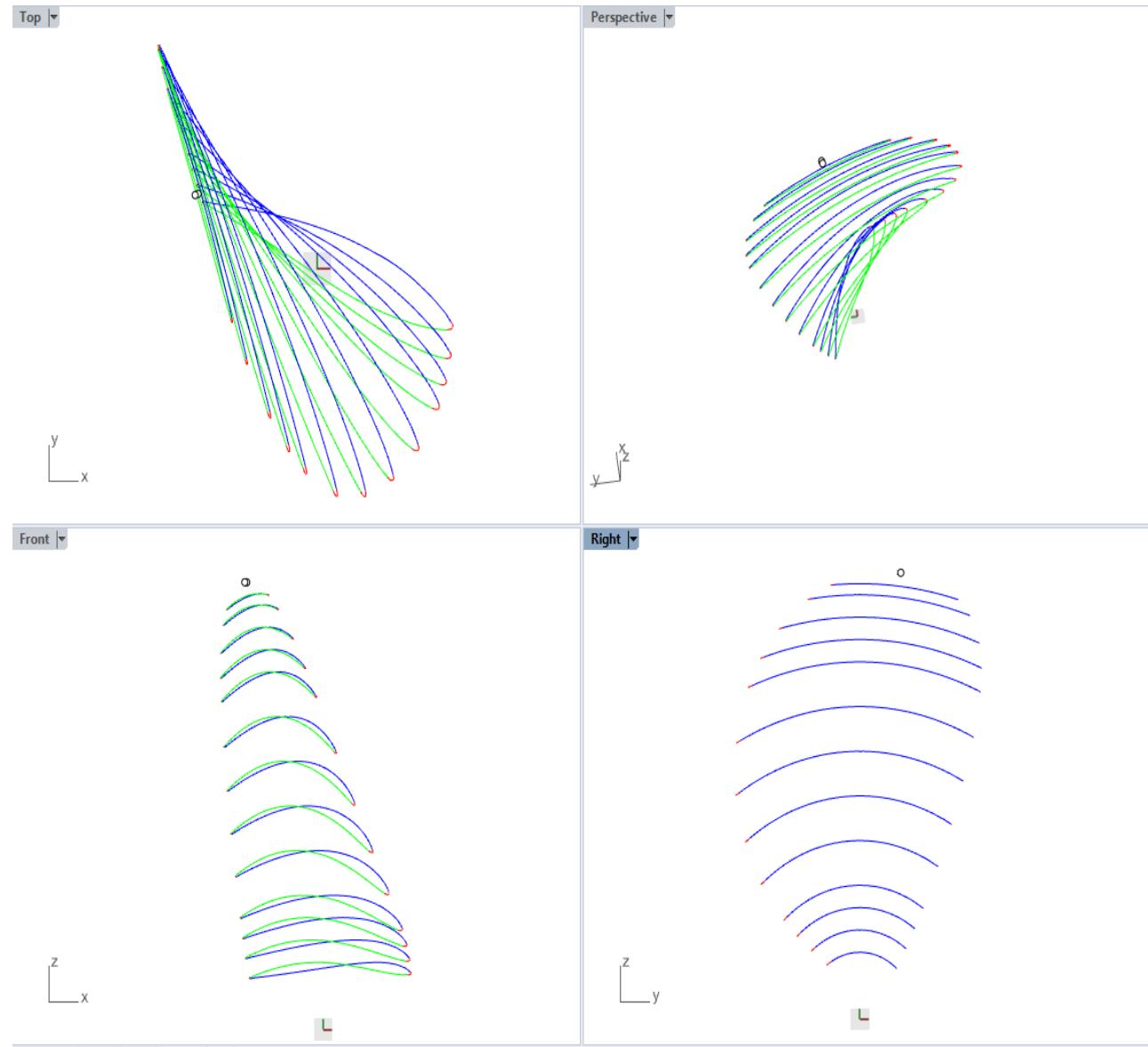
Automation Transformations

- 3) Pull back sections
 - I. Create a cylinder



Automation Transformations

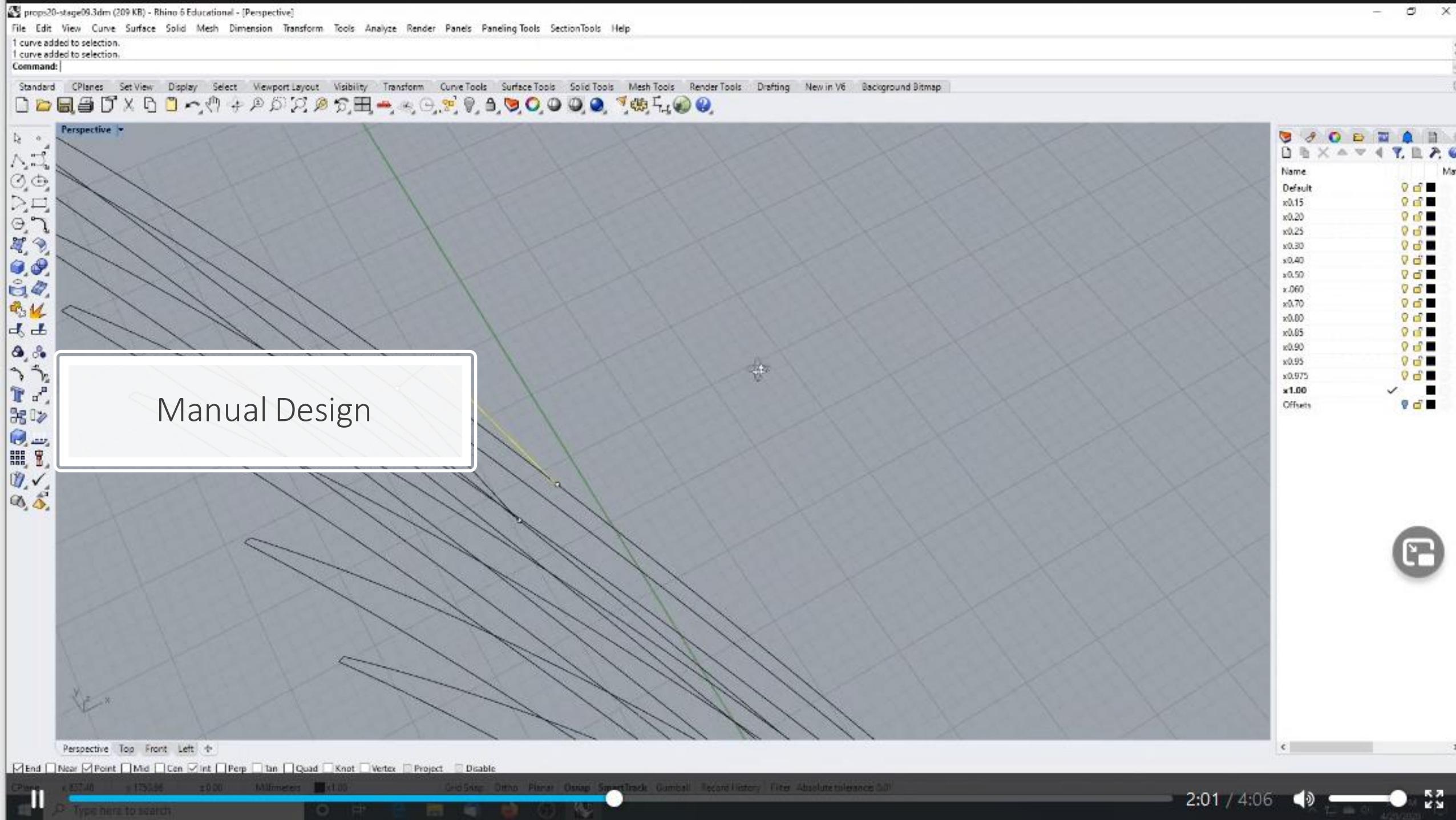
3) Pull back sections
II. Distort curves and
pull back sections



Manual Design

Process of the Blade Tip Curve

- 1) Add three polylines between the two middle points of layer "x0.975" and two points on layer "x1.00"
- 2) Fillet curve by radius for Face equals 6 and for Back as 9.
- 3) Trim and join three curves and delete the straight lines.
- 4) Move all the points to the "Offsets" layer.



Automation Blade Tip

Create the blade tip

1) Create a cylinder

use radius as length of cylinder

2) Distort points at top

3) Pull back points at top

4) Create auxiliary polyline at blade tip

5) Fillets the polylines

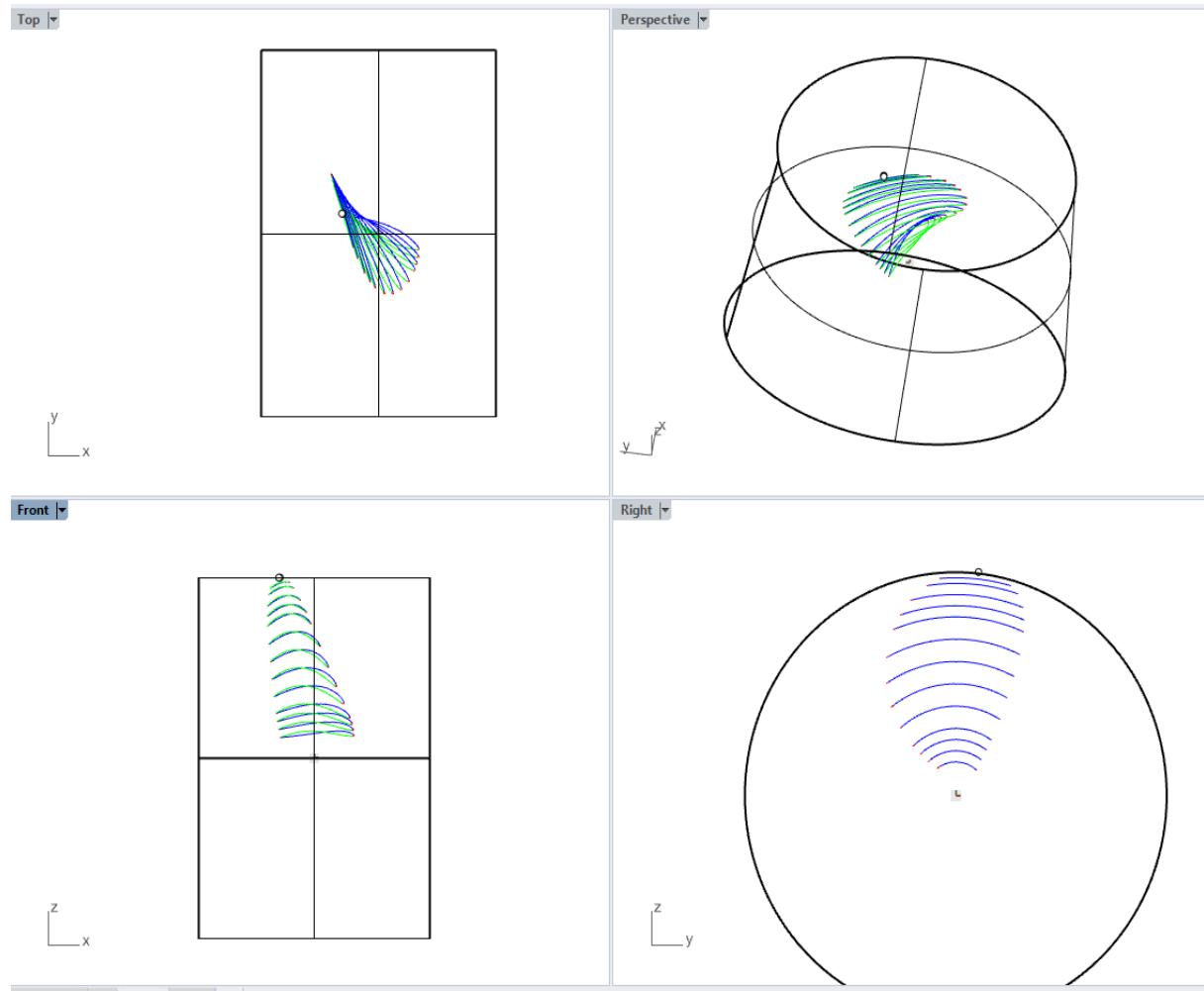
smaller on face side than at back because of rake

6) Create actual blade tip curve

7) Delete the blade tip points (no longer needed)

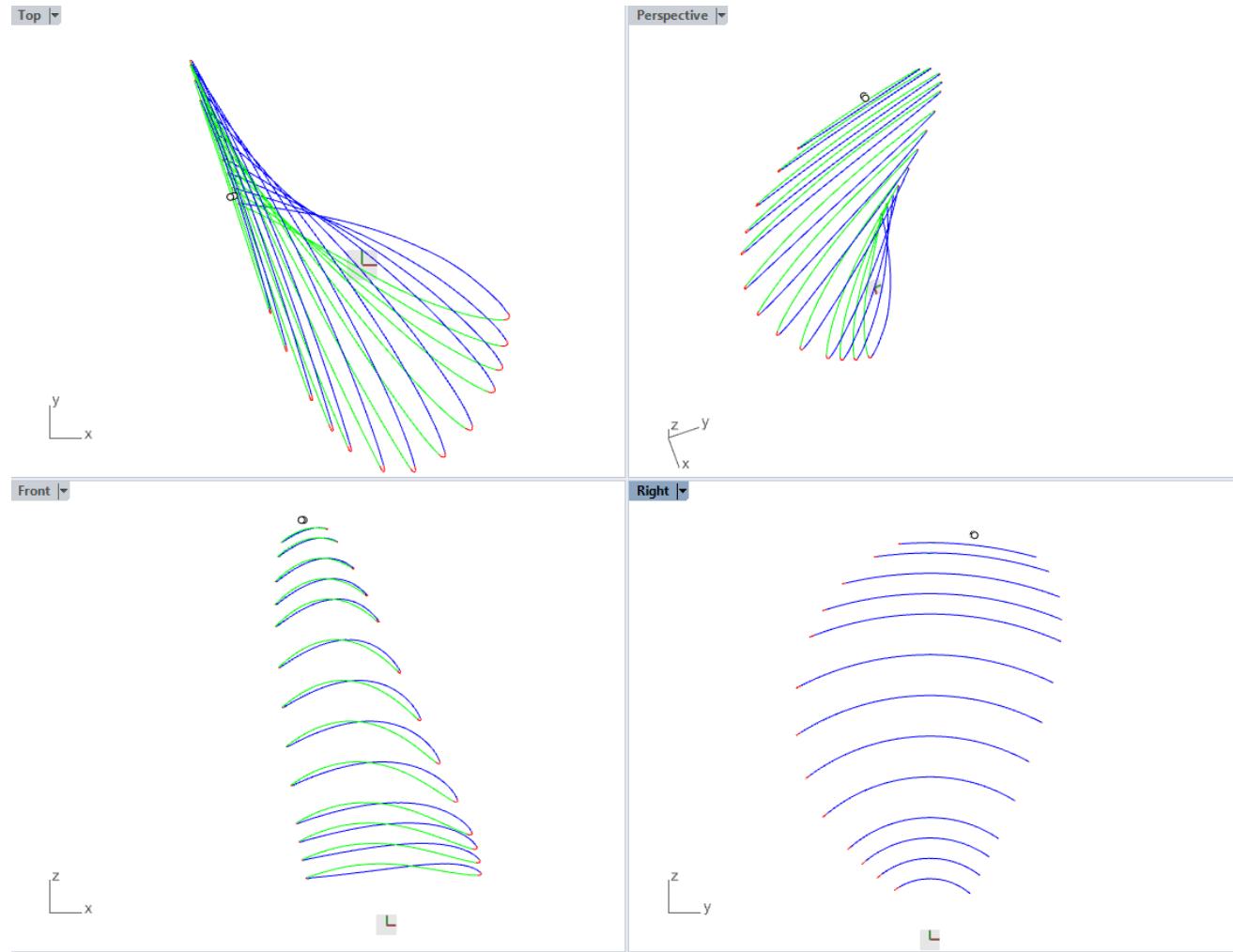
Automation Blade Tip

1) Create a cylinder



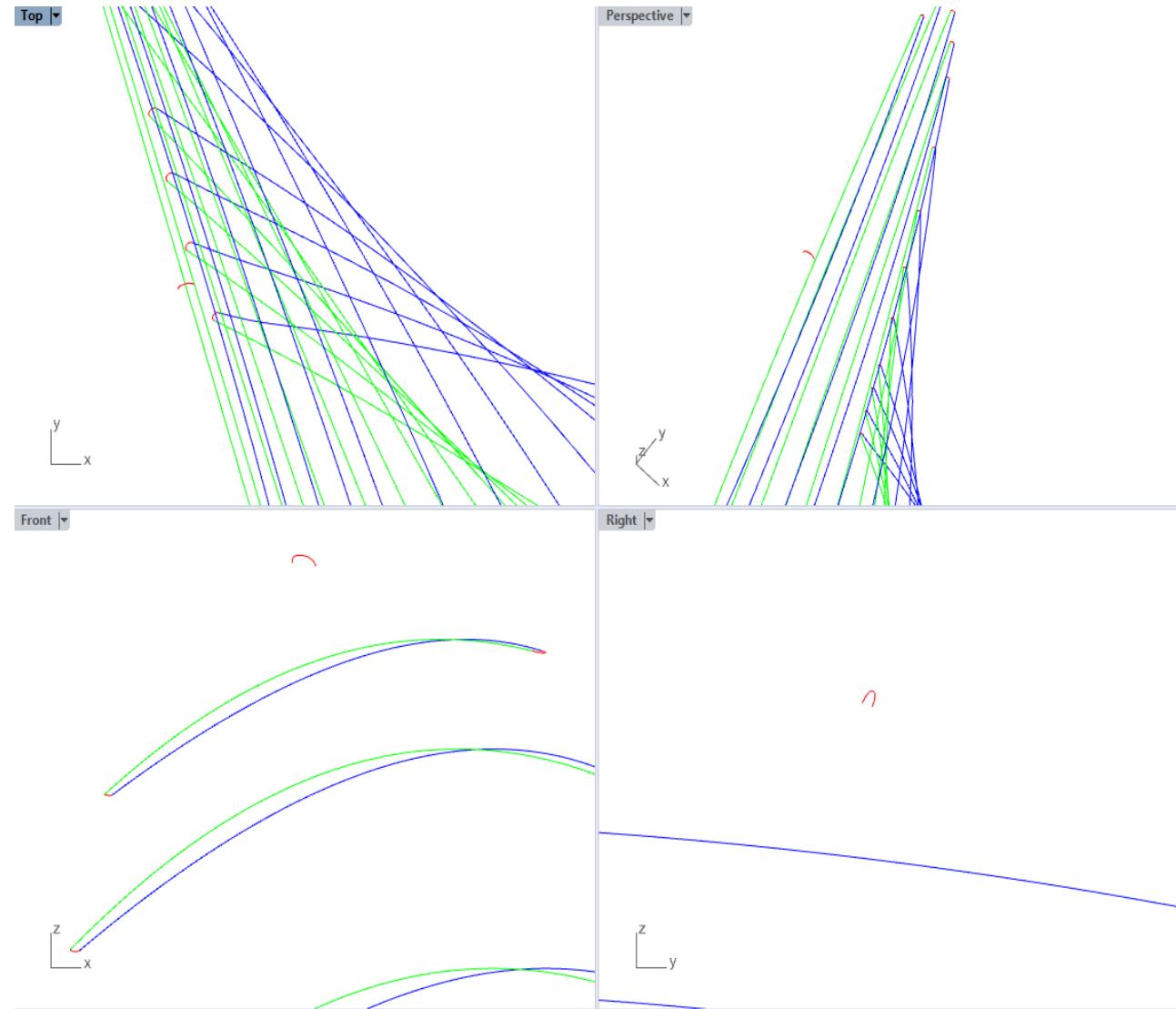
Automation Blade Tip

2) Pull back & distort blade points



Automation Blade Tip

3) Create an actual blade tip



Manual Design

Process of the Blade Contour Curves

1) Add three new layers

"Face Curves" -> Green

"Back Curves" -> Blue

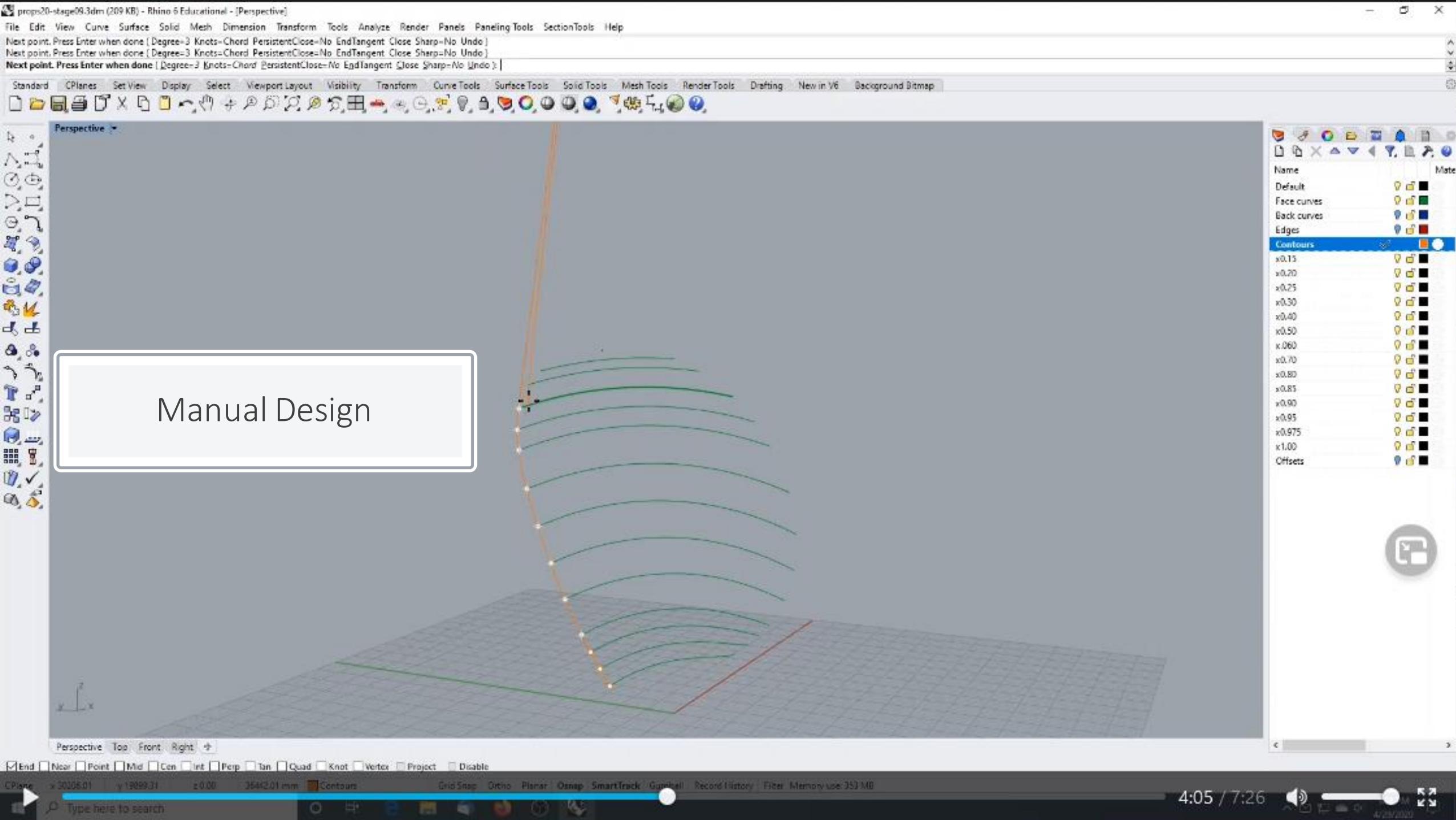
"Edge Curves" -> Red

2) Move each curves to their corresponding layers.

3) Make a new layer called "Contour" and set the color to "Orange".

4) Interpolate the end of Face and Back curves, from trailing to the leading edge.

5) Move the blade tip curve to the "Edge Curves" layer.



Automation Blade Contour

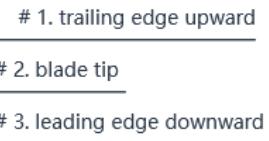
Create contour curves

1) Create a new layer "contours" and activate it

2) Make a list for the points to be interpolated

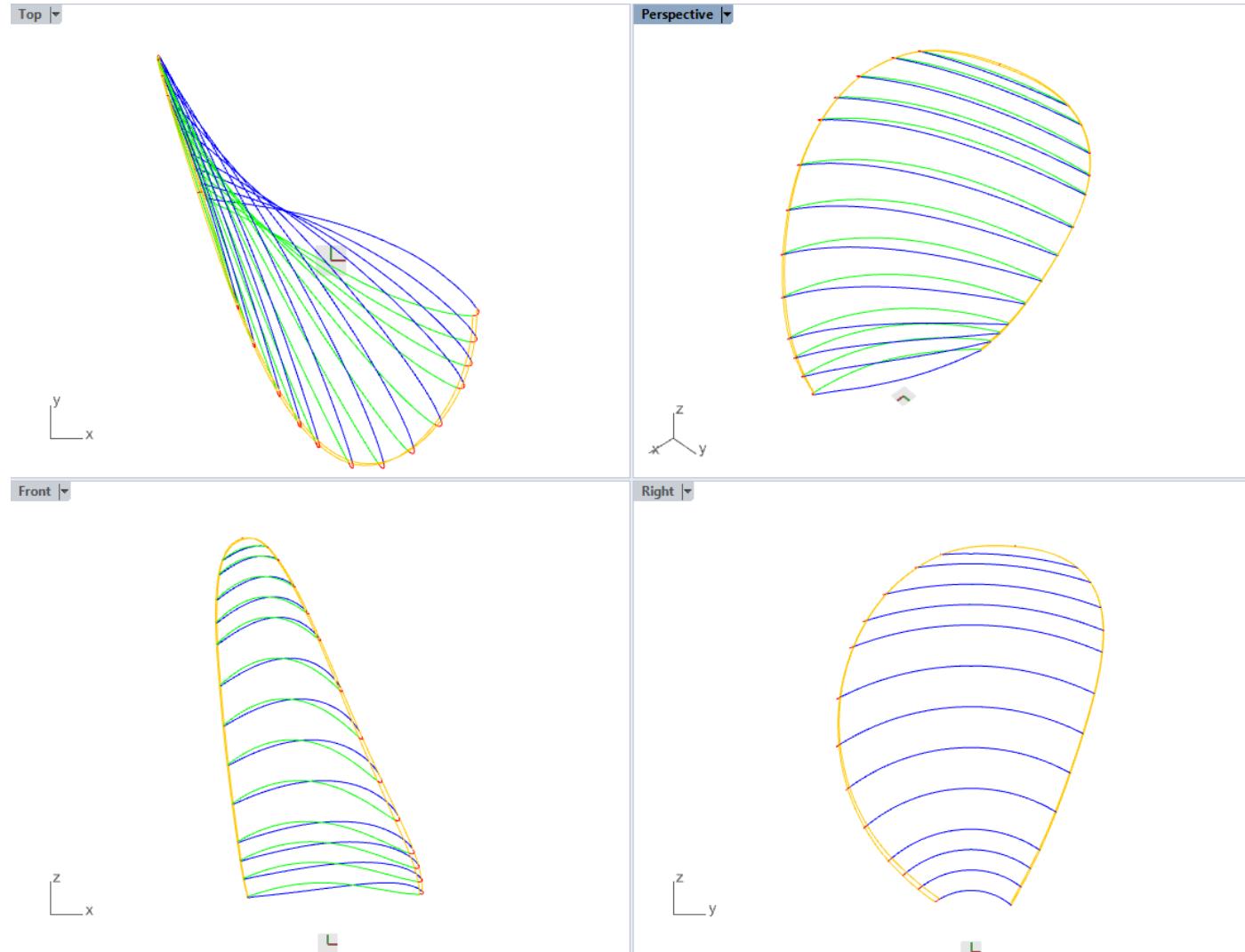
3) Sort points in correct order

4) Create interpolation curve



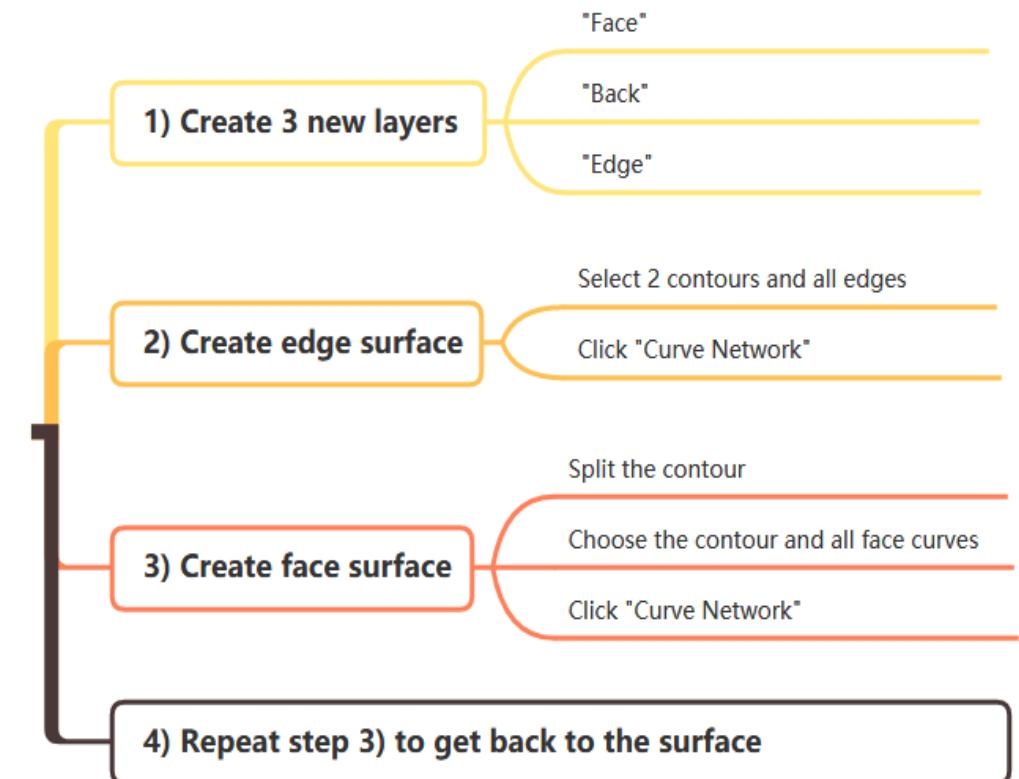
Make sure the knot vector is based on chord length

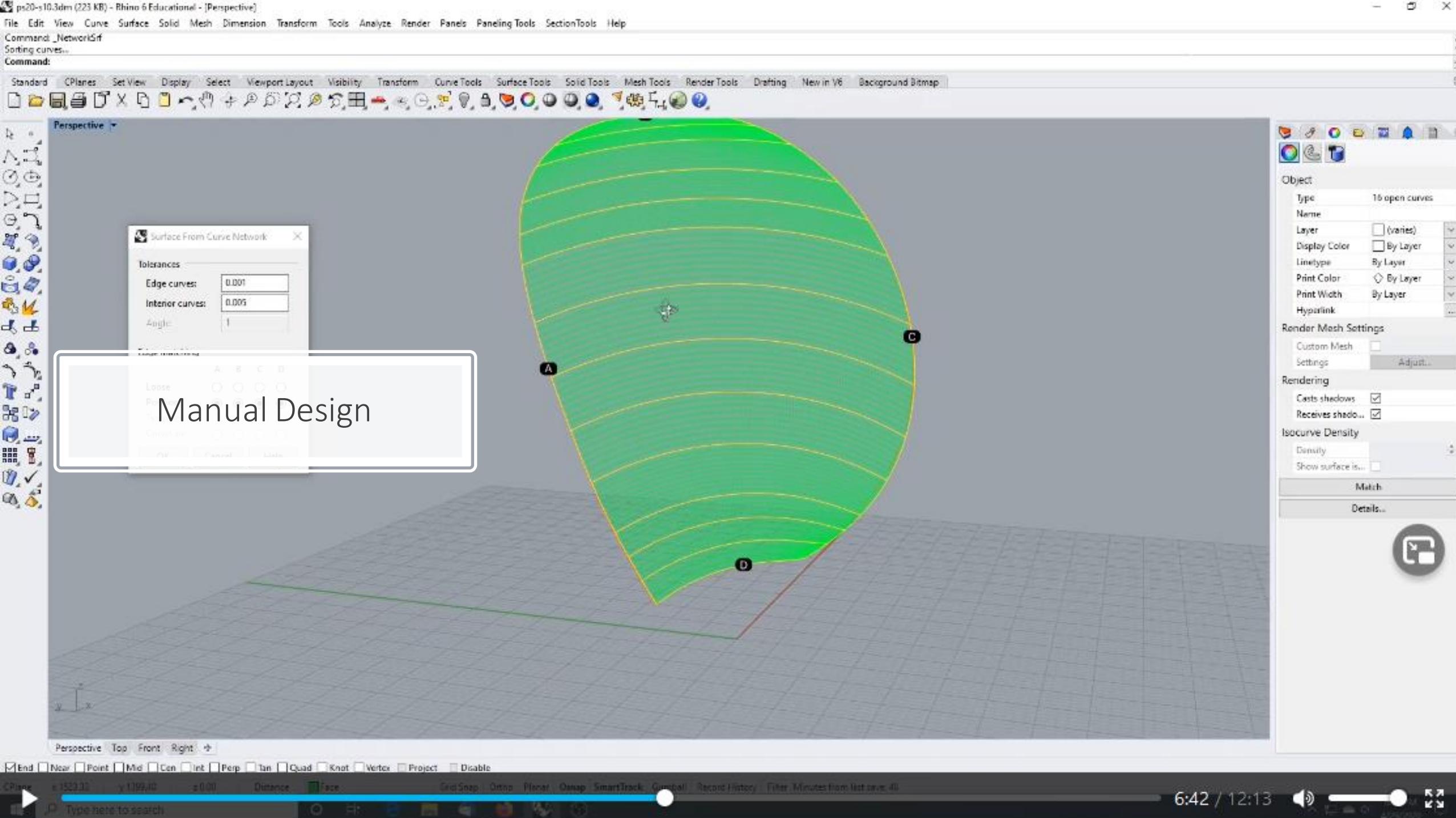
Automation Blade Contour



Manual Design

Process of creating blade surfaces





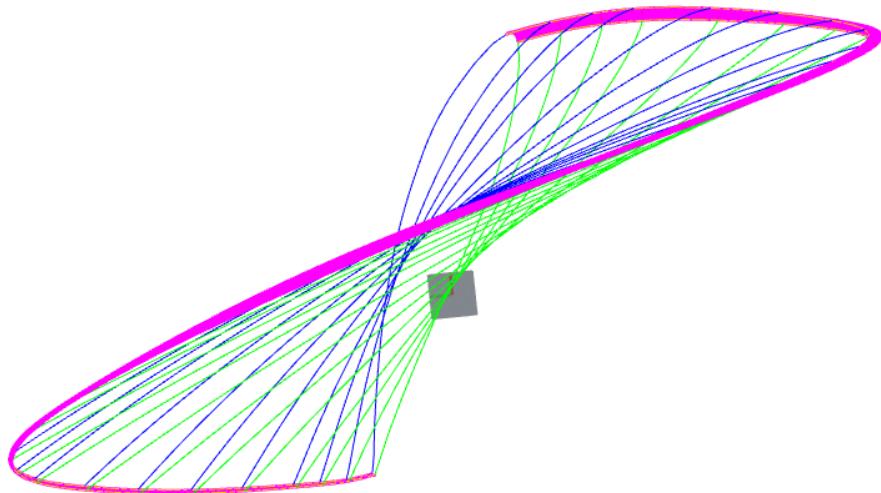
Automation Blade Surface

Create Blade Surfaces

- 
- 1) Create the edge surface
 - 2) Split the contour
 - 3) Face / Back Surfaces

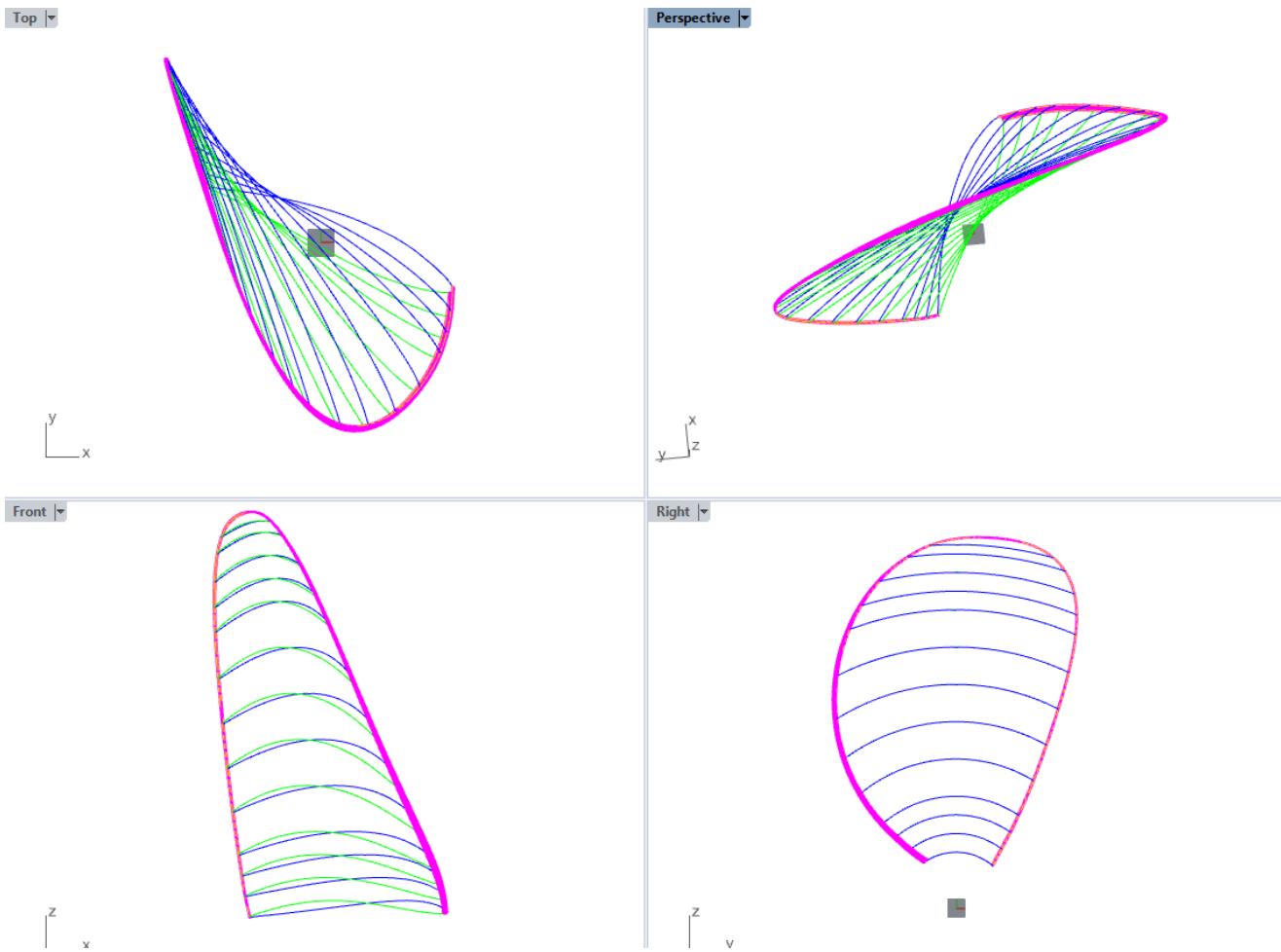
Automation Blade Surface

1) Create the edge surface



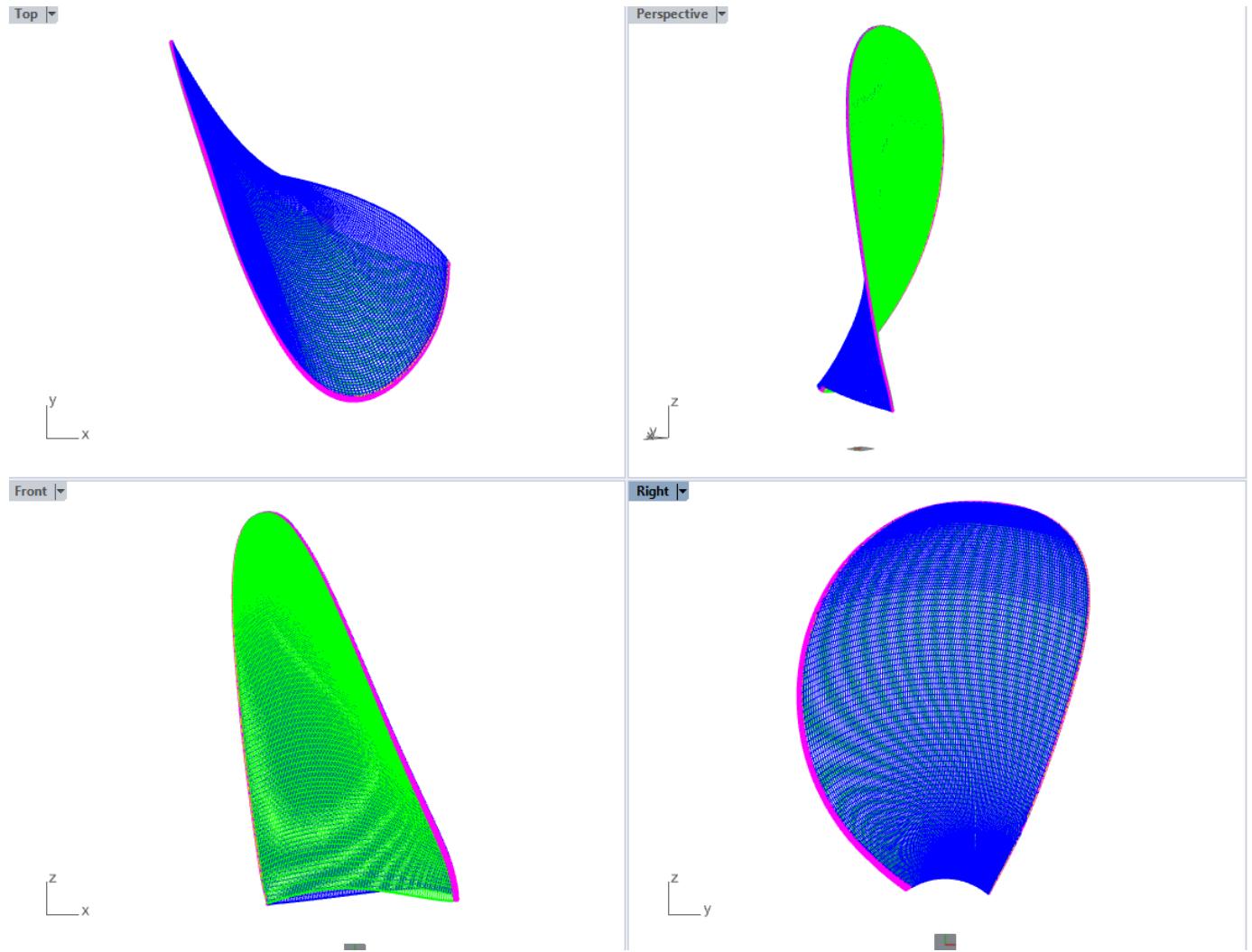
Automation Blade Surface

2) Split the contour



Automation Blade Surface

3) Face / Back surfaces



Manual Design

Process of designing the Hub Surface Patch

1) Auxiliary points

Activate the "Contour" layer

(0,500)

"Front": create additional points

(-750,400)

(850,400)

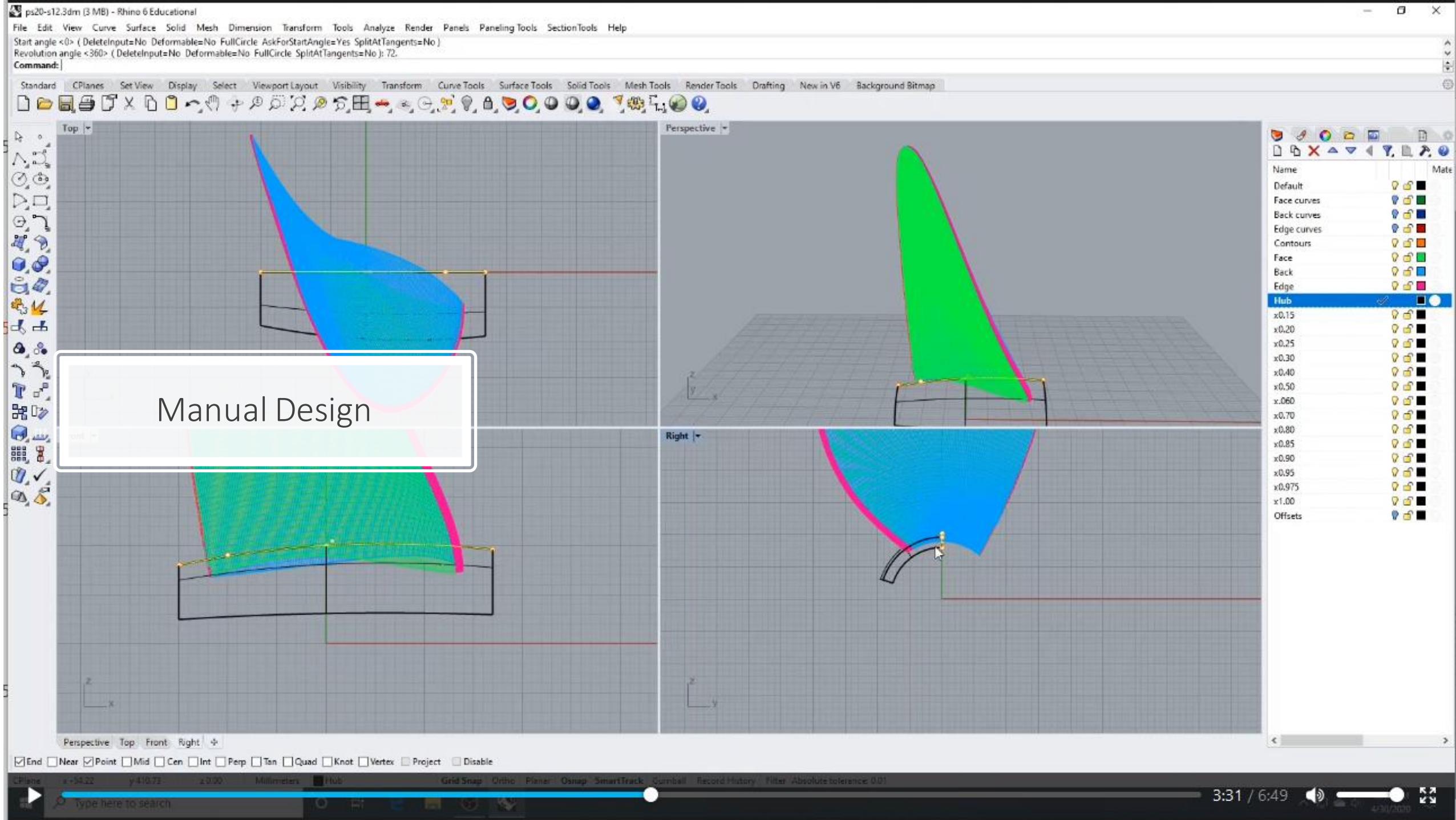
2) Get the surface

Interpolate three points

Create "Hub" layer and activate it

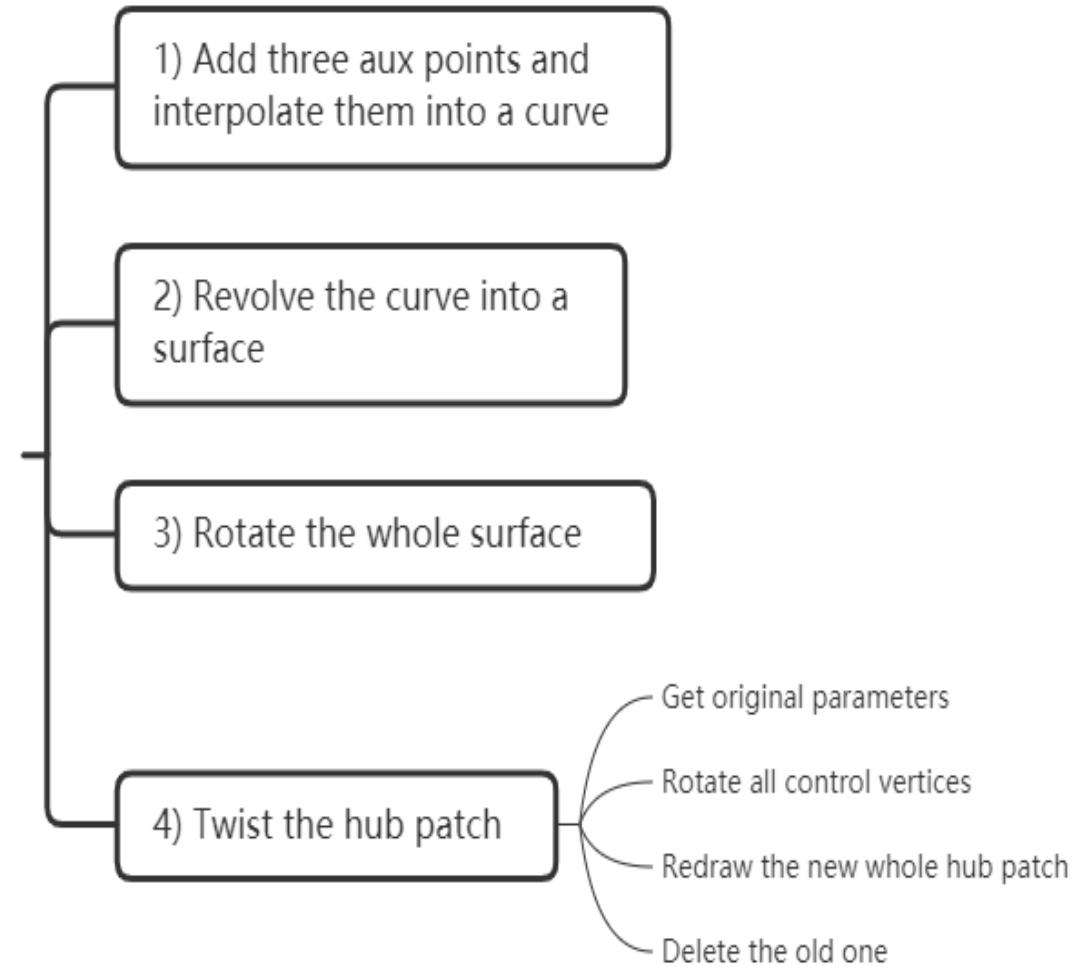
"Revolve" to make a surface for 72 degrees

3) Twist the result with an angle of 72 degrees



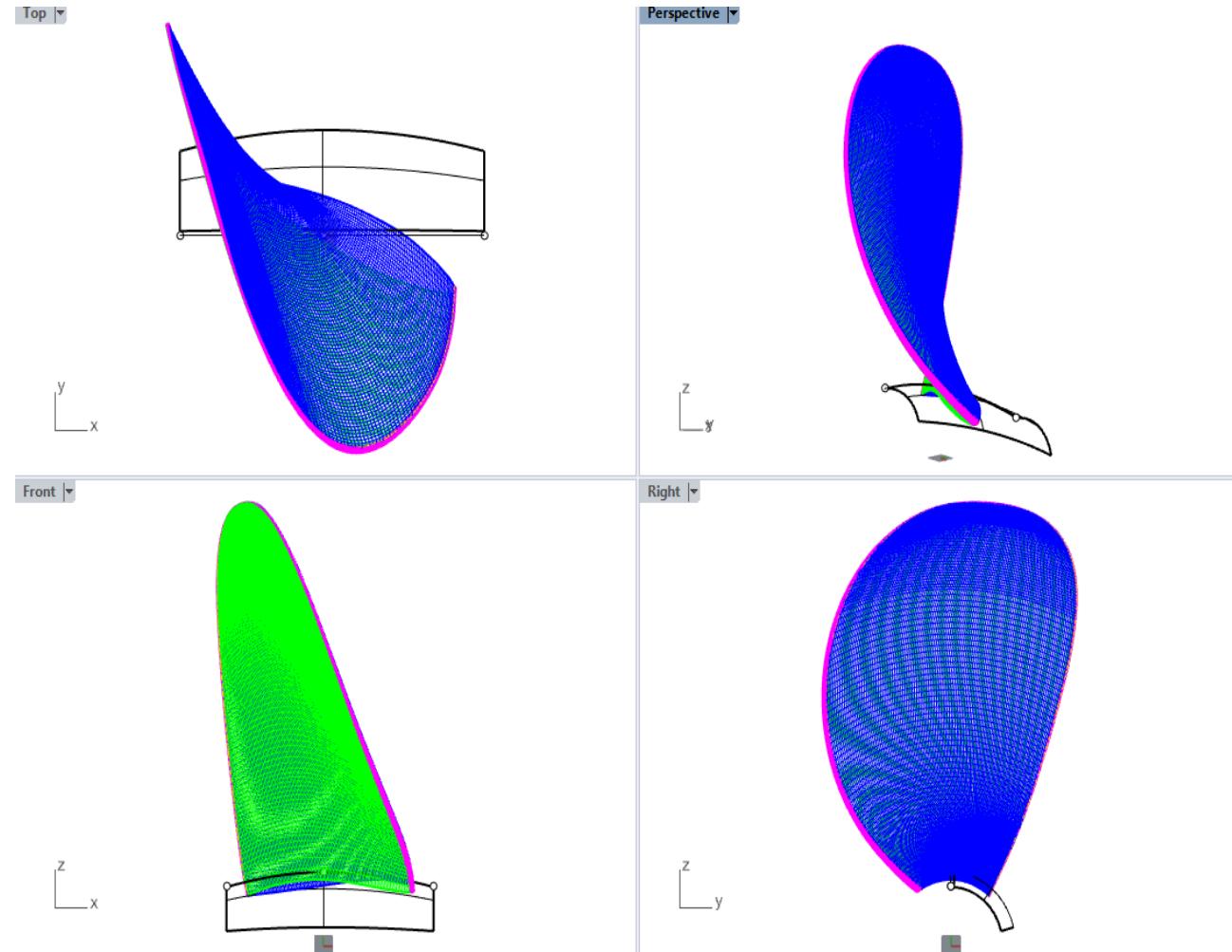
Automation Hub Patch

Create the Hub Patch



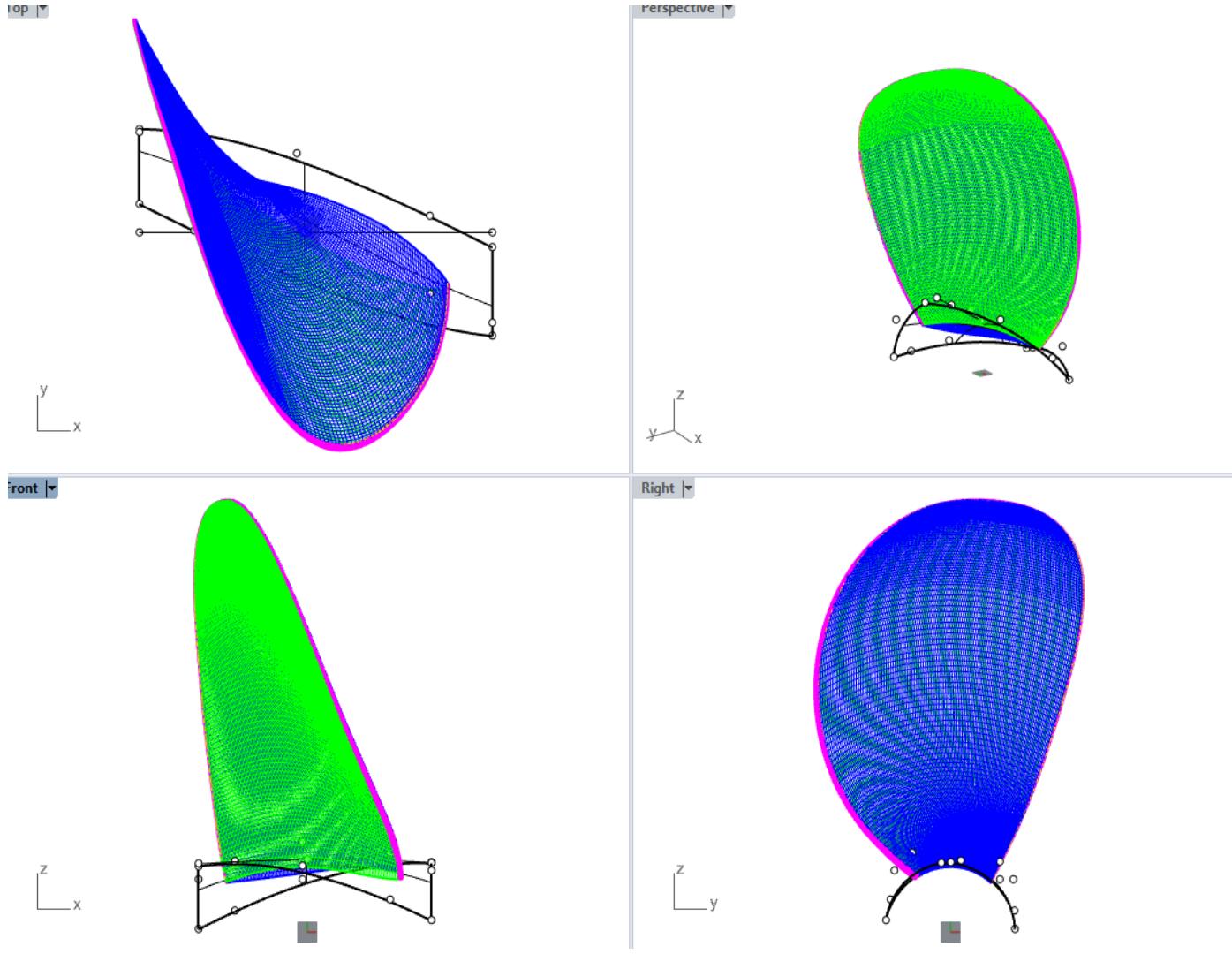
Automation Hub Patch

1) Create the hub surface



Automation Hub Patch

2) Twist the hub patch



Manual Design

Process of Root Fillet Surfaces

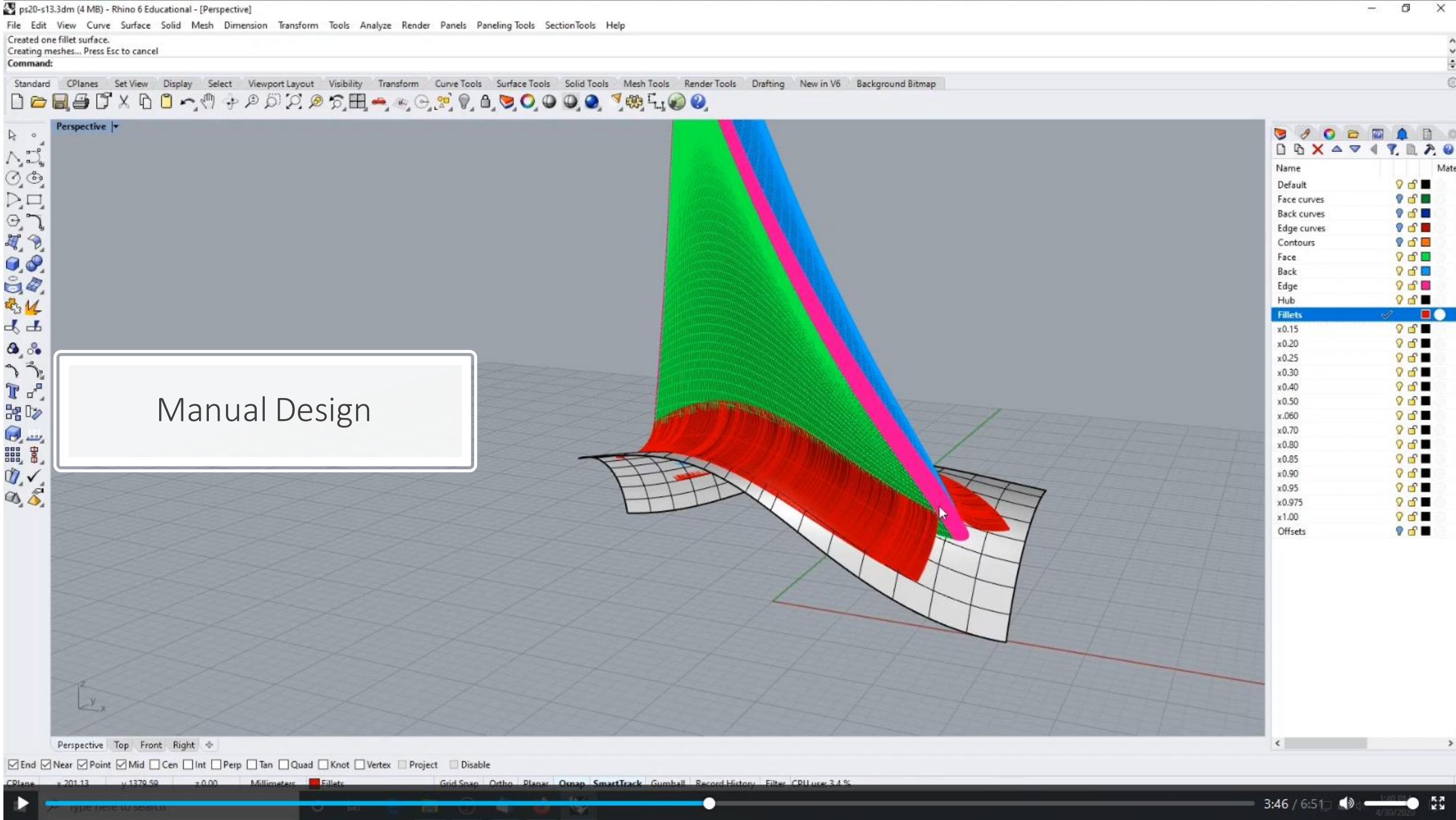
1) Create a new layer of "Fillets"

Choose the face surface, and then the hub surface.

2) Fillet surfaces

Use "Fillet Surface" which radius equals 161

3) Repeat step 2) for the back surface and hub surface.



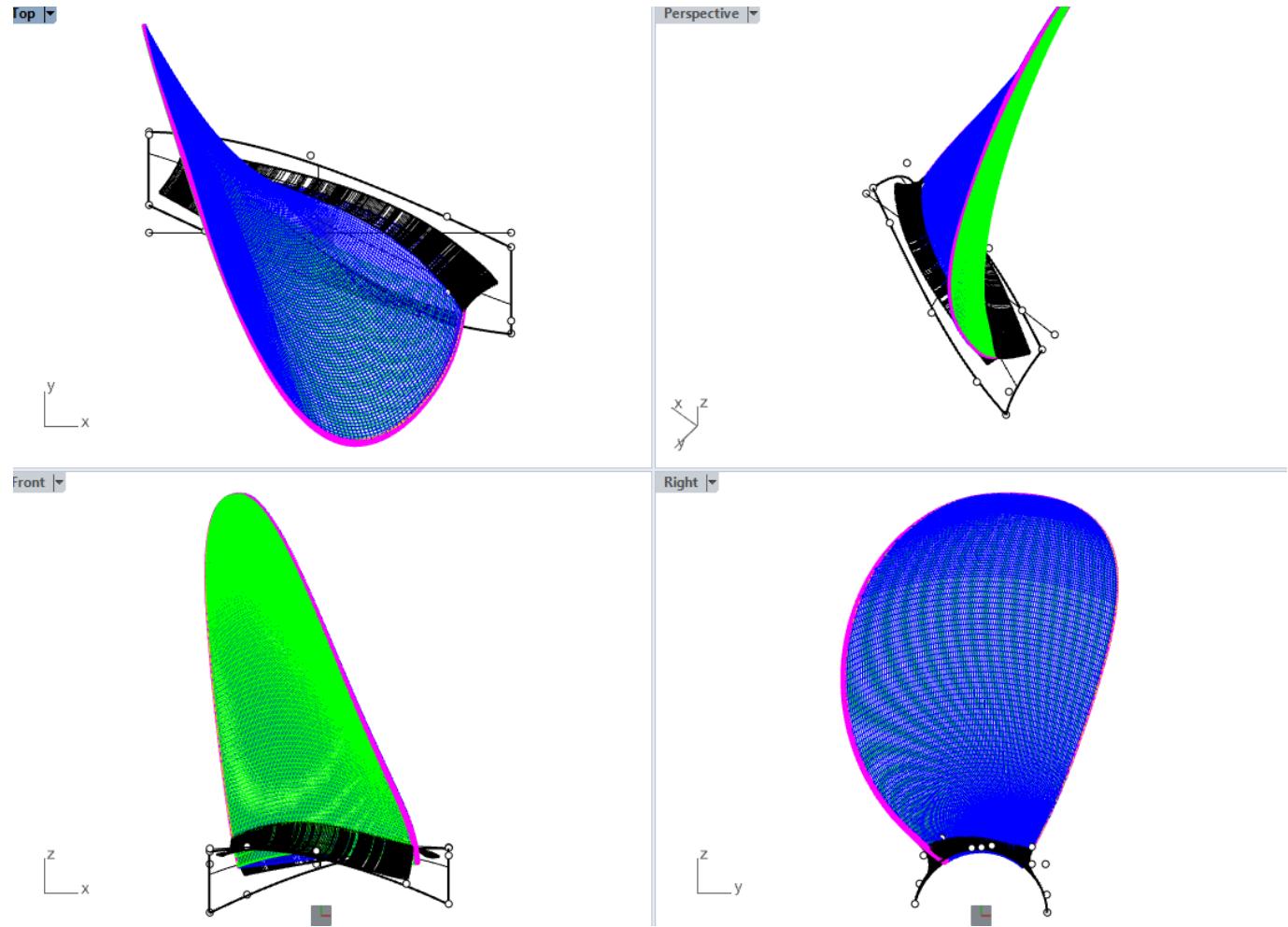
Automation Root Surfaces Fillets

Create Blade Surfaces Root Fillets

- 1) Create a new layer and activate it
- 2) Get the surface domain of the hub patch surface
- 3) Get the surface domain of the blade surface
- 4) Fillet the surfaces

Automation Root Surfaces Fillets

1) Create face and back fillets



Automation Root Surfaces Fillets

Create Root Edge Fillets

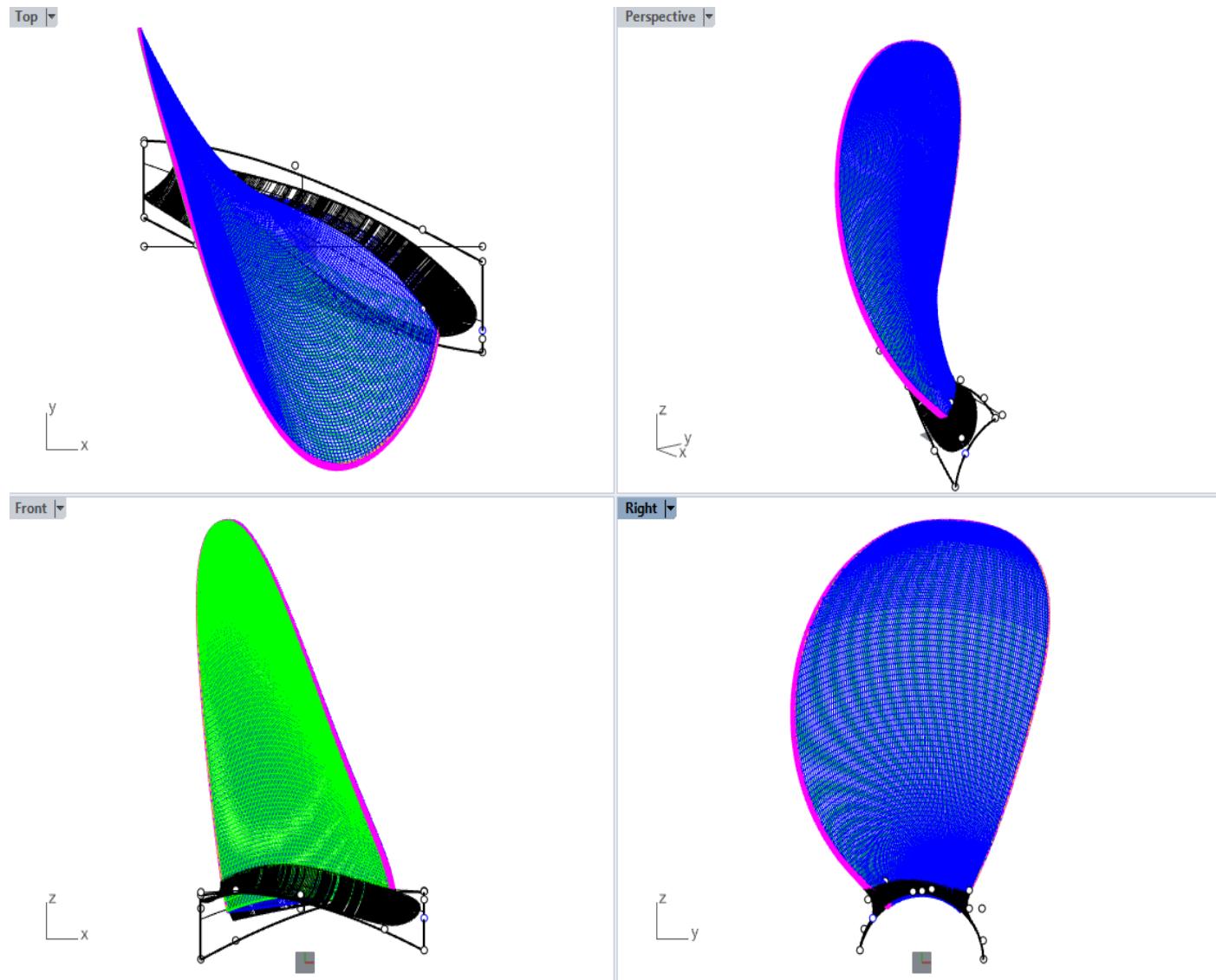


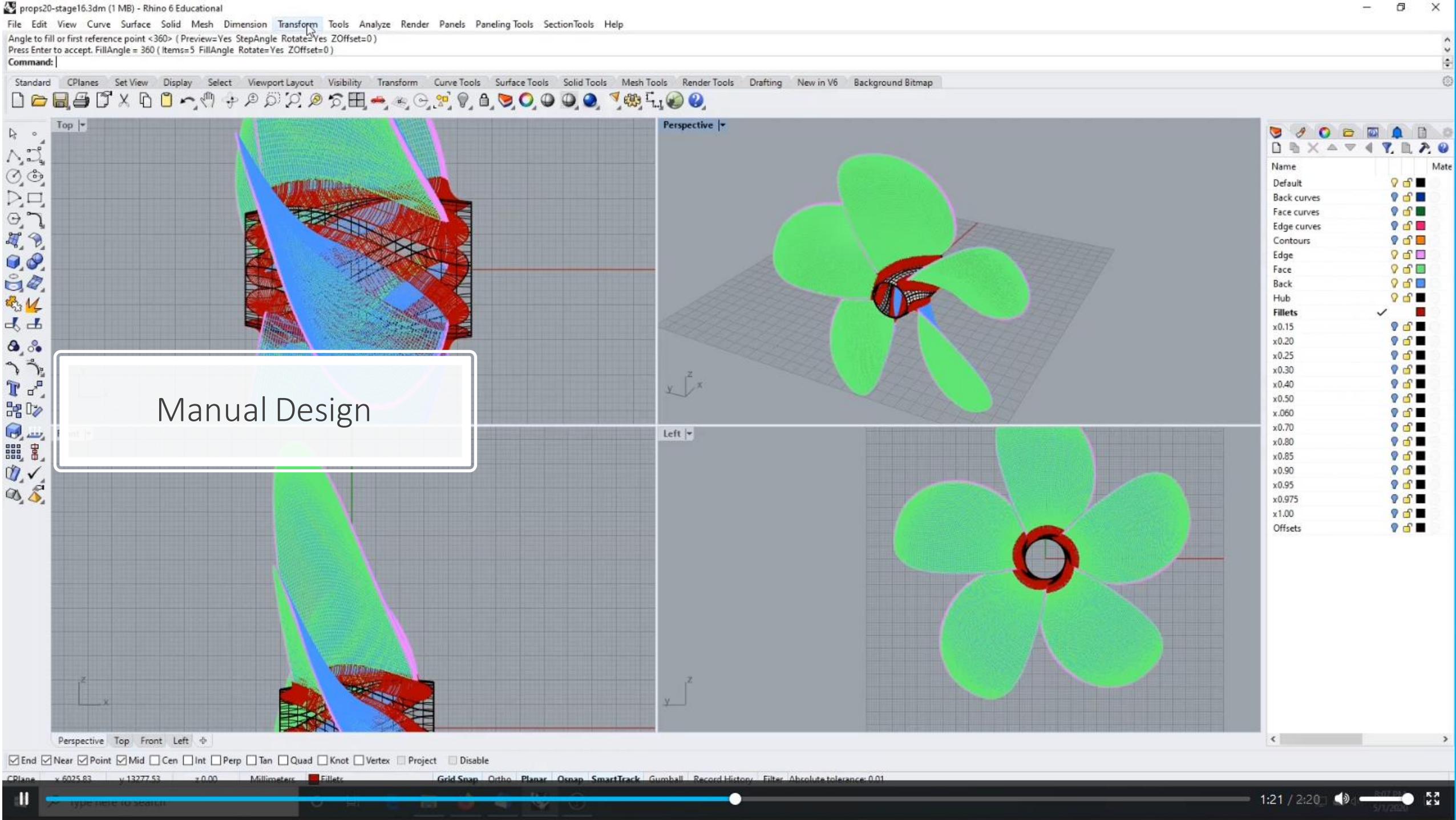
- 1) Get the surface domain of the hub patch
- 2) Get the surface domain of the edge surface
- 3) Fillet the surfaces



Automation Root Surfaces Fillets

2) Create root edge surface fillets



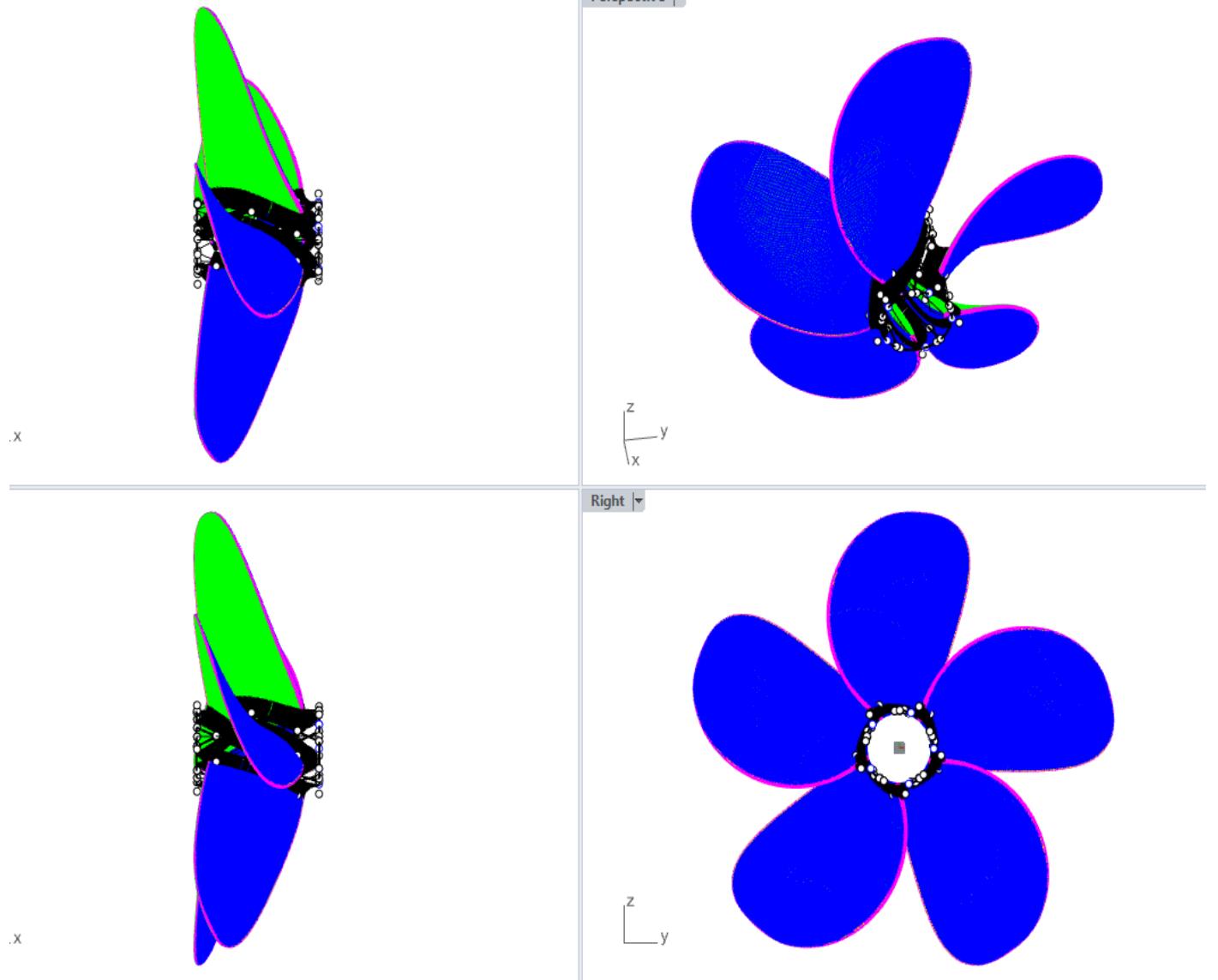


Automation Complete by Polar Array

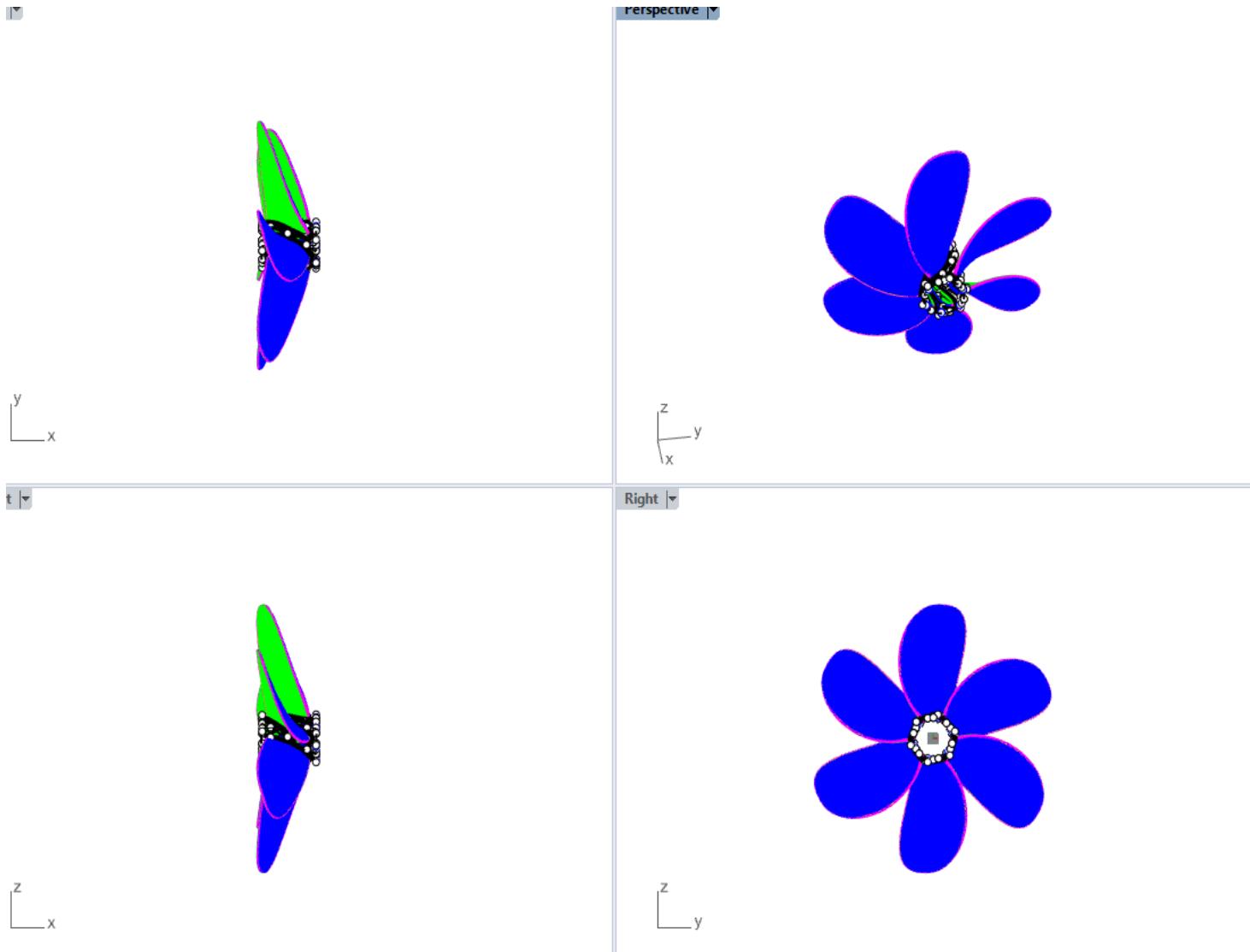
Polar Array

- 
- 1) Determine the rotate angle
 - 2) Create a loop for each blade position
 - 3) Get the transform matrix
 - 4) Polar array the blade part

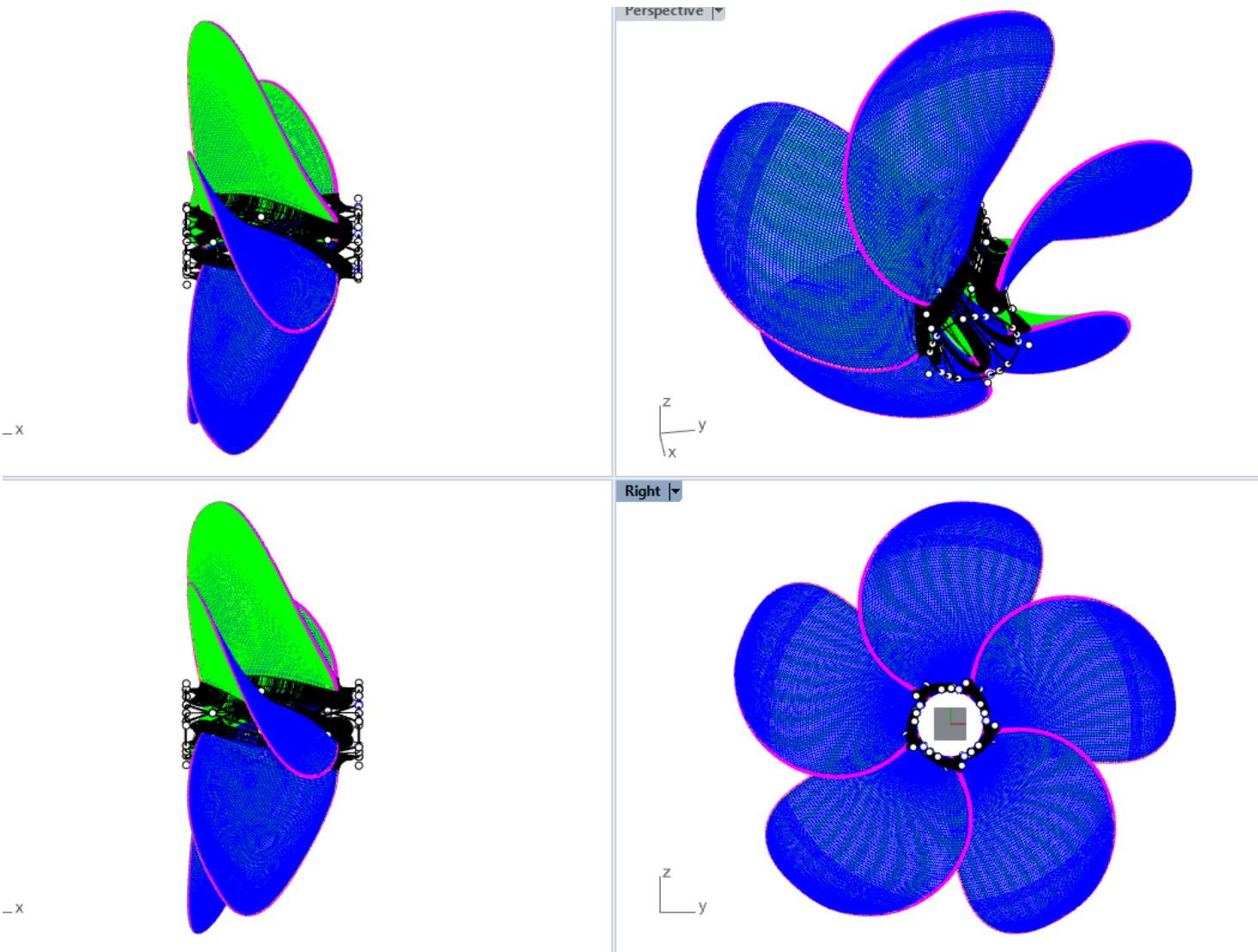
Automation Complete by Polar Array



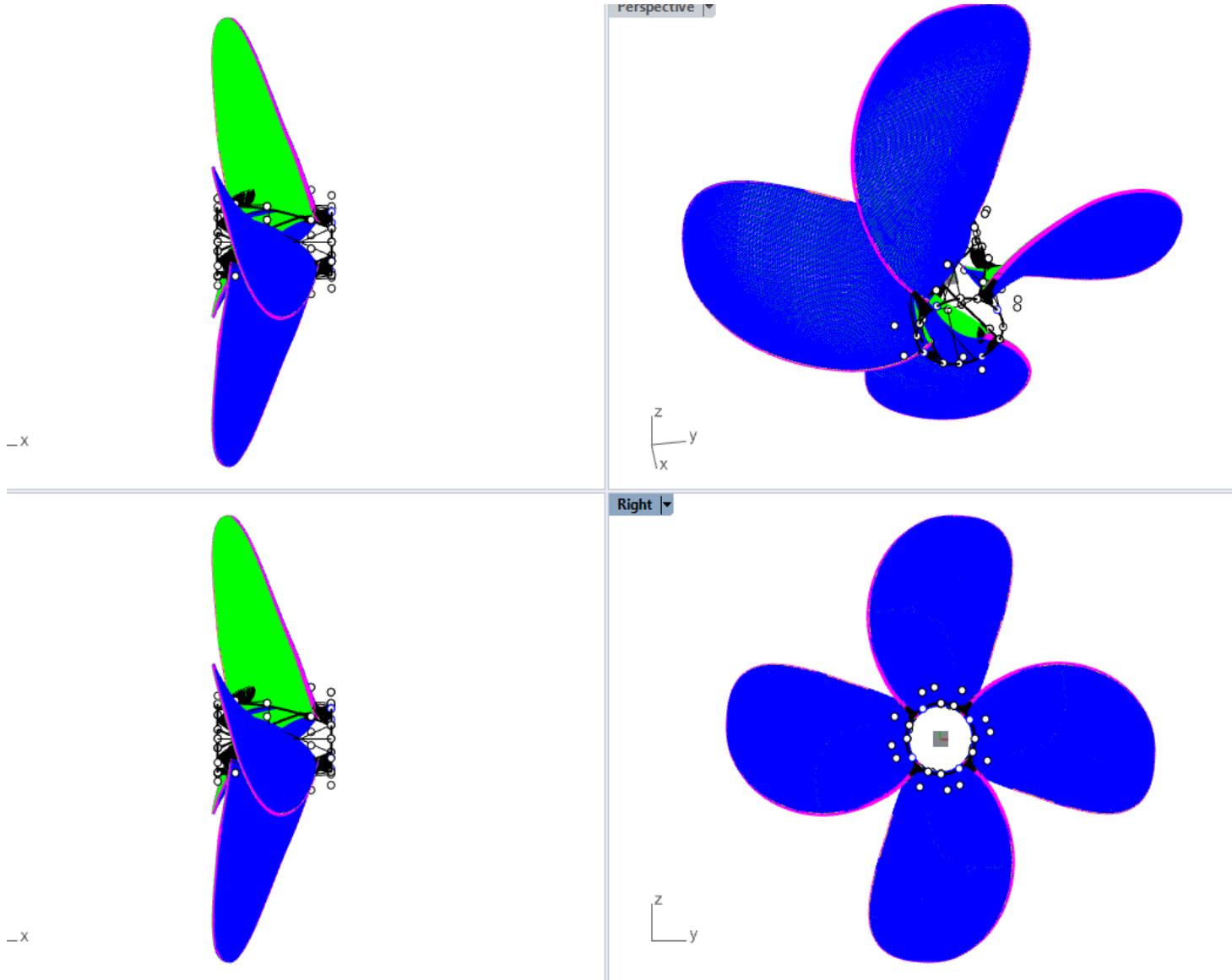
Other Examples



Other Examples

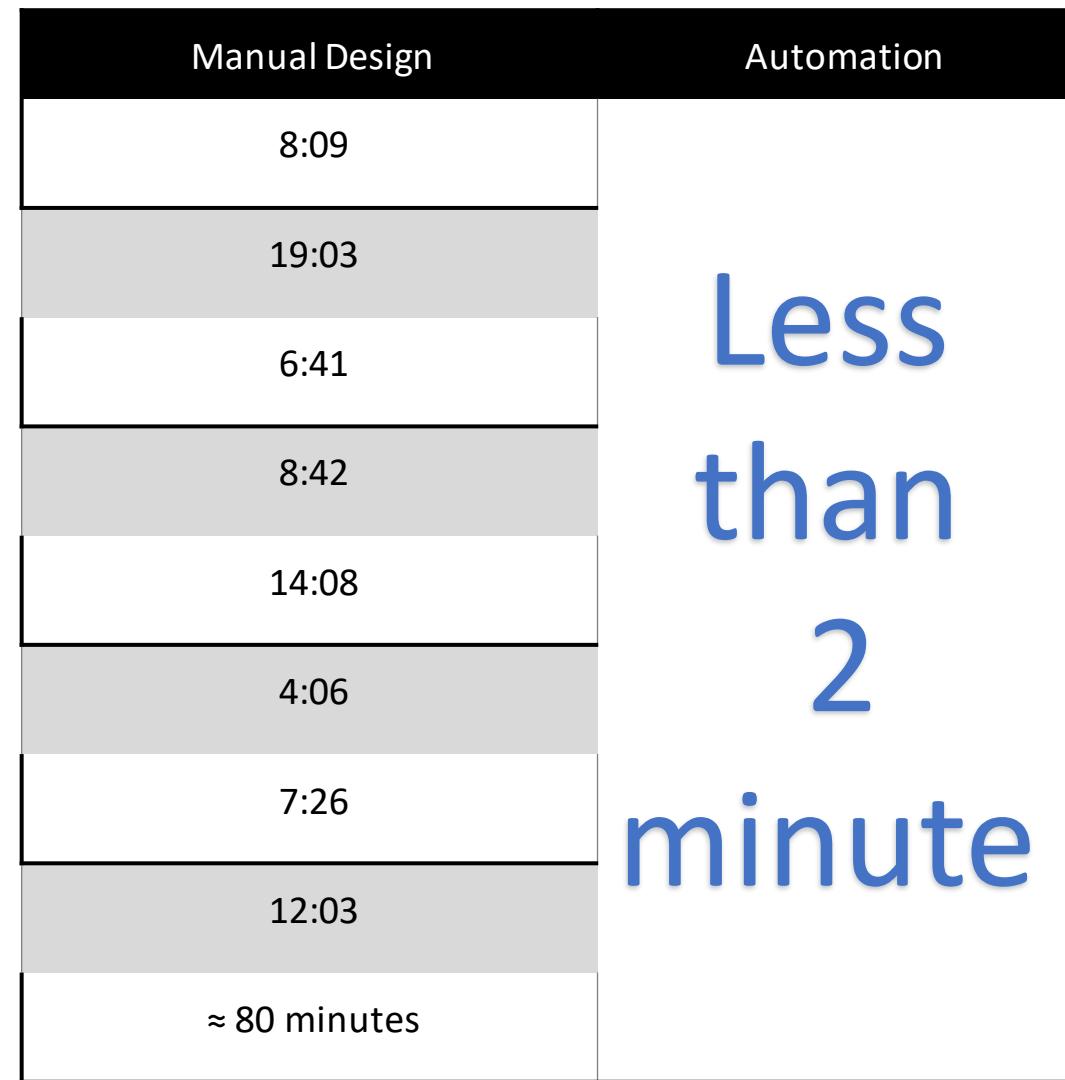


Other Examples



Discussion

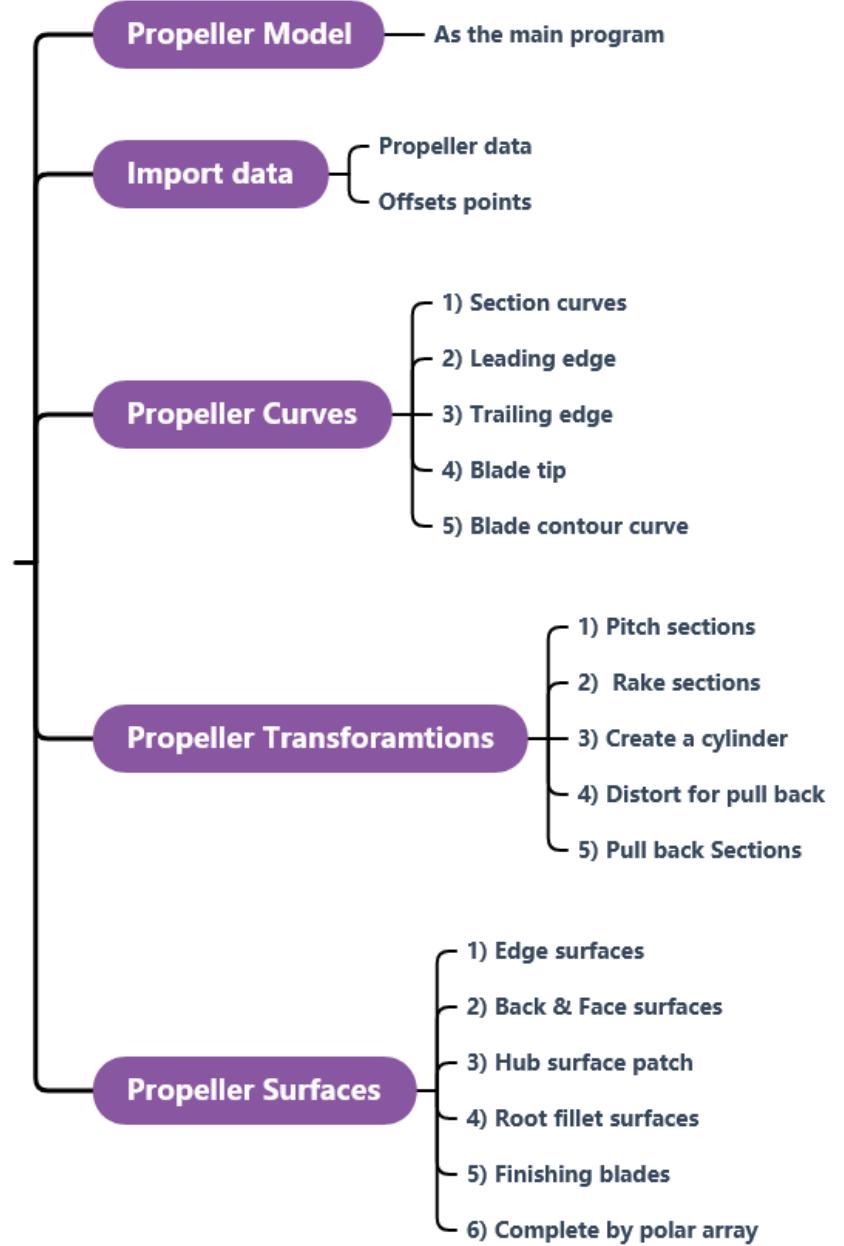
1. Conclusion



Less
than
2
minute

2. Future work

AUTOMATION OF PROPELLER WHOLE DESIGN PROCESS SUMMARY



Future work

- 1) The third vertice
- 2) Root fillet
- 3) Hub patch trimming

Demonstration



Thanks for your attention!
Have a wonderful holiday!



contact qli3work@gmail.com