

91 Burrendong Road  
Coomabah 4216  
Queensland, Australia  
+61 7 5529 6892  
peter@carbon-works.com.au

## From CarbonWorks...

Author: Peter Schwarzel  
Phone: 0408 681 932  
Doc No 147-15 Rev4  
TT - 200mm V4 Process

10-11-2011

Author: Peter Schwarzel

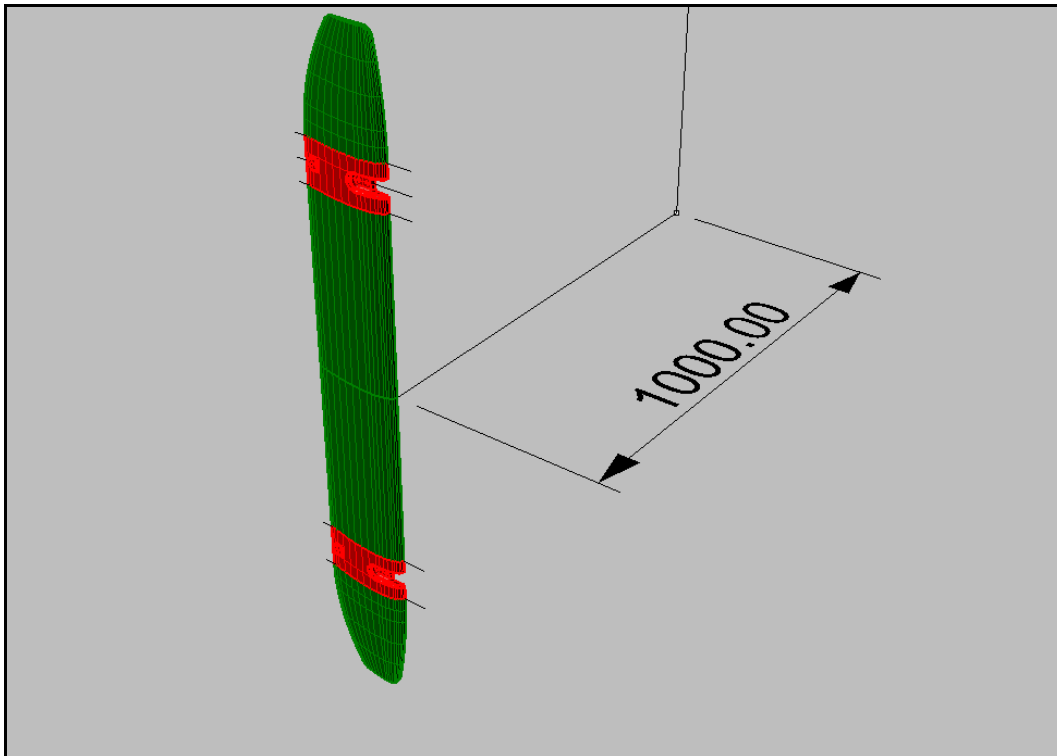
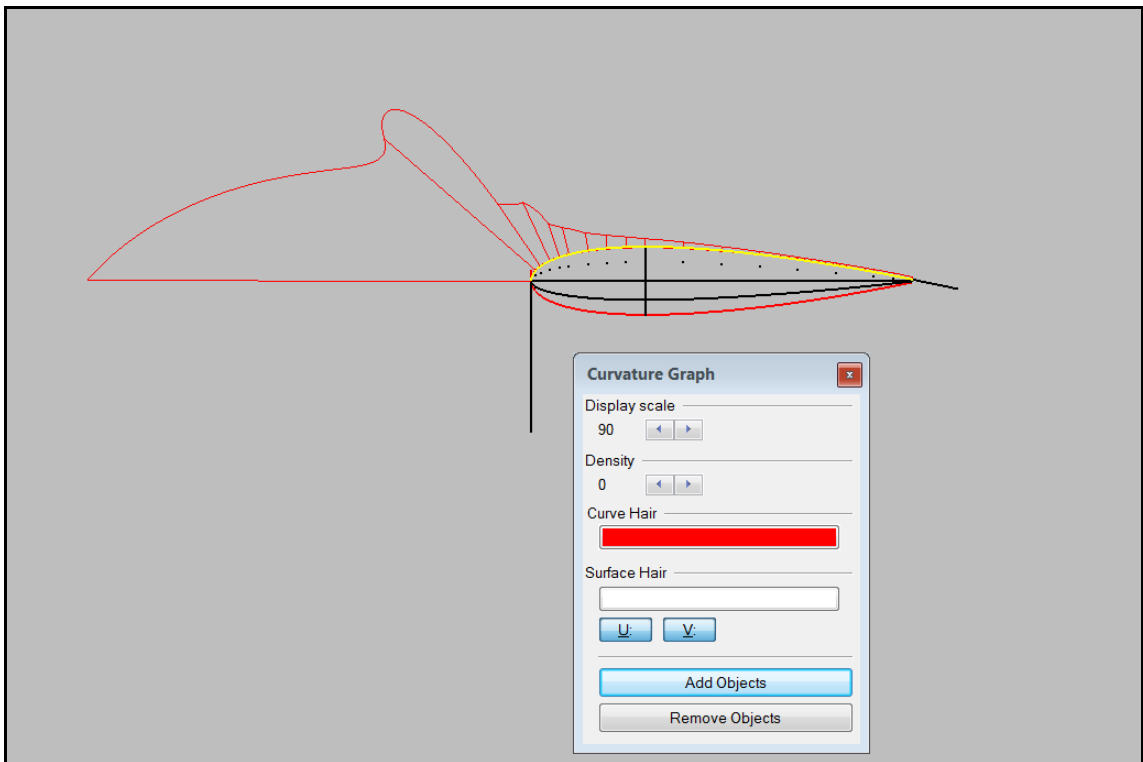


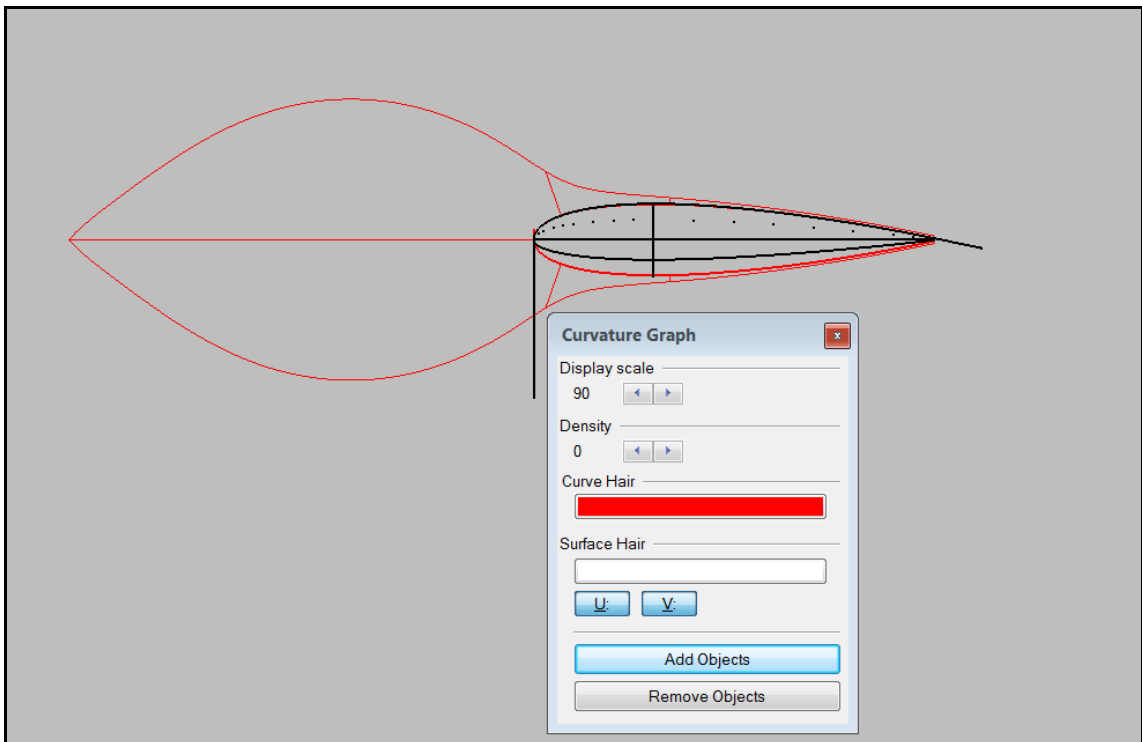
Figure 1 – TT-200mm-V4 surfaces in Rhino3D

Building an accurate aerofoil is not an easy thing to do. Here's how I do it. As this will be CNC machine cut we need to ensure the surface is very accurate as we do not want to do major hand finishing.

- 1) Build a NACA 0020 spline in Rhino and fair it, this becomes the reference section; a half a side only in this case. As the trailing edge (TE) does not come to the midline I project the TE to the leading edge (LE) and cut the small bit of the nose "off" the section. This provides a flat bottom to work with. In this case I then add a 0.5mm flat to the LE and TE. This is there to provide a flat for dimensional referencing & for machining to. If you try to machine a feathered edge it will be a problem. In NURBs programs such as Rhino3D it is very important to set up it's geometric tolerances correctly otherwise your surfaces will be of poor quality.



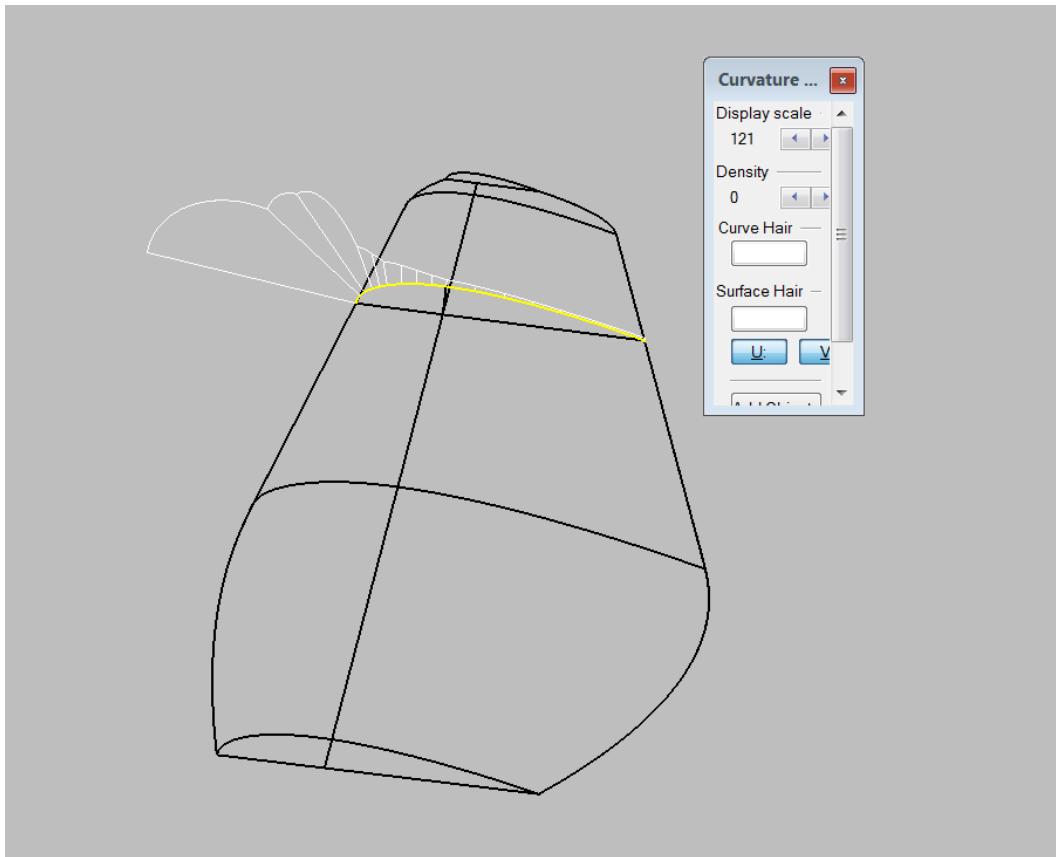
**Figure 2 – 10 point spline for NACA section showing curvature comb, note the notchy comb**



**Figure 3 – Faired curve. This has been rebuilt to 0.001mm maximum deviation to the original curve using a blend curve, but you can see its much smoother than the original curve. The pointy front end of the curvature comb can be improved as well.**

- 2) Once the reference section or curve is designed it is lofted over the plan form that we want. In this process various errors can be introduced so the surface must be checked for curvature and edge accuracy. We are aiming at what is called a “watertight” polysurface. There are 122 surfaces in this model. We need a watertight surface as when we bring it into the FEA model if we have cracks between the surfaces these cracks will appear in the FE mesh.

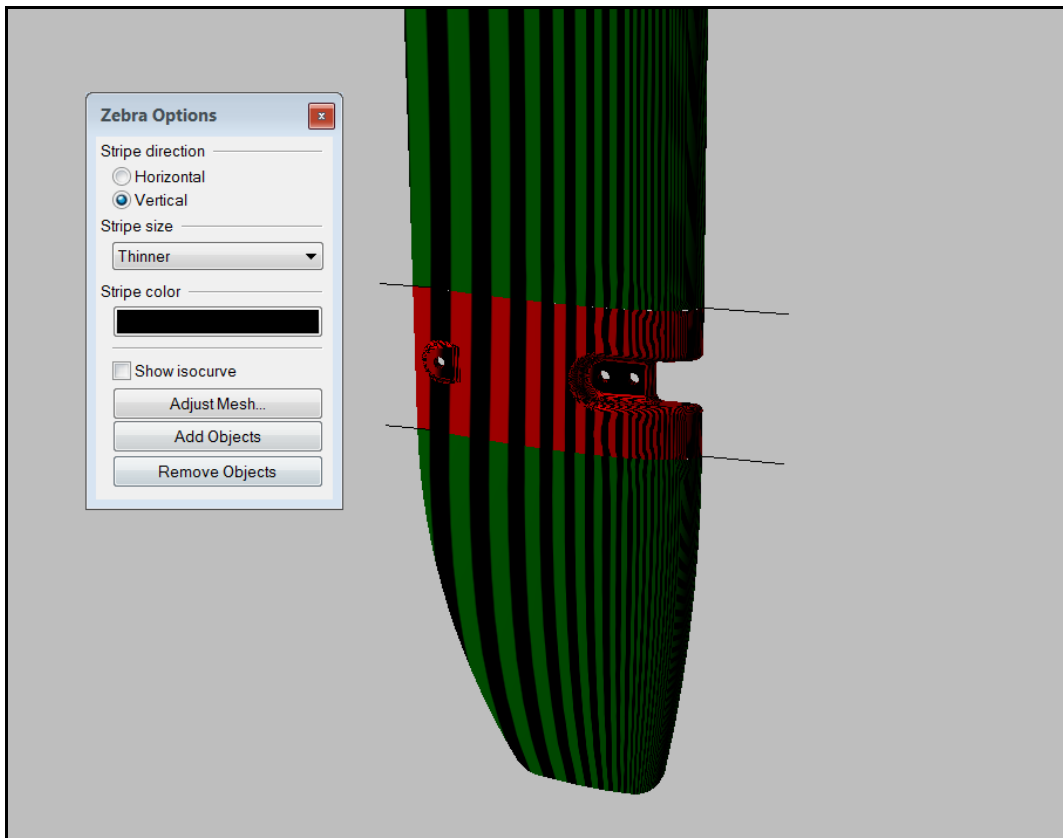
Although we have crack fixing tools in the FE software every time we use these tools we move the mesh away from the original surface. The original mesh is always the more accurate ie the nodes lie on the surface. Any mesh operations after the first meshing will move nodes away from the original surface definition.



**Figure 4 – lofting armature. A series of lines that define the edges and sections that will be turned into a surface. Also the primary curve here is shown with a curvature comb.**

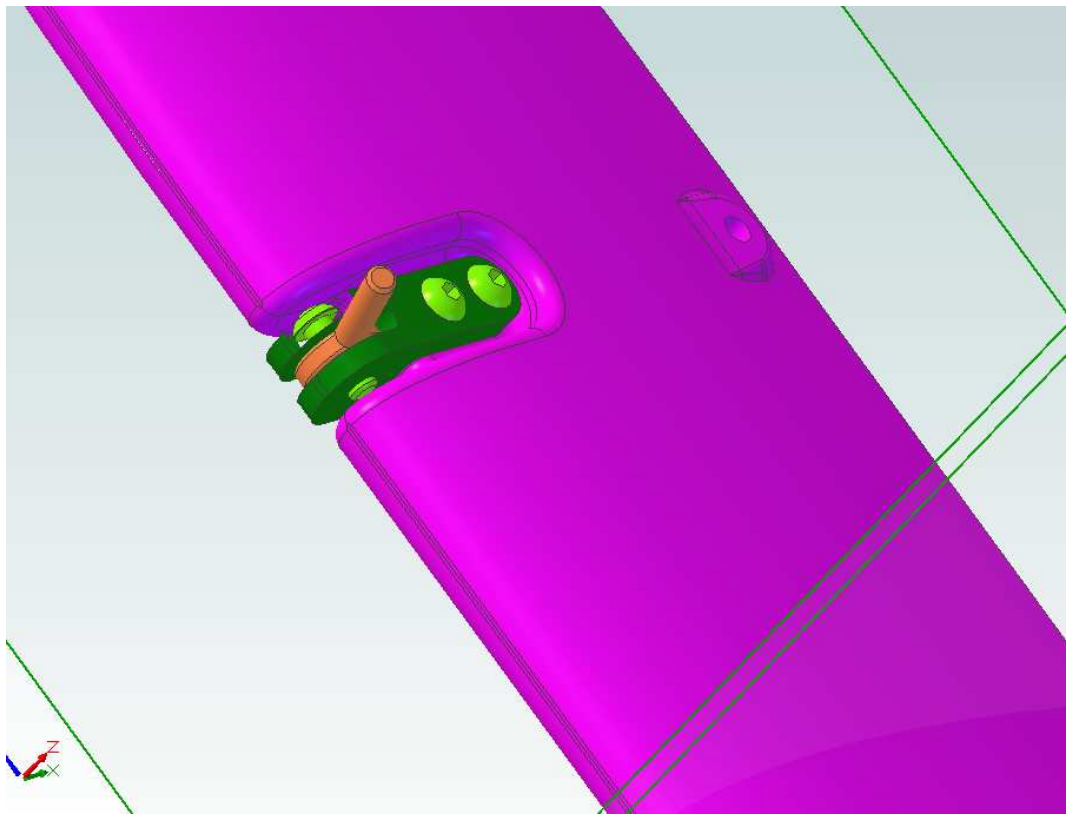
Lofting a foil can be done in many ways. My preference in this case is to keep the maximum thickness in a line. Also some theories say that a taper ratio of 40% to 50% is a good approximation of an elliptical loading. So I have tapered this blade 50%. The LE and TE tapering curves are radii (G1). I have played with G2, G3 and G4 curvature continuity but an arc is easy to do and is consistent. Using high order continuity curves can be fiddly.

- 3) When I'm sure we have a watertight surface, that's very fair and accurate I import it into Alibre for detailing. In this case this is the recesses and filleting. I'm hoping to be able to do the entire model soon in Alibre as they have introduced some surfacing tools.



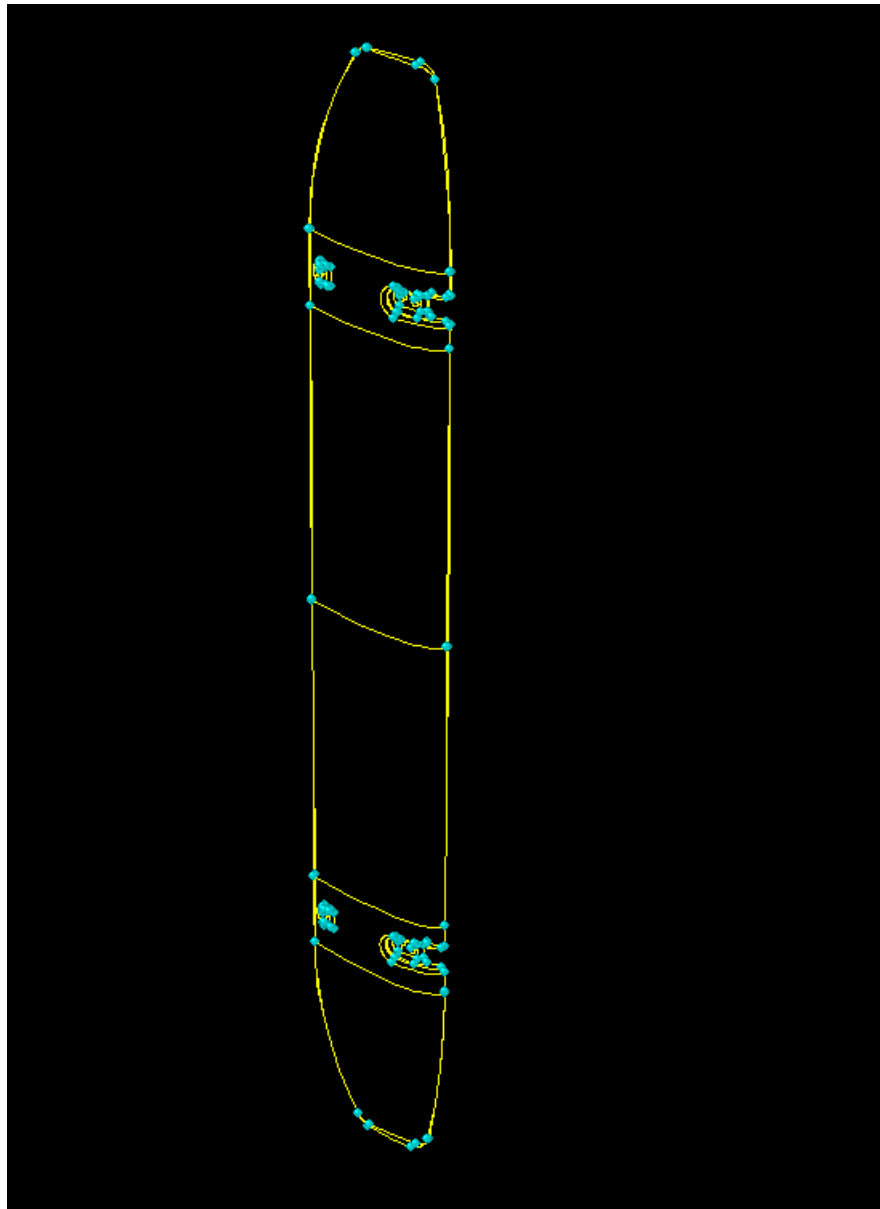
**Figure 5 – Zebra plot of curvature showing a good surface. All the stripes are parallel.**

- 4) Once in Alibre I can place the recesses and holes easily, produce drawings, assemblies and calculate weights and various things about the blade. In Alibre I can move the details around if I have to, I can't do this in Rhino as it's not a parametric modeller.
- 5) Once the blade is detailed, I then export it back to Rhino and do more surface checking as Alibre does not have surface checking tools. I also can split the surfaces into various sections... say where I need to reinforce the laminate eg around holes. I can also place each surface into a layer so it will be identified by the FE system and set up as a separate material automatically. Eg in Fig 1 you can see the blade is broken into red and green areas. The red will be a reinforced area; the green will be the basic area.



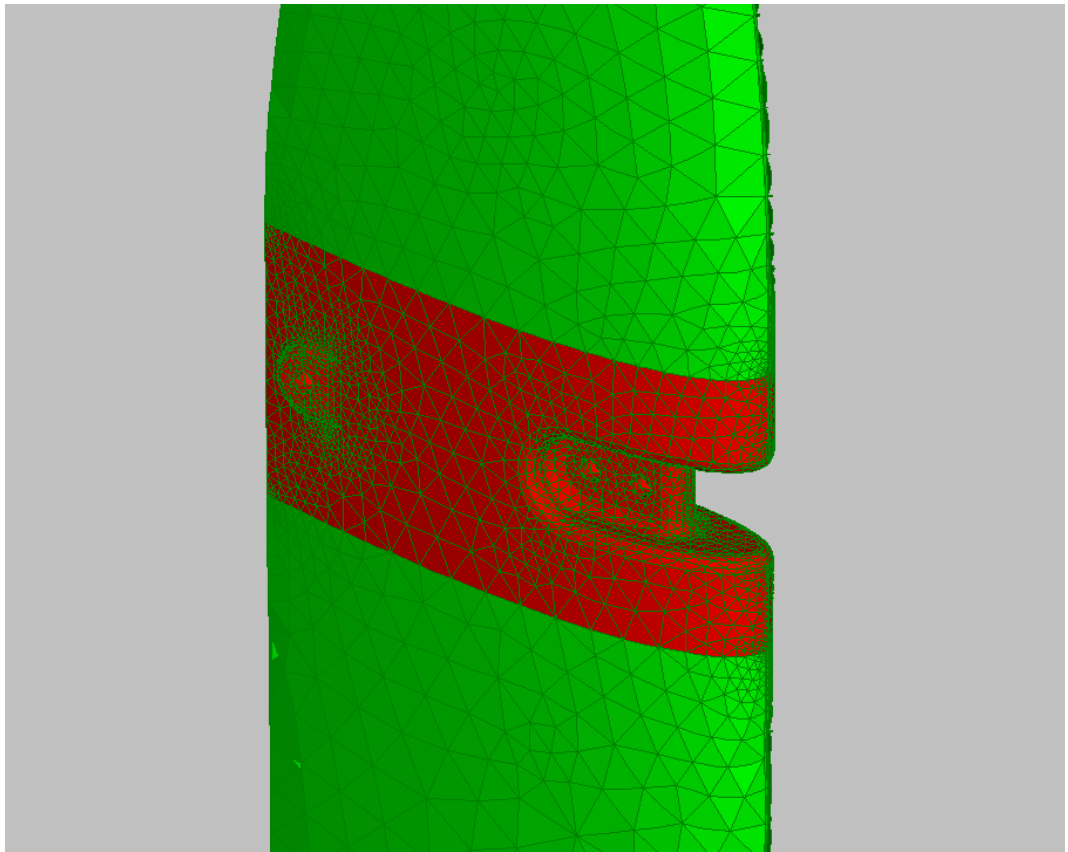
**Figure 6 – Assembly in Alibre**

- 6) Once happy with the blades geometry I export it as an iges or step file ready for import into the FE system. The geometry has to be checked and sometimes “defeatured”. Very small features mean a very fine mesh. Very fine meshes take a long time to solve and small features usually do not contribute to the overall results much; unless it is the feature you want to analyse. So in this case small features are refined and removed by using tools in the FE system.

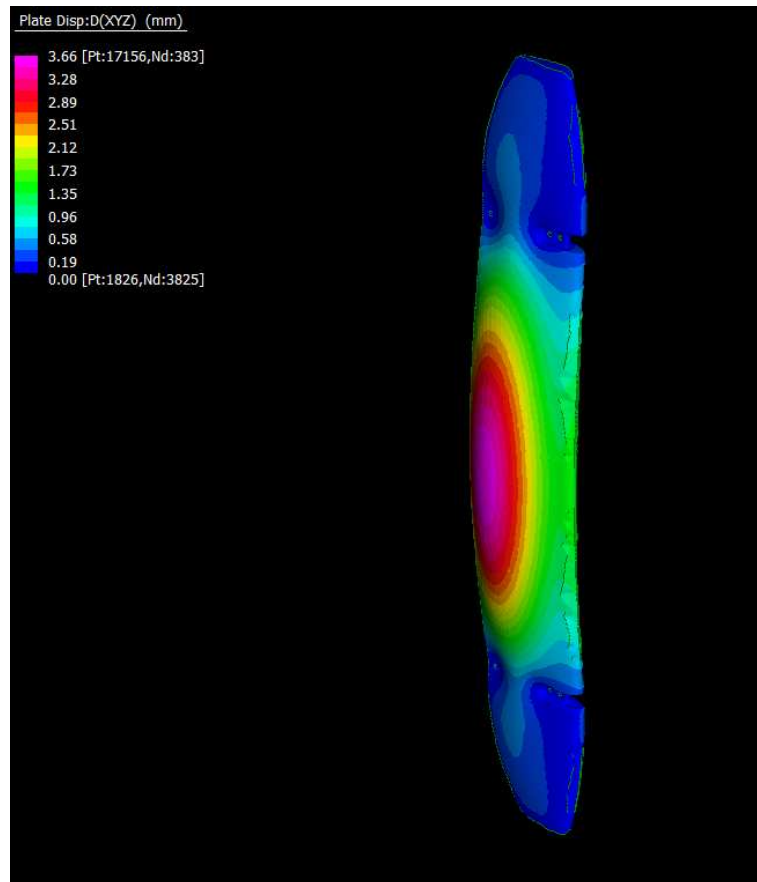


**Figure 7 – FE geometry ready for meshing**

- 7) Then we mesh. In this case I shall use a triangular mesh. This is because we have lots of small nooks and crannies in our geometry and triangles will fill these in nicely vs squares. I don't usually use tris but I think this is a good move here.
- 8) Test running of the model is done and the mesh is checked for various problems. If the mesh is too coarse it will not detect small buckles. If too fine it will take a long time to solve. There are many issues that can occur with meshing but that's a long story.



**Figure 8 – triangular mesh, 17000 elements. It's a quadratic mesh so has mid nodes to allow the element to bend and follow the surface.**



**Figure 9 – Typical result for FEA. This is the deflection of the blade when it spins at 300rpm and includes the aero load.**

- 9) Then the blade has to be restrained, loads applied and solved. The solutions investigated will be linear deflection and stress, linear buckling & non-linear geometric stress and deflection. Each solution tells us something about the structure. And again thats another story.

Regards Peter Schwarzel