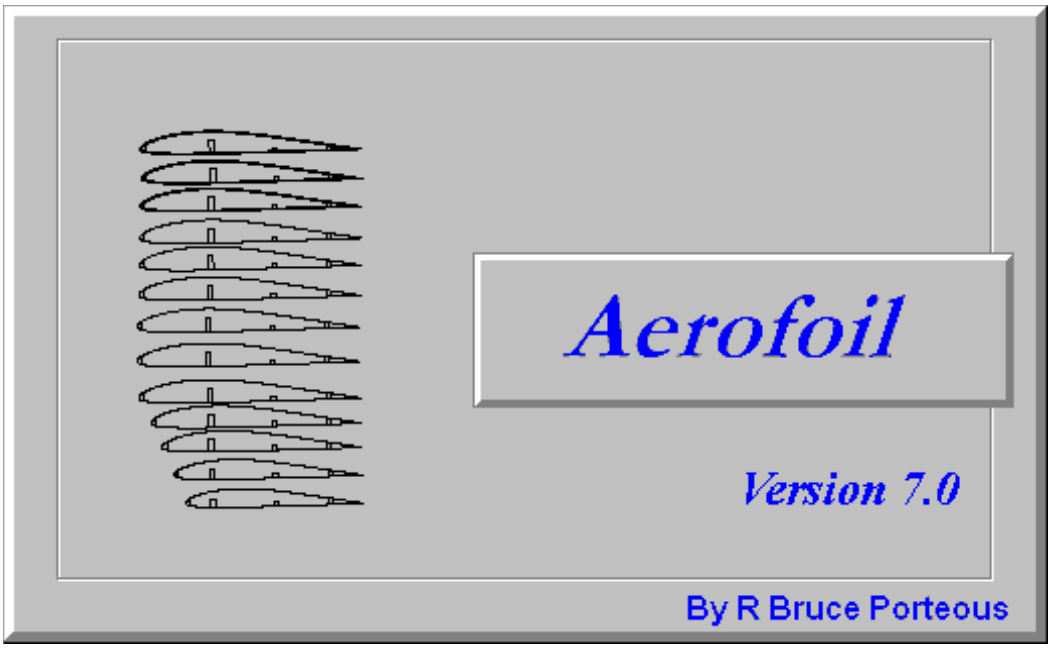
Aerofoil v7.0

Plotting and 4-Axis G-Code generation



This software is available at:
https://github.com/rbp28668/Aerofoils

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Change Log

Date	Description	Author
19 May 2020	Updated for version 6.1	RBP
14 Oct 2020	Updated for version 7.0	RBP

Table of Contents

Introduction

Now at version 7.0, this program allows you to plot wing sections on paper and to produce G-Code for a separate cutter program. In both cases this includes spars, leading and trailing edges, and skins.

The original It was first written a number of years ago, to run on an early PC-AT with MS-DOS. In this incarnation it's main function was to drive a CNC wing-cutter. When the program was re-written to work under Windows it was extended to include plotting and printing. Now the program has 2 distinct functions – plotting on paper and producing G-Code for a CNC Cutter – in particular the associated *Cutter* program.

The use of G-Code was introduced in version 6 and now aims to be interoperable with programs such as Jedicut, Profili and Mach3.

Knowledge of the program's provenance is useful when you are using it to plot sections of a wing, a 3 dimensional object, on a 2 dimensional piece of paper. The basic principle is that you define the wing structure, at root and tip (as if you were defining templates for cutting a foam wing) and then plot sections of that structure. This makes tapered wings easy and there is no need for the root and tip sizes or sections to be the same: the program will interpolate between the root and the tip.

In addition to plotting wings it will also plot ellipses or half ellipses for formers. The same principle of defining 2 ends and taking sections along the resultant 3 dimensional object applies as for when you plot wings.

Finally, and this is only really of use when driving a CNC cutter, the program allows you to add waypoints which will guide the cutter between cores.

New for Version 7

Version 7 is primarily around usability and flexibility. It includes:

- Various bug-fixes from 6.1 release.
- Ability to take forward and reverse cuts and separate cutting top and bottom surfaces.
- Revised wing dialog to reduce clicks and show root and tip sections
- Zero length moves filtered out of G-Code
- Cut documents can be created from plot documents and vice versa (useful if you want to plot a few ribs on paper in conjunction with cutting a core).
- Now pays attention to the closed flag in DXF LWPolyLine import.
- Optionally optimises G-Code output when plotting a wing. Results in smaller G-Code files.
- Block (plan) view of cutter and foam block. Useful for visualising tapered/swept wings.
- Tapered wings can now be aligned by leading or trailing edge.

Installation

Simple – copy *aerofoil.exe* and or *cutter.exe* into a folder along with the data sub-directory (which contains the aerofoil sections) on to your hard drive. It doesn't matter where the folder is although it is usually a good idea to put it in a folder where all the users of the PC can access it.

Note that it is possible to build both 64 bit and 32 bit versions which have the suffix _x64 and _x86 respectively. Both these versions have been developed and shown to work under Microsoft Windows 10.

If you want to create shortcuts to the program then point them to *aerofoil.exe* in whichever install folder you decided on.

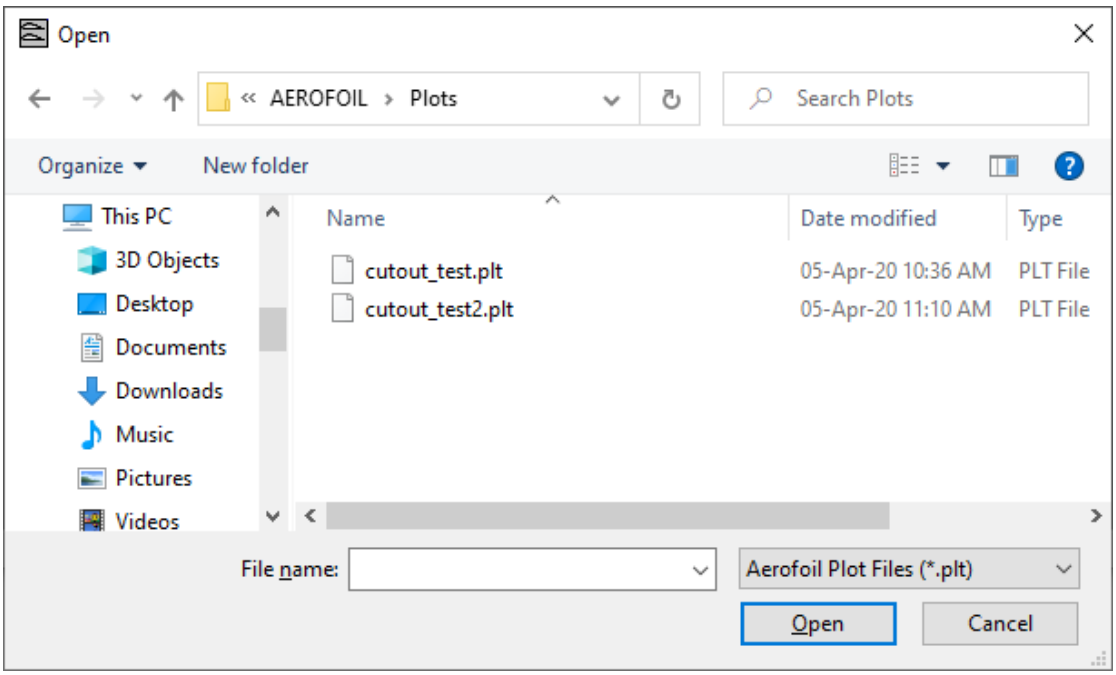
Un-install is also simple – delete the program and its data files. There is no install or un-install program. If you created any shortcuts, delete them too.

Running

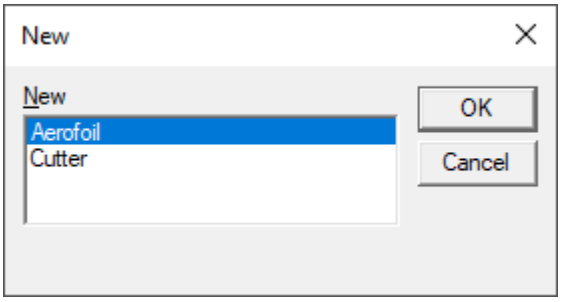
Open up the folder that contains *aerofoil.exe* and double-click it. The program should start and give you a blank sheet similar to the picture below.

At this point there no plot or cut defined. The *File* menu can be used to load up a plot file or a cut file or to create a new plot or cut. Plot files are for plotting out on paper (e.g. for making a built-up structure or root or tipe ribs. Cutter files are for driving a CNC cutter. They aren't interchangeable although you can create the start of a cutter file from a plot and vice-versa.

File/Open will produce the usual Windows file open dialog. Either select *Aerofoil Plot Files (*.plt)* or *Cutter Files (*.cut)* from the drop down as needed and chose the plot or cut file to load.



Alternatively, to create a new plot or cut, select *File/New*. Aerofoil will display the following dialog to ask you whether you want an *Aerofoil* (for plotting on paper) or a *Cutter* for producing CNC output.

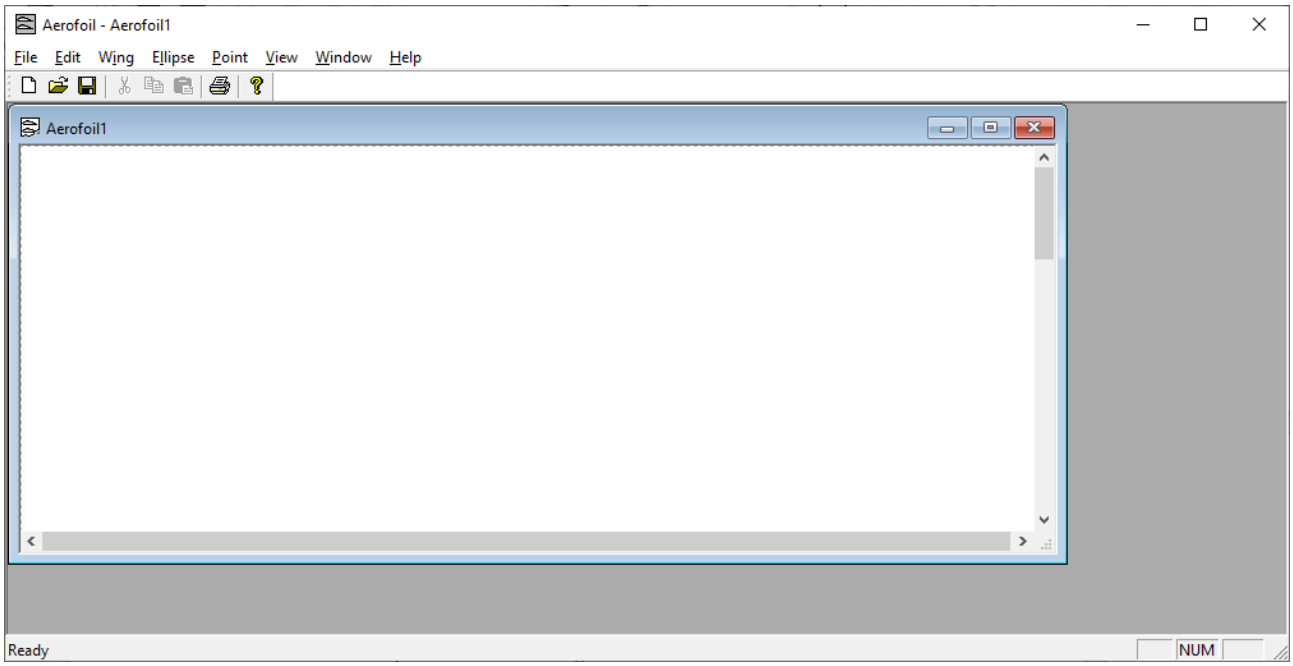


At this point either go to *Plotting a Wing* or *Driving a Cutter*.

Plotting a Wing

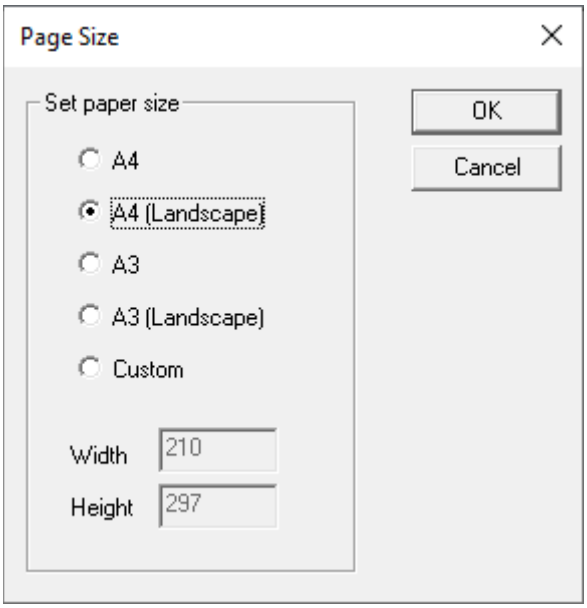
This is plotting wing sections on paper. If you want to cut a core go to *Driving a Cutter* later in the document.

On selecting *File/New* then *Aerofoil* you should see a blank plot similar to the following.



Set the Plot Size

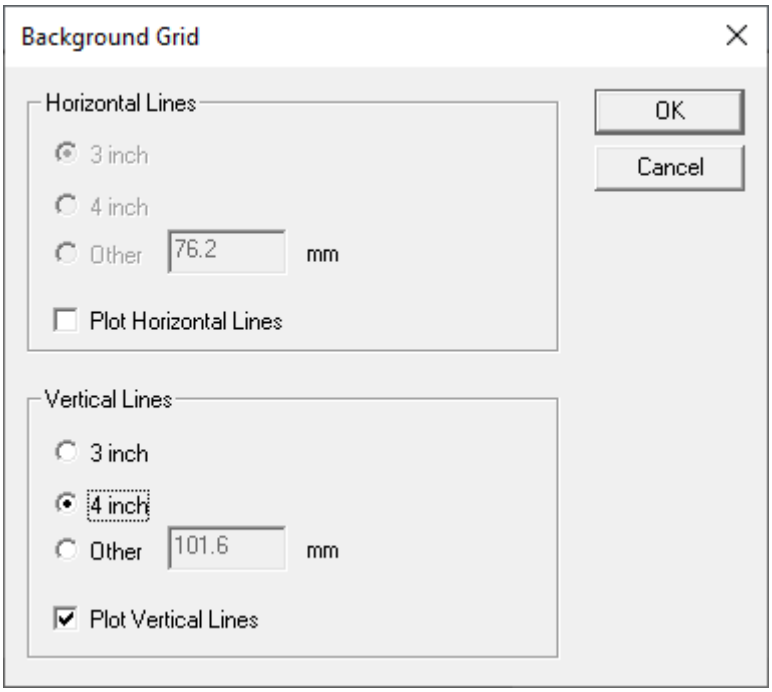
Before doing anything else, it's a good idea to set the plot size that you're working with. Select *File/Plot Size* and enter the plot size into the dialog shown below.



For normal printers, A4 landscape will normally be what you want.

Set a Grid

This step is entirely optional – if you are going to print out the plot and glue it to sheets of balsa for later cutting, it's helpful to have guilde-lines drawn that correspond to the width of the balsa you will be using. To set up these guide-lines select *File/Grid*. The program will show a dialog similar to the one shown below.

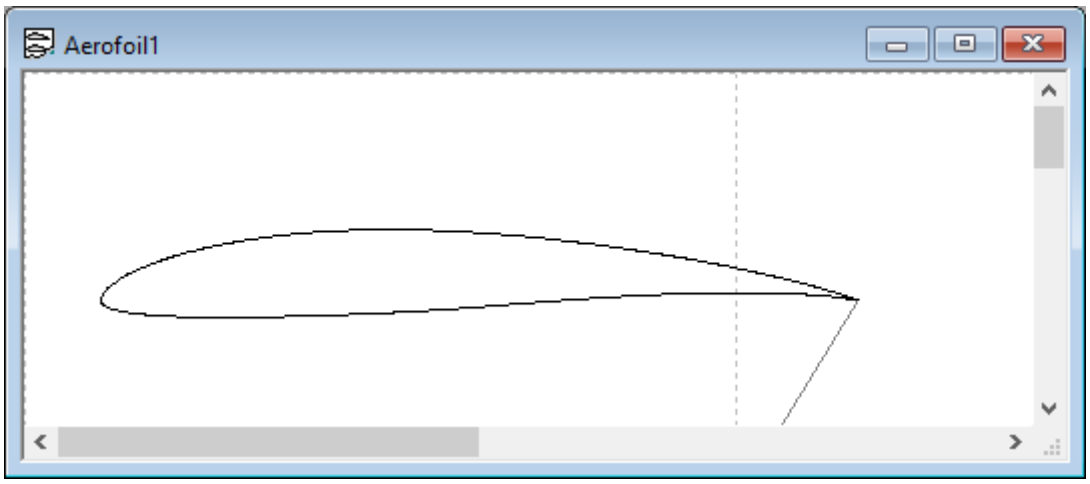


Horizontal or vertical lines will only be plotted if the corresponding checkboxes are ticked. If the box is ticked then you can enter the spacing of the grid. You have 3 options the common 3 or 4 inch size or you can enter another value in mm. Finally click on *OK* to save the settings. Note that the grid is just a drawing guide and is not saved with the plot.

Create the Structure

To create a new wing, select *Wing/New*. The program will pop up the standard file-open dialog. This is to allow you to select the root section. Select the data (.DAT) file with the section coordinates for the root. If this is the first time you'll need to navigate to the data folder where all the coordinate files are stored. As soon as you close the first file-open dialog, another one pops up to allow you to enter the tip section.

You should then see the plot of the root section of the wing as shown below.



Note that the program in this case has just the root section – modifying this and modifying what is plotted (e.g. chord line, cutting markers, labels etc is covered in *Modifying the Plot* later.

Now, that the program's view of the structure probably not what you want. In particular the chord size is almost certainly wrong. To change this you need to edit the basic wing structure. Highlight the section by clicking on it (it should go gray) and either select *Wing/Edit* or right click and select *Edit Wing*.

The *Edit Wing* dialog is shown above. This allows you to edit the basic geometry of the wing, including the (half) span, the size of leading and trailing edges, root and tip section, the size and position of spars and any cutouts in the wing.

The parameters for the root and the tip are shown in this dialog. You can change the sections with the *Change root section* and *Change tip section* buttons. Changes in the wing section, size, washout, cutouts, spars etc are shown in the root and tip plots. *Span* is only really important when cutting a core as it defines the distance between the root and tip sections.

For plotting on paper the *Thickness Modifier* entry is probably the most useful. This changes the thickness of the section. For example a *Thickness Modifier* of 1.2 will make a 10% thick section into a 12% thick section.

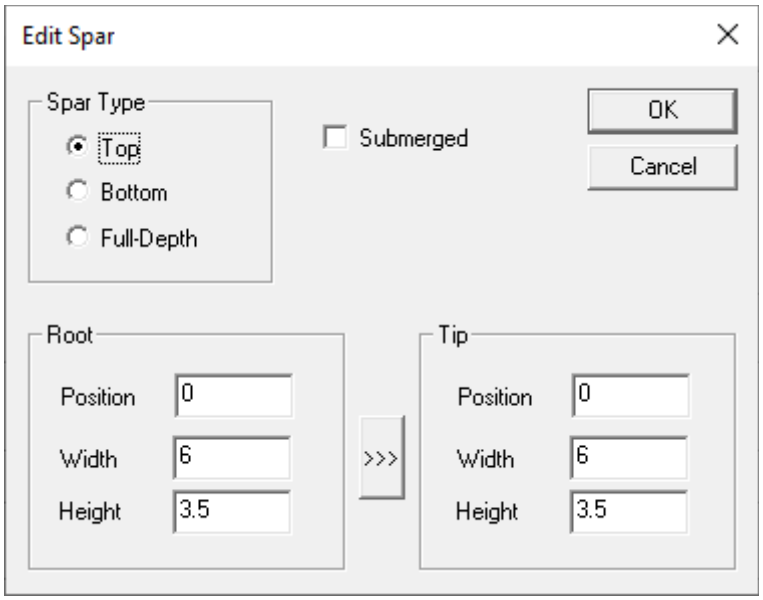
The other parameters: *Sweep*, *Height* and *Washout* allow the position and angle of the section to be changed. Not so important for plotting on paper but essential if it's driving a CNC cutter.

Adding Internal Structure

So, now that the basic geometry is set up let's add some structure. First we'll add a ¼ inch leading edge and a ¾ inch trailing edge. The program only accepts dimensions in mm so enter 6.3 for the leading edge and 19 for the trailing edge. Let's also define a skin thickness of 1/16 inch or 1.5mm. The next step is to add some spars.

Spars

In the spars box, click on *Add*. You should see the spar dialog shown below.

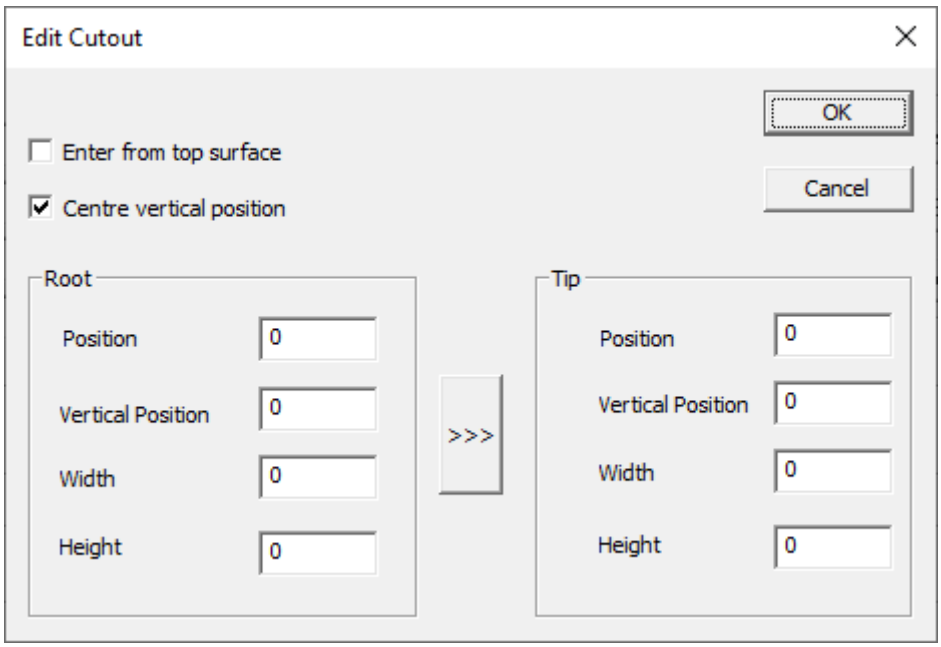


This allows 3 types of spar – top surface, bottom surface or full-depth. "Submerged" determines whether the spar is flush with the surface of the wing or is submerged under the skin. Usually if you've got a balsa skin you'll want a submerged spar. You also need to specify the position and size of the spar at its root and its tip (the position is the distance in mm from the leading edge) A short-cut is to use the ">>>" button to copy the root settings to the tip.

Any number of spars can be entered and they are displayed in a list in the spars dialog.

Cutouts

It's also possible to enter cutouts in the wing to mark positions for lightening holes or servo leads. In the same way as for spars, cutouts can be added, edited and deleted. If you click *Add* in the Cutouts box you will see the dialog below.



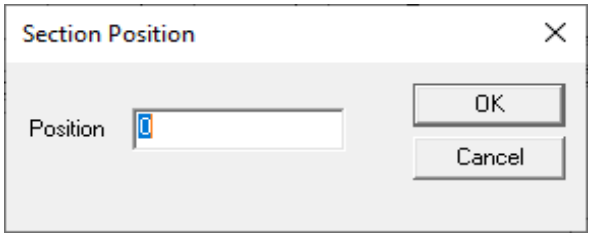
Currently only elliptical cutouts are supported. *Position* is the position along the chord where you want the centre of the cutout. *Vertical Position* is relative to the chord line but note the *Centre vertical position* option which centers the cutout between the upper and lower surfaces. The >>> button will copy the root settings to the tip.

Note that *Enter from top surface* only applies to generating cuts where the wire has to go into the cutout from one side or other. Normally that would be the lower surface of the wing.

Select Sections to Plot

Once you've set up the wing structure you can plot multiple sections from that wing.

Click on an existing section of the wing to select the wing you want to plot a section of. Then select *Wing/New Section* from the menu bar. You'll get a dialog asking for the section's position:



This gives the position, in mm, of this section from the root. One of the parameters of the wing definition is *Span*. The position, relative to the wing's span parameter determines where the section is interpolated. 0 always plots the wing section – if the wing's *Span* is set to 1000 then a *Position* of 1000 will plot the tip section and 500 will plot a section half way between the root and the tip.

When you click on *OK* in the Section Position dialog the program will draw another section. You can then click on it's outline to select it and drag it to a new position on the drawing.

Tip: It's useful having a spreadsheet to hand with all the rib positions calculated in mm if you're doing multiple ribs.

Plotting Cores

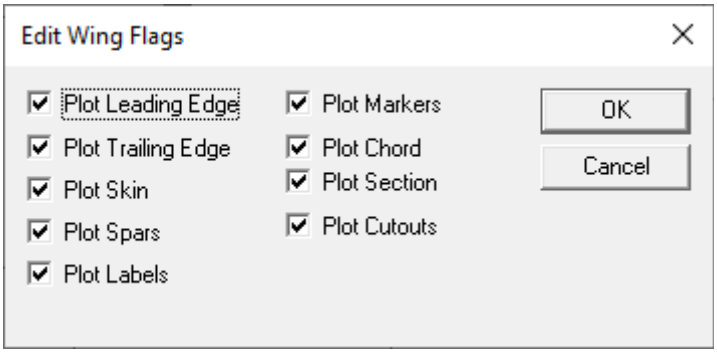
As well as the full structure of the wing sections the program will also plot templates for foam wings if you don't have CNC hardware.

Select *Wing/New Core* from the main menu. The program will draw a core on the drawing, drag it to where you want it. You can change it's position on the span by right clicking it and selecting *Position*.

Modifying the Plot

Once you've set up a drawing you can modify what's there and how it's drawn. Firstly, anything on the drawing can be moved by dragging with the mouse.

Secondly, there are flags that control exactly what in a wing (or ellipse) is drawn. These affect all the sections of that wing. Select the section of the wing or ellipse and, either right click it and select *Wing Flags* (for a wing) or, select *Wing/Flags* from the main menu. You'll get a dialog that specifies a number of options:



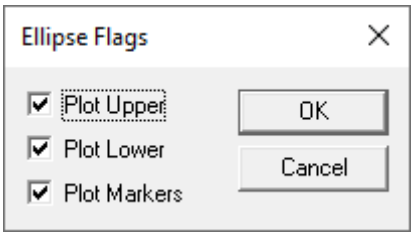
Most of these are fairly obvious. Markers are 10% markers for cutting foam cores by hand. Section determines whether the section is interpolated or both the root and tip are plotted separately.

Plotting Ellipses

The program also allows plotting of elliptical sections for use in creating fuselages etc. The top and bottom heights don't have to be the same. To add an ellipse, or actually a pair of ellipses as we can interpolate between them much as we do for wing sections, select *Ellipse/New* from the top menu. You should then see a dialog like the one shown below.

Enter the top and bottom height of the ellipse pair. Half width is the width from the centre to the edge of the ellipse – think radius rather than diameter. As before >>> copies the settings from the first ellipse to the second.

The Flags dialog for an ellipse is simpler than that of a wing:

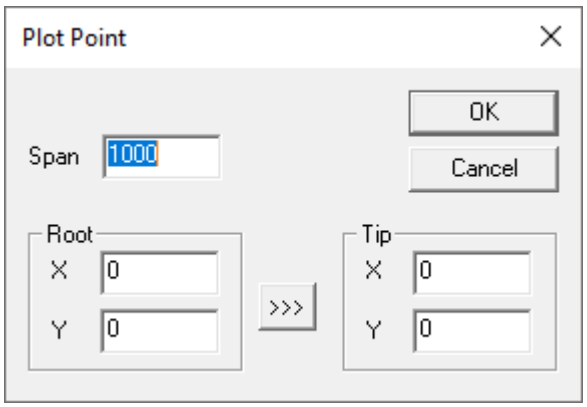


It allows you to specify plotting only the top or bottom halves as well as center markers.

Reference Points

It is possible to add reference points to the plot which are drawn as little "bow-tie" symbols. These can help with alignment over sheets of wood etc.

From the top level menu select Point/New. You should see a dialog like the one below. For a plot there's no reason to change the values as you can drag its position on the plot anyway.



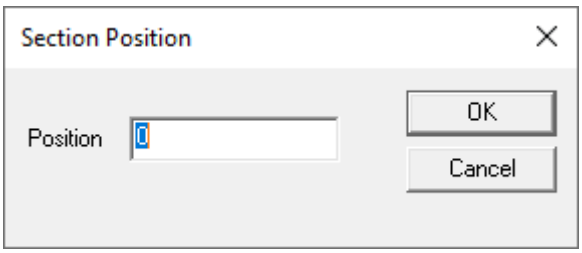
Editing a Plot

Aerofoil sections, ellipses and points can all be dragged around the plot using the mouse. Clicking on an item selects it and you can then able to edit its properties, by :

- Right clicking the item and using the popup menu
- Using the edit menu. Note *Edit/Edit Structure* is sensitive to the type of object selected.
- Using the *Wing*/*Ellipse* or *Point* menus.

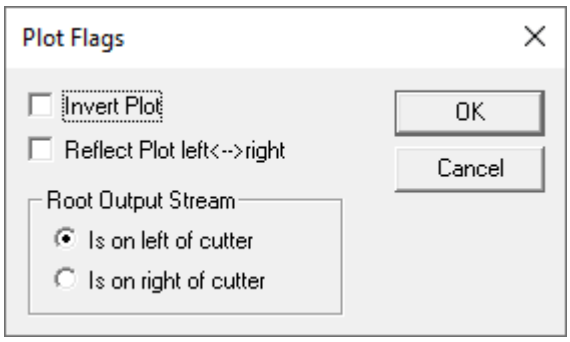
Setting Interpolation Position

All items on the plot are some form of section of a 3 dimensional item which is why even ellipses and points have two ends – first and second or root and tip. *Edit/Position* will bring up the *Section Position* dialog shown earlier and below to allow you to interpolate between the two ends.



Inverting and Reflecting Items

It's also possible to invert or reflect the plot of an individual section. Select the section with the mouse and either right click it and select *Plot Flags*, or, select *Edit/Plot Flags* from the main menu. You'll see a dialog like the one below:

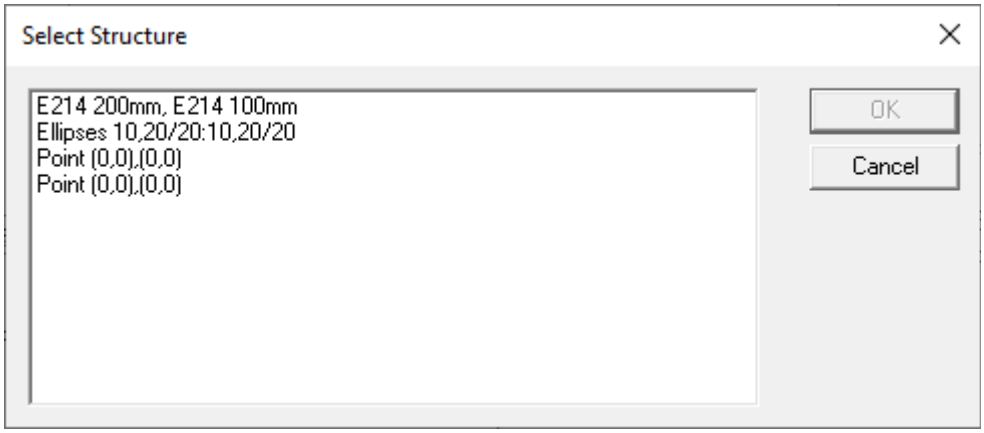


Here, *Invert Plot* and *Reflect Plot left <--> right* allow you to flip the section vertically or horizontally respectively. This can be invaluable when trying to cram a set of ribs onto a sheet of balsa.

The *Root Output Stream* setting is really for a CNC cutter to allow you to switch which end of the cutter cuts the root.

Deleting Sections and Structure

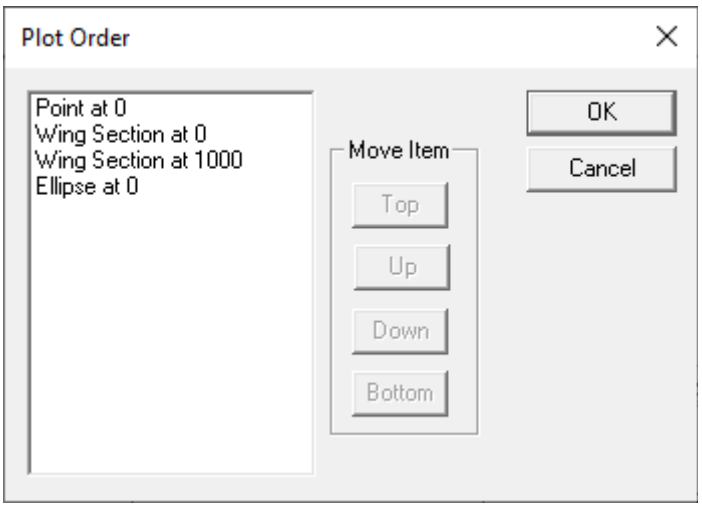
Edit/Delete deletes whichever section is currently selected. That doesn't delete the underlying structure though. Use *Edit/Delete Structure* for this which will display a dialog similar to the one below to allow you to select the structure item to delete.



Select the structure item and *OK* to delete it, *Cancel* if you didn't want to delete anything.

Plot Order

Edit/Plot Order allows you to modify the order in which items are plotted. Not normally an issue but this will be reflected in the Postscript or Laserjet (HPGL) output. The *Plot Order* dialog is shown below. If you select one of the items in the list the buttons to the right allow you to move it to the top or bottom of the list or up and down an entry at a time.

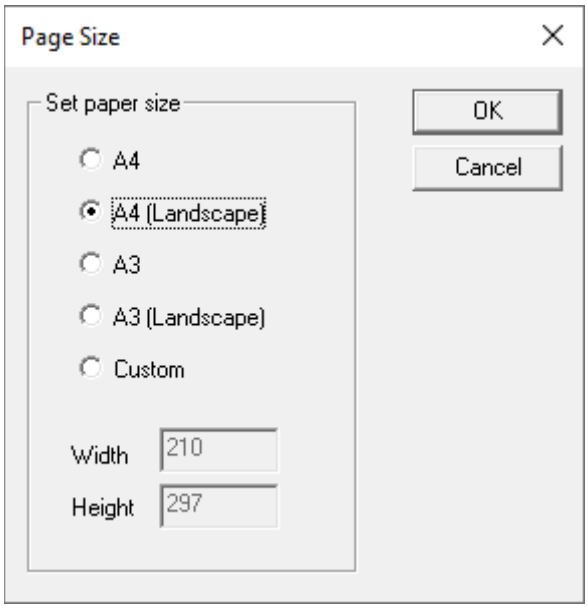

Plot Order
Point at 0
Wing Section at 0
Wing Section at 1000
Ellipse at 0
Move Item
Top
Up
Down
Bottom
OK
Cancel

Printing and Export

Printing

It's generally a good idea to set the plot size to match your printer so that you can align objects on the screen to avoid page boundaries.

File/Set Plot Size gives you the dialog shown below.



This caters for normal paper sizes and alignments but does allow you to set a custom size as well. The program draws a dotted rectangle around the selected plot size on the screen. Use this as a guide to the printable area – you can drag objects across these lines but they won't get printed.

File/Print and *File/Print Preview* work as you'd expect with the usual windows dialogs.

Export

As well as printing, Aerofoil can export data in a number of formats: DXF, Laser Jet and Postscript.

DXF

DXF allows you to export sections to be imported into Computer Aided Design (CAD) packages. Aerofoil is itself a CAD program – but a special purpose one. Most general purpose CAD packages will import DXF. To export as DXF select *File/DXF Output* and enter the name of the file to export to in the Save As dialog that pops up.

Postscript

It may be that you have access to a postscript printer, or want to send a file to someone else who has one. Aerofoil allows export in native postscript. Apart from allowing plot files to be saved and printed later, the postscript asks the printer to generate lines as thin as possible.

To export as Postscript, select *File/Postscript Output* and enter the name of the file to export in the Save As dialog that pops up.

Note that if you save a postscript file then the usual way to print it is to copy it to the printer device

(e.g. PRN:) not to print it as a text file. Printing it as a text file will make the printer driver encode the Postscript with another layer of Postscript which will waste an awful lot of paper!

LaserJet

In a similar fashion to generating Postscript, Aerofoil will also generate HP-PCL for sending to a Hewlett-Packard laserjet.

To export as HP-PCL, select *File/Laser Jet Output* and enter the name of the file to export in the *Save As* dialog that pops up.

Generating a Cut from a Plot

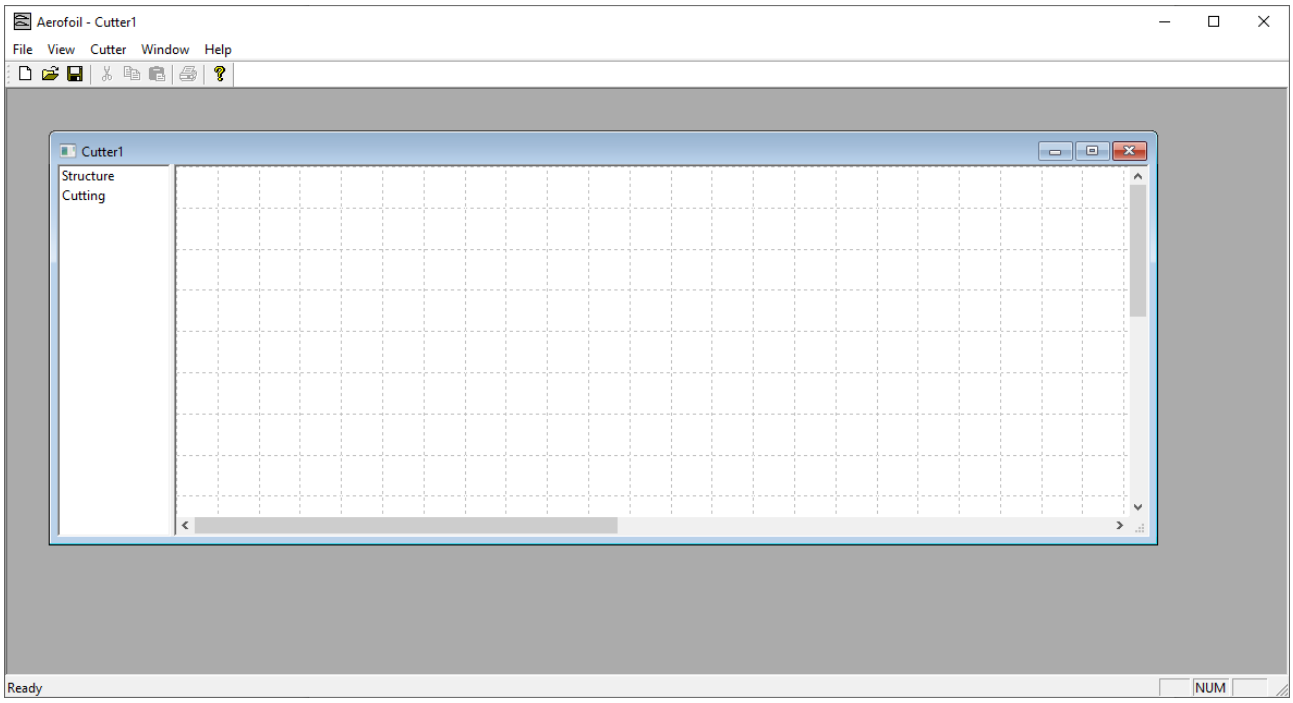
Once a plot has been set up it's possible to create a cut file from the plot. This copies across the geometry of the underlying structure to provide the basis to build up a set of foam cutting instructions. To do this select *File/Create Cutter Document*. Note that this is a separate document – changes in the plot will not be reflected in the cut and vice-versa.

Driving a Cutter

Aerofoil provides first class support for generating G-Code to drive a 4-Axis CNC wing cutter. The original program had the ability to directly drive cutter hardware. This has now been moved to a *Cutter* program which interprets the G-Code and drives the CNC hardware. This has several advantages, not least of which being that the G-Code generated by Aerofoil can be sent to CNC hardware controlled by Mach3 or similar CNC programs.

Creating a Cutter File

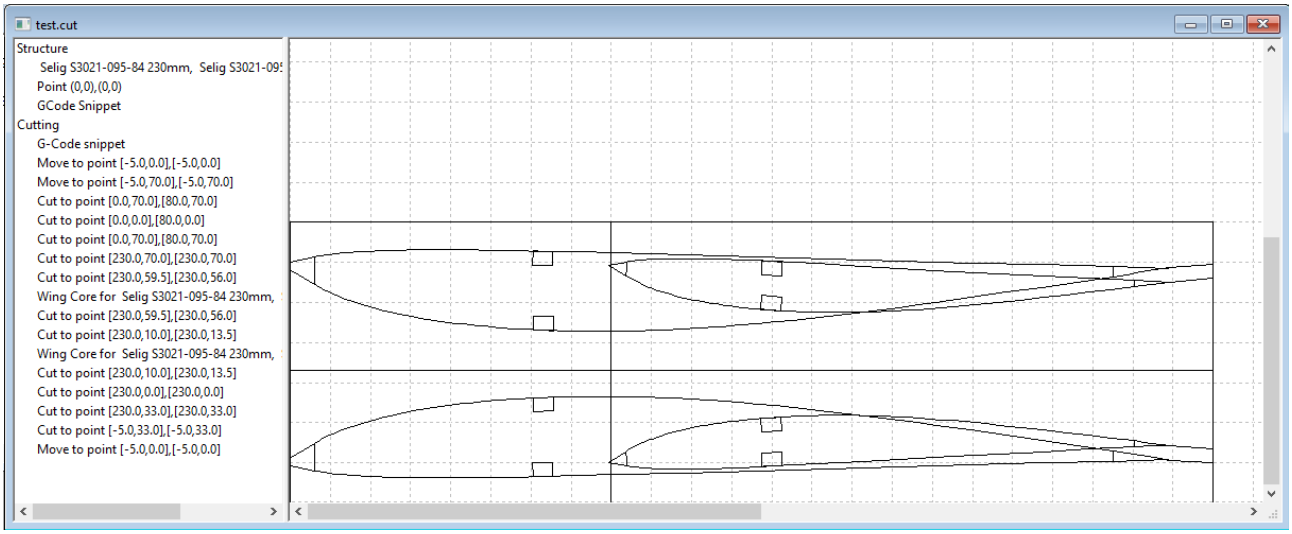
After selecting File/New followed by Cutter you should see an empty cut file displayed similar to the one shown below.



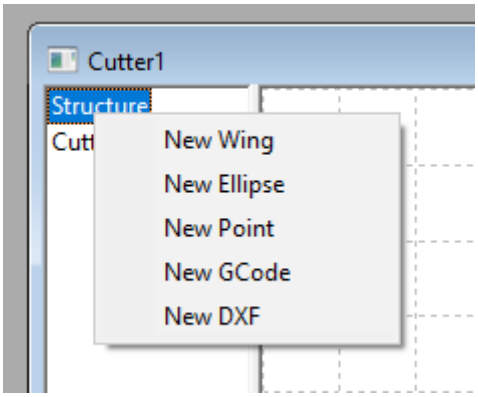
There are 2 areas within the cutter display – a tree view on the left that has (currently empty) *Structure* and *Cutting* entries and a display area on the right that shows a graphical display of the current cut file. The separator between the two parts can be dragged left and right to allow more or less display of the tree view.

A tree view is used here as it provides an immediate visual indication of the order in which items will be cut. This is very important when running a CNC system!

The split between the *Structure* and *Cutting* entries is a core concept. In *Structure* you define the "things" you want to cut, in *Cutting* you define how and where you want them cut. This approach has the obvious advantage when cutting cores – you define the geometry of the wing once then tell the cutter to cut 2 cores, a left and a right one. This can be seen in the image below where a single wing has been defined (Selig S3021) and a mirror pair of cores are configured for cutting, interspersed by cut/move to point to move the wire to the correct position before, between and after cutting the cores.



Right clicking on the Structure element in the tree will show a popup menu that allows you to create new structure elements as follows:

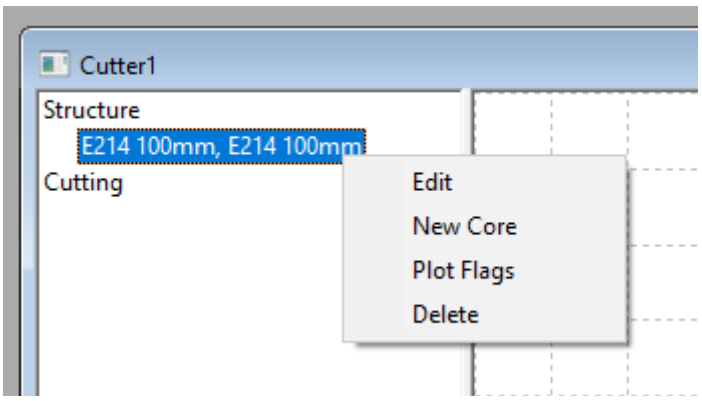


The different types of structure are covered in the following sections.

Creating Wing Structure

Select *New Wing* from the *Structure* popup menu. You will then have 2 successive file-open dialogs to select the sections for the root and tip of the wing.

Once you have selected the root and tip sections you'll see the entry for the wing and can edit it by right clicking the entry and selecting *Edit*.

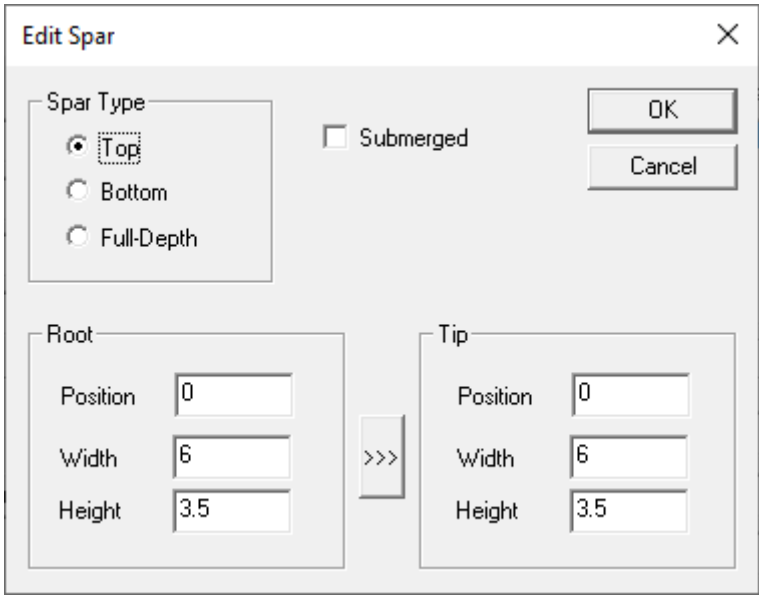


Edit will show the standard *Edit Wing* dialog shown below and you can change chord, washout, spars, cutouts and leading and trailing edges in the same way as you can creating a plot.

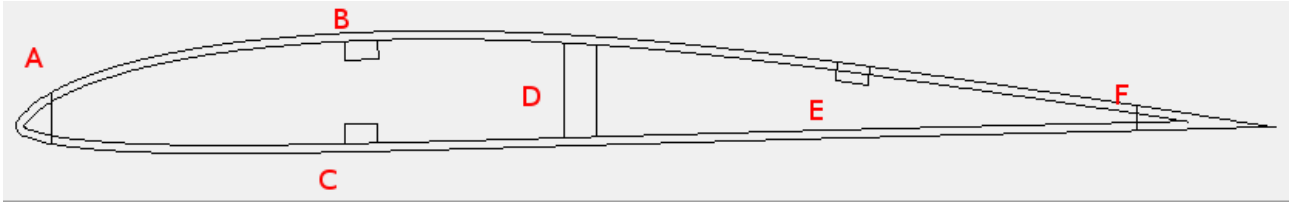
Adding or editing a spar will

Tip: When creating a wing structure usually just leave height at zero and use sweep to set the relative position between the root and tip. Use the transform feature on the actual cut to determine where the cut is positioned on the foam block.

The *Edit Spar* dialog is shown below. Top, bottom and full depth spars can be defined. *Submerged* determines whether the spar is submerged under the skin. Note that *position* is the start of the spar as measured from the leading edge.



Various variations are shown in the annotated aerofoil picture below:



A is the position of the leading edge.

B is a top surface, submerged spar – you can see it's wholly underneath the skin.

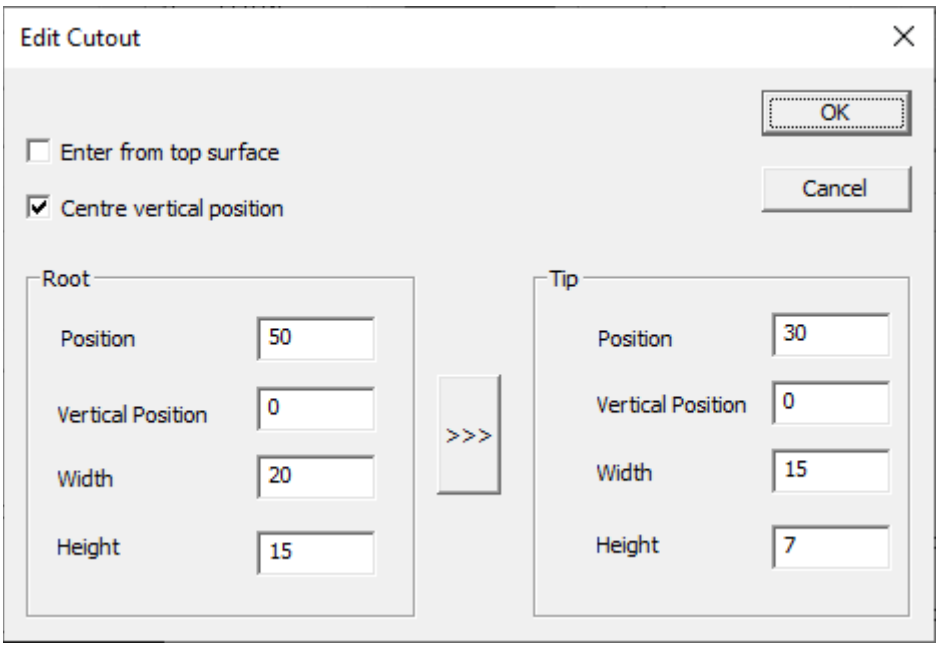
C is a bottom surface, submerged spar.

D is a full depth submerged spar.

E is a top surface spar. It's not marked as submerged so it is flush with the surface of the wing.

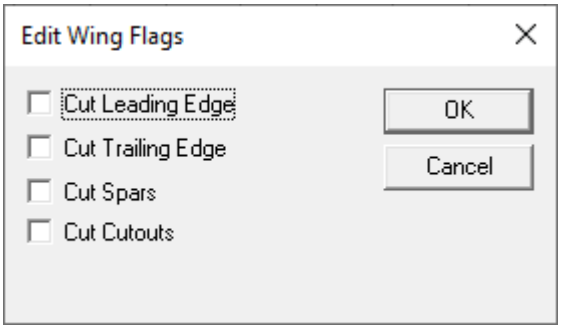
F is the trailing edge cut.

When adding or editing a cutout you will see the *Edit Cutout* dialog shown below. Cutouts are elliptical. With the cutter the wire must cut through the core to the position of the cutout. By default this cut is on the bottom surface. Selecting *Enter from top surface* will change this and the cutout will be started on the top surface.



Centre vertical position centres the cutout between the skins – usually this is easier than having to adjust the vertical position.

Selecting *Plot Flags* from the wing popup menu will display the *Edit Wing Flags* dialog that controls whether leading edge, trailing edge, spars or cutouts are cut from the core.

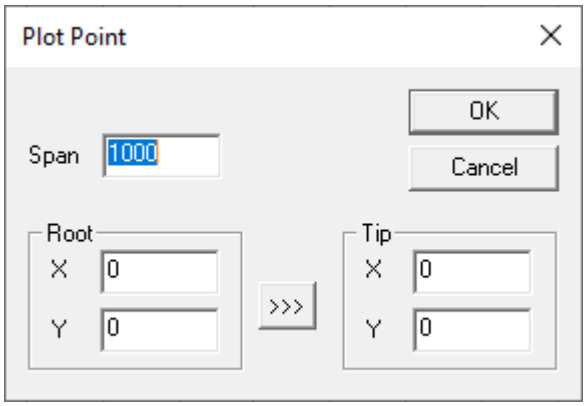


Creating Ellipse Structure

Ellipses can be used for cutting fuselage decking or similar shapes. Select *New Ellipse* from the *Structure* popup menu. This will show the *Ellipse Pair* dialog where you can enter the sizes of the ellipses at both ends. As before the >>> button will copy the contents of the first ellipse to the second.

Creating Point Structure

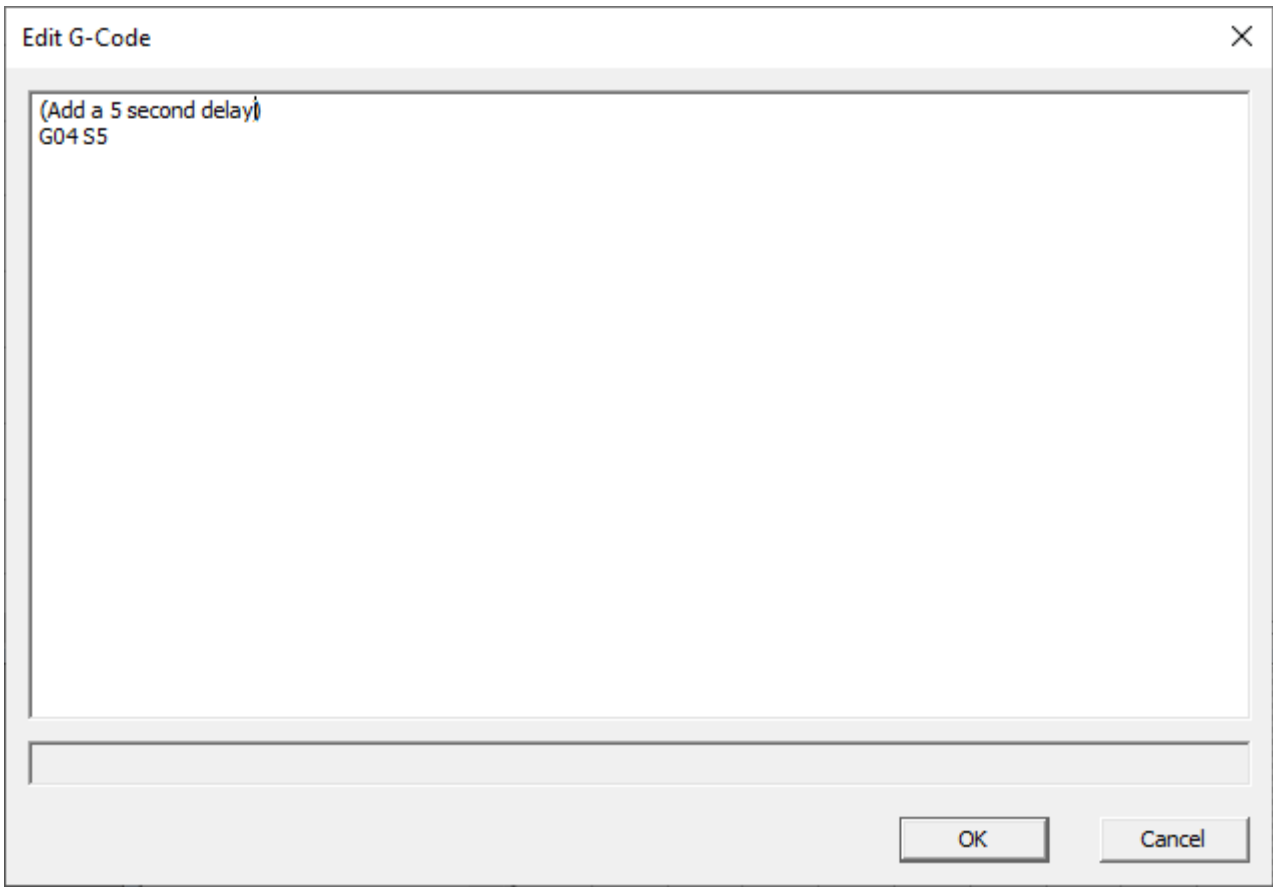
Select *New Point* from the *Structure* popup menu. You will see the Plot Point dialog. Note that this defines where the wire of a cutter should go in all 4 axes and so has a position for both root and tip.



Tip: When setting up the cut path you invariably want the cutter to go via a number of points before it starts cutting the actual foam component. To do this make sure you include a Point at [(0,0)(0,0)] in the structure which will then allow you to create various waypoints before, between and after the actual components.

Adding Arbitrary GCode

You can add snippets of arbitrary GCode in to the list of structures so they can then be included in the cut sequence. Select *New G-Code* from the *Structure* popup menu. This will pop up an Edit G-Code dialog where you can add a small snippet of G-Code. See the Cutter manual for more details of G-Code.



Creating DXF Structure

This allows you to import 2D DXF files into the program. The import has some limitations and currently supports Arc, Circle, Ellipse, Line, LWPolyLine and Point in a DXF file. In practice this is enough to usefully import shapes generated by TurboCad. Note that the full DXF specification is available at https://images.autodesk.com/adsk/files/autocad_2012_pdf_dxf-reference_enu.pdf .

As this is dealing with 2D shapes the same shape is cut through the foam block i.e. the shape effectively becomes an extrusion of that shape.

To import a DXF file, select *New DXF* from the *Structure* popup menu. This shows a file open dialog to allow you to select the DXF file to import.

Converting Structure to a Cut

Once the structures that you want to cut are defined you need to set up the cut. Structure specific options are discussed below but there are a few concepts that are worth touching on first:

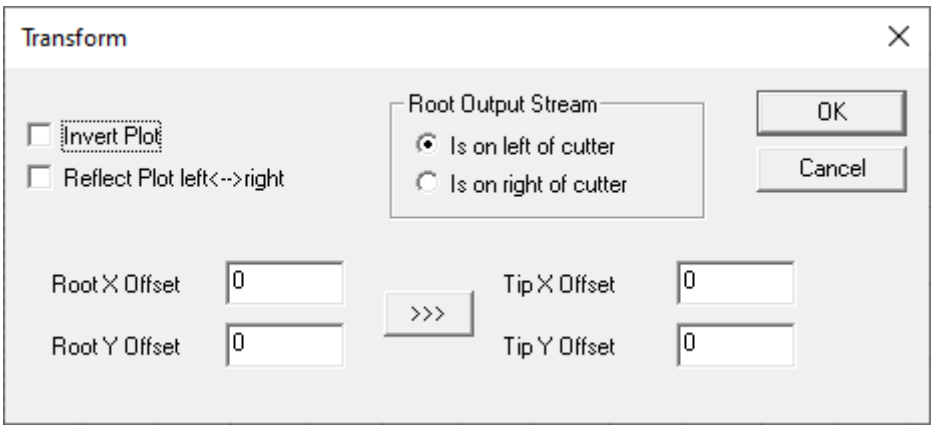
- All the cuts or cutter actions (bar *Home*) are produced from corresponding structure item's right click menus.
- Most cut items can be transformed by reflecting, inverting or setting their position. This includes wings, ellipses, points and DXF imports. G-Code snippets can't be transformed. Use of transforms is the reason why generally it's best to leave positions alone in the structure.

- All the cuts can be deleted from their right-click context menu.
- All the cuts can be moved up or down the cutting order using their right-click context menu.
- Deleting a cut doesn't delete the underlying structure.
- Deleting a structure element deletes all the cuts that rely on it.

Most cuts can be moved in and out, left and right, inverted and reflected using the Transform dialog. This allows you to position a cut in the foam and to make pairs of cores.

The *Transform* dialog is shown below. *Invert Plot* and *Reflect Plot* allow the cut to be inverted (upside down) or reflected left to right (mirror image) respectively. Whilst convention has the root on the left side of the cutter it's possible to swap sides using the *Root Output Stream* options.

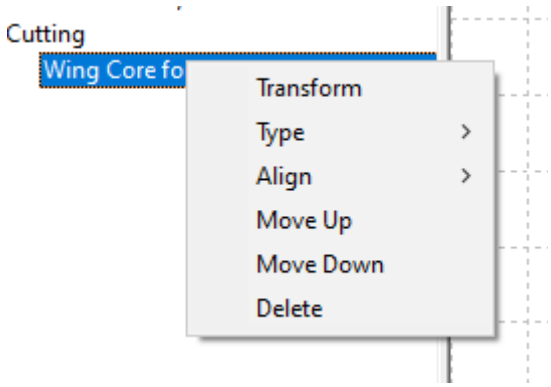
The Root X and Y offsets and Tip X and Y offsets allow the exact position of the item to be defined in machine space. This is the usual way to position a core, ellipse, cut point etc. Note that the transform does work on a DXF import as well.



Wing Sections

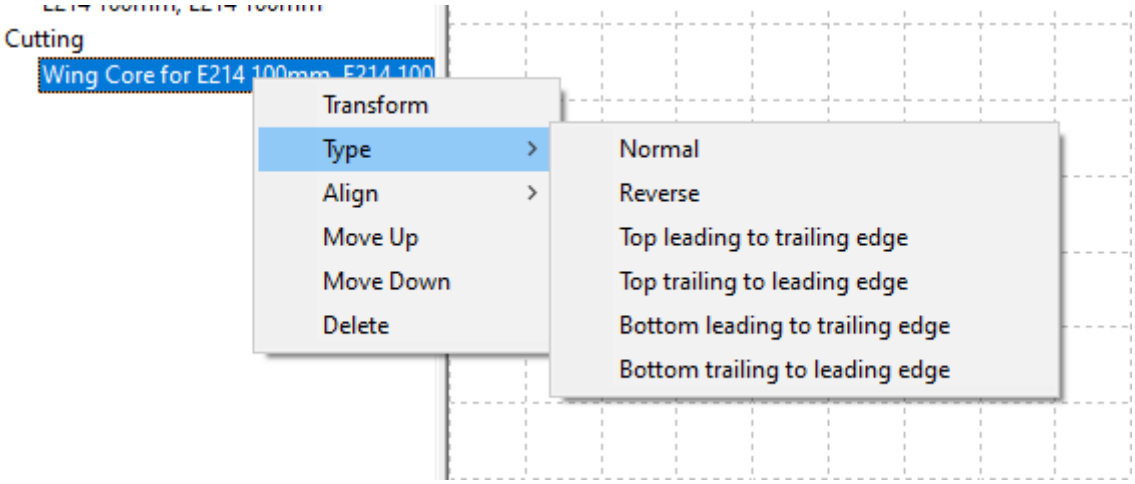
Right click on the wing structure you want to cut and select *New Core* from the popup context menu. You should now see a Wing Core entry in the Cutting list. Transform and move up/down the cutting order as needed using its right-click context menu. Note that the right-click popup also has options for modifying the type and alignment of the core as shown below.

The type and alignment options are discussed in more detail below.



Core Type

Type allows you to select what sort of cut you want and its direction. The options are shown below.



Normal – cut all the way round the wing, starting at the trailing edge and cutting the upper (of the wing) surface first.

Reverse – cut all the way round the wing, starting at the trailing edge and cutting the lower surface first.

Top leading to trailing edge – start at the leading edge and just cut the top surface.

Top trailing to leading edge – start at the trailing edge and just cut the top surface.

Bottom leading to trailing edge – start at the leading edge and just cut the bottom surface.

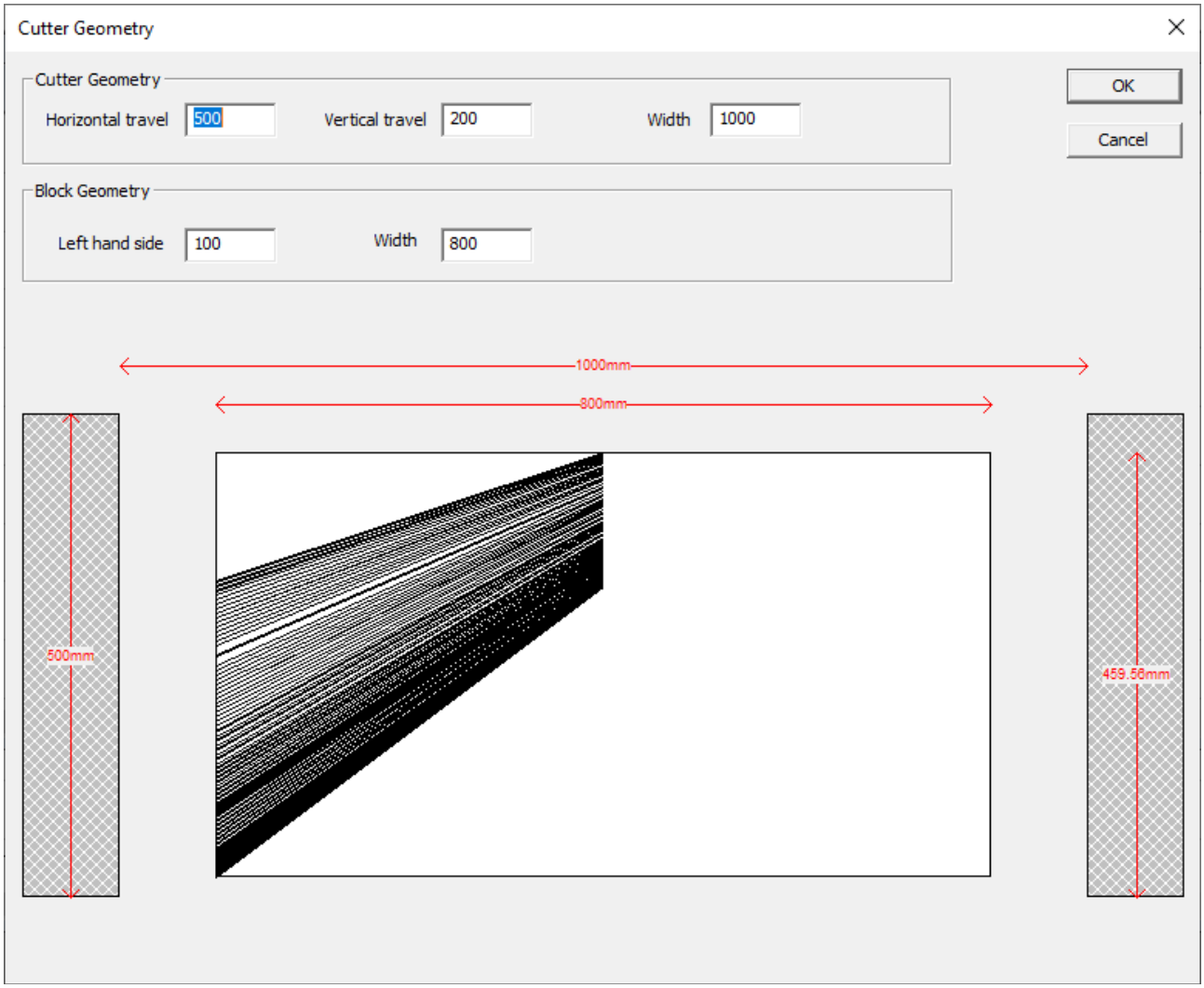
Bottom trailing to leading edge – start at the trailing edge and just cut the bottom surface.

Cutting the top/bottom separately allows you to cut from the leading edge if needed and to generate lead-in or lead-outs from the core.

Core Alignment

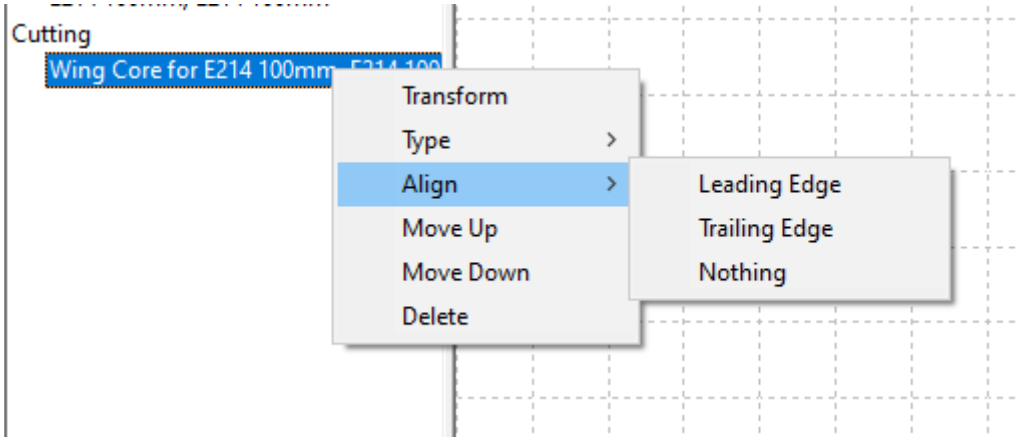
Heavily tapered wings are difficult to cut “as drawn” as they use a lot of foam and may need the cutter to drive outside its limits to produce a cut. This can be seen from the cutter geometry plot

shown below.

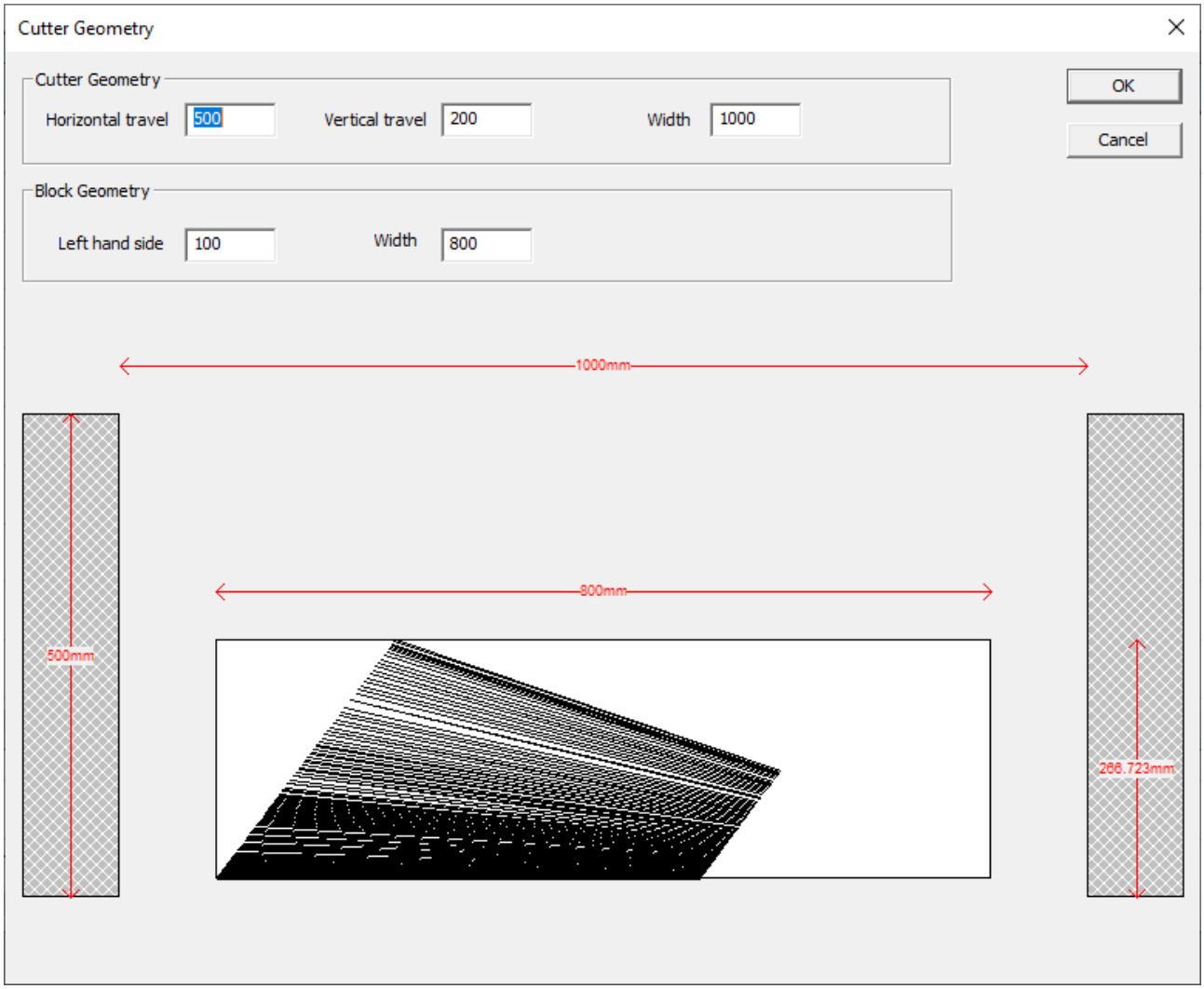


For this wing, the foam fills the cutter bed and, extrapolating the leading and trailing edge lines to the edges, can't be cut anyway.

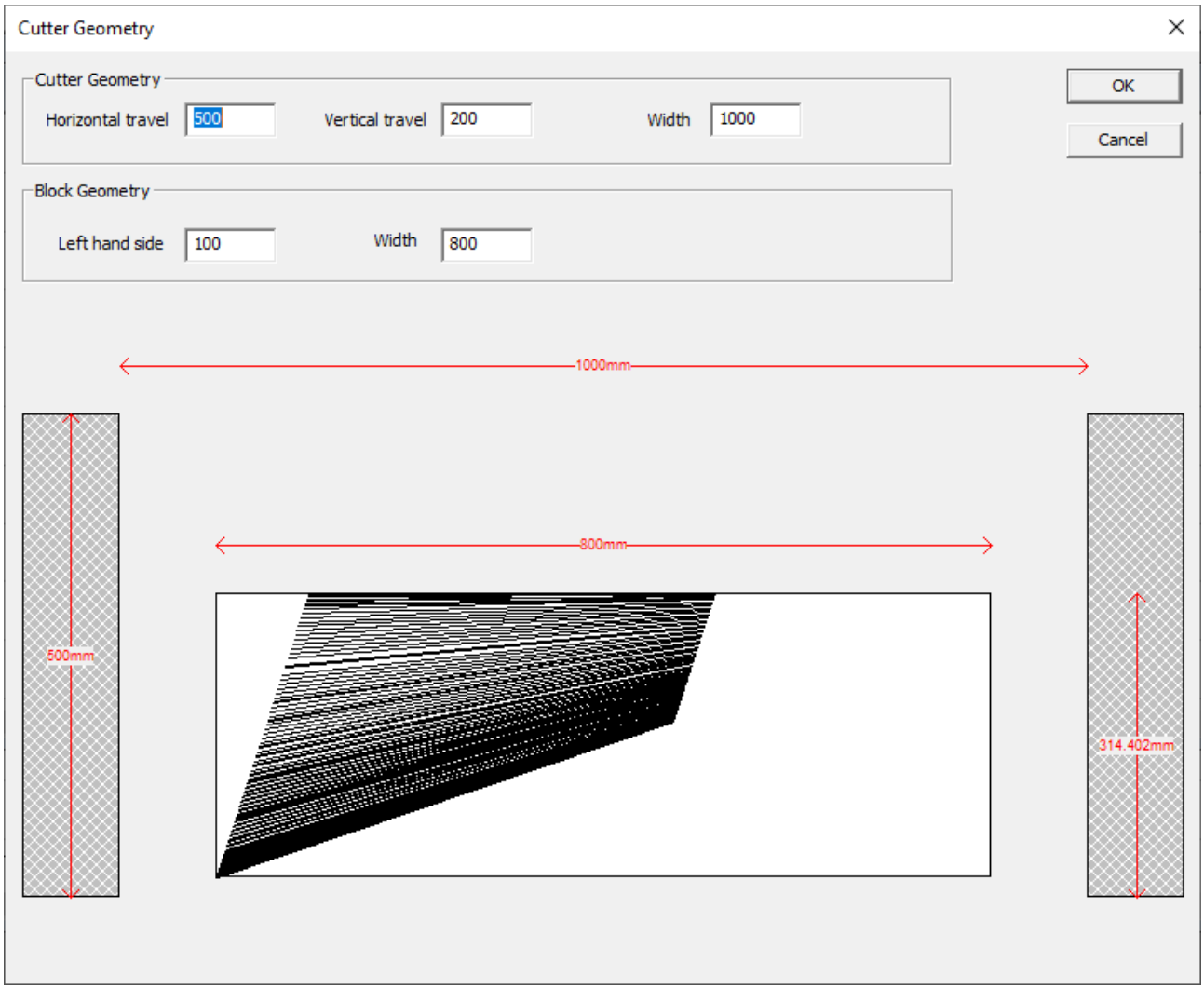
As shown below, the *Align* option on the Wing Core popup menu allows you to align the core either by the leading or the trailing edge.



Aligning by *Leading Edge* does just that as can be seen in the Cutter Geometry dialog shown below.



Similarly, Aligning the *Trailing Edge* aligns the trailing edge with the cutter.



Selecting *Nothing* in the *Align* menu cancels any rotation.

> **Note:** that having the span set properly in the wing definition is important here. In effect, all the plotted points are now 3 dimensional. The original x,y locations (along the horizontal axes and up the vertical respectively) have now been joined by a z value which says how far across the cutter the point is. It's having x,z points that allow the rotation to take place. For rotation, Z on the root is taken to be zero but the Z on the tip is the span value. It's now this span value that sets the wing size, not the block size.

Ellipses

Right click on the *Ellipses* structure you want to cut and select *New Cut* from the popup context menu. You should now see a Wing Core entry in the Cutting list. Transform and move up/down the cutting order as needed using its right-click context menu.

Waypoints

Right click on a Point entry in the structure (if there isn't one create a new one at 0,0). You now have a choice of *New Move* or *New Cut* in the context menu. Moves are for use when the wire it outside the foam block and will go at full speed. Cuts are for when you're cutting foam during the move and will move at the current feed rate. Your should now see a *Move to point* or *Cut to point* entry in the Cutting list. Transform and move up/down the cutting order as needed using its right-click context menu.

G-Code Snippets

Right click on the *G-Code Snippet* structure entry you want to cut and select *New Cut* from the popup context menu. You should now see a *G-Code Snippet* entry in the Cutting list. Move up/down the cutting order as needed using its right-click context menu.

DXF Components

Right click on the *DXF Object* structure entry you want to cut and select *New Cut* from the popup context menu. You should now see a *DXF Object* entry in the Cutting list. Move up/down the cutting order as needed using its right-click context menu.

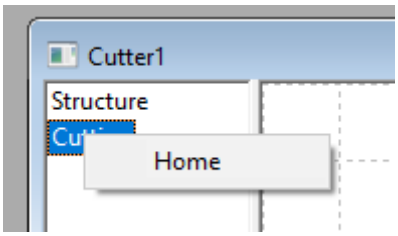
Changing Cut Order

Each item can be moved up and down the cut order by using its right click menu and selecting *Move Up* or *Move Down* as appropriate. Changes to the order should be visible in the display in the right hand pane – hopefully it should be obvious if there's a move or a cut straight through a part!

Cut items can also be deleted using their right click menus.

Home

The only cut item that can created without structure is the Home command i.e. recalibrate the cutters position against its home or limit switches. To do this right click on the *Cutting* item in the tree structure and click on *Home* in the popup as shown below.



G-Code Output

Aerofoil does not drive a 4-axis cutter directly. Instead it outputs G-Code that the companion *Cutter* program reads and uses to program the cutter movement. G-Code is a fairly standard way of defining CNC movement. The G-Code that *Cutter* accepts is defined in the Cutter manual but here are the highlights.

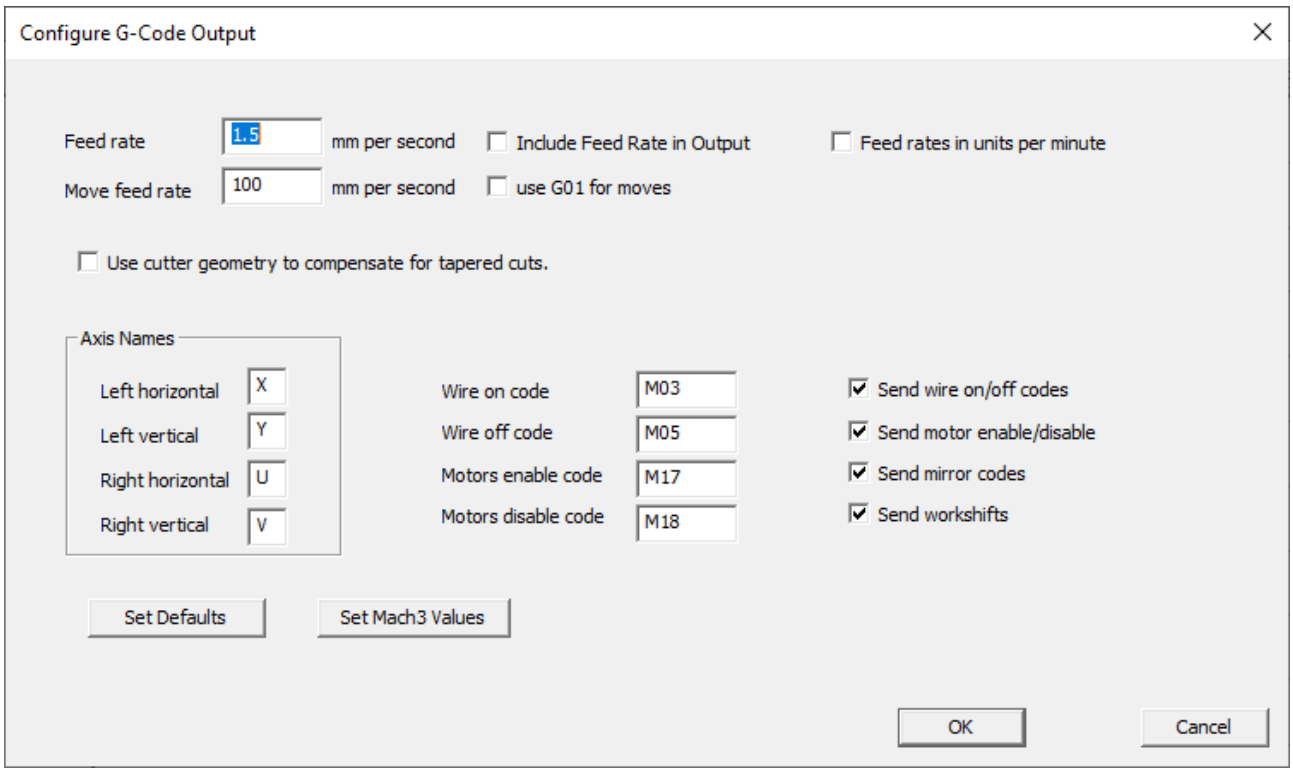
The 4 axes are called X, Y, U, V by default which correspond to left horizontal axis, left vertical axis, right horizontal axis and right vertical axis. 0 positions are at the bottom and closest to the front of the cuter so that +ve movement moves away and up. Axis names are configurable as some systems use X,Y,A,Z.

Default feed rate is set in mm per second but can be over-ridden.

Cutter implements various commands for enabling/disabling the stepper motors, turning the wire on and off and moving the motors. Some of these can be over-ridden.

Configuring G-Code

The emitted G-Code can be configured by selecting *Cutter / Configure G-Code Output*. The system will display the following dialog which allows various parameters to be set.



The feed rate can be set in mm per second. It is not included in the output by default (so that the same G-Code program can be used to cut different materials).

Some systems use G01 for fast moves in which case both a *Feed rate* and a *Move feed rat*e need to be entered and *Include Feed Rate In Output, use G01 for moves* should be checked. Usually if this is done (for Mach3 for example) then *Feed rates in units per minute* should also be checked.

The *Cutter* program is aware of the geometry of the cutter and will compensate for the edges of the foam block not bing right up to the cutter axes when cutting a tapered wing. Aerofoil can also do this calculation for systems that cannot compensate for the taper and the G-Code coordinates will reflect that compensation if *Use cutter geometry to compensate for tapered cuts* is set.

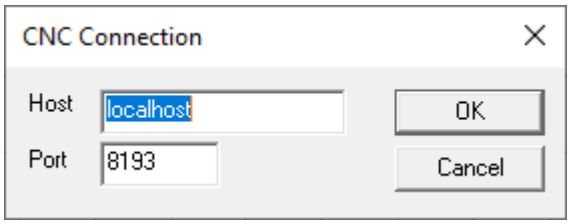
As stated earlier the 4 axes names can be set using the *Axis Names* section.

Machine codes for turning the wire on/off and enabling/disabling the motors can be set and optionally written to the G-Code output.

Send mirror codes and *Send workshifts* allow the commands to reset mirroring and workshifts to be included or excluded from the G-Code preamble.

Sending G-Code via Network

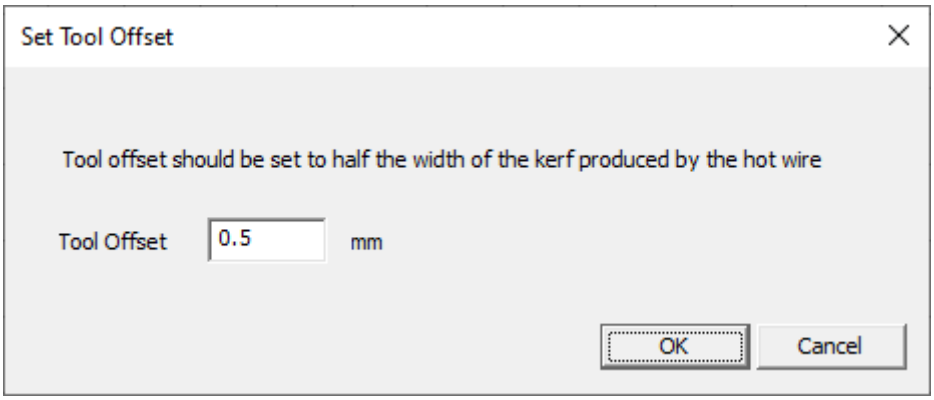
As well as saving a G-Code file to disk that can be read in late, Aerofoil can send G-Code directly to *Cutter* over a network using TCP-IP. For this to work you need to enter the host (the machine name or IP address) where *Cutter* is running and the port it is listening on. By default *Cutter* listens on port 8193. Note that using localhost or 127.0.0.1 as the host will send the data to the machine you're running *Aerofoil* on.



To actually send the data select *File/CNC Output*. This then streams the data to the given host and port. If you haven't already setup the CNC connection you'll see the dialog above before the data is sent and will need to enter a valid host and port.

Tool Offset

Tool offset allows you to compensate for the width of the kerf produced by the hot wire or "melt-back". Select *Cutter/Tool Offset* from the top level menu and you will see the following dialog.

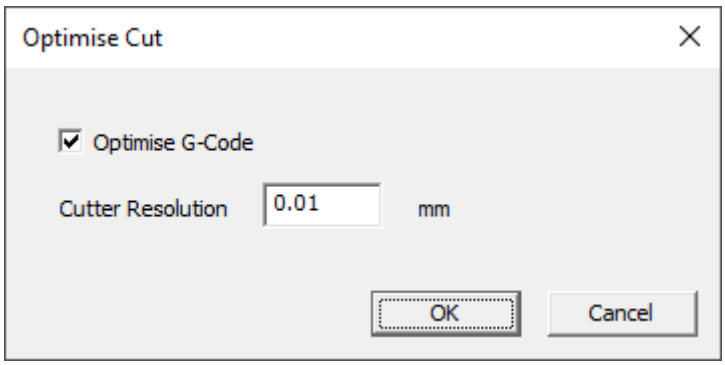


Note that the tool offset is half the width of the kerf - it's the distance the software needs to move the wire out so that the edge of the cut is in the desired place.

Optimising GCode output

The GCode output consists of a series of straight lines that approximates the curve of the wing. Ideally, where the curvature is small, so should the line segments, but on a flat bottomed wing for example, the straight line can be represented by a single line. Optimising the GCode output takes the resolution of the cutter and minimises the number of lines whilst ensuring that the error between the straight line and the smooth curve is less than the resolution of the cutter.

This is set up by selecting *Cutter/Optimise Output*. This then displays the *Optimise Cut* dialog below. This allows you to turn optimisation on or off and to enter the cutter resolution to use.



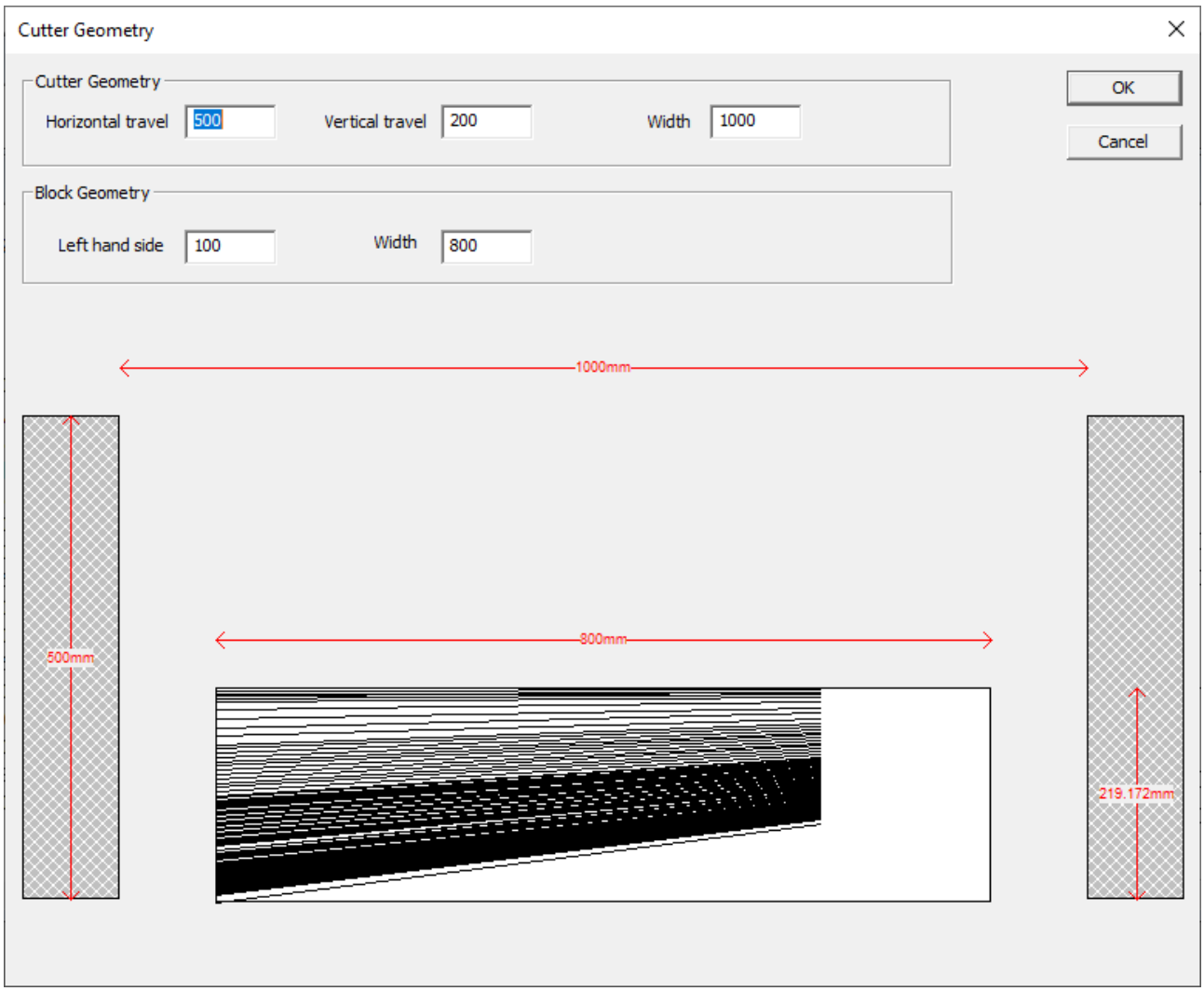
Cutter Geometry

Setting up the cutter geometry allows Aerofoil to do 2 things:

1. It can calculate the correction needed to cut tapered wings, both in simulation and, if selected, when the G-Code is generated.

2. It can scale diagrams correctly to show the available travel.

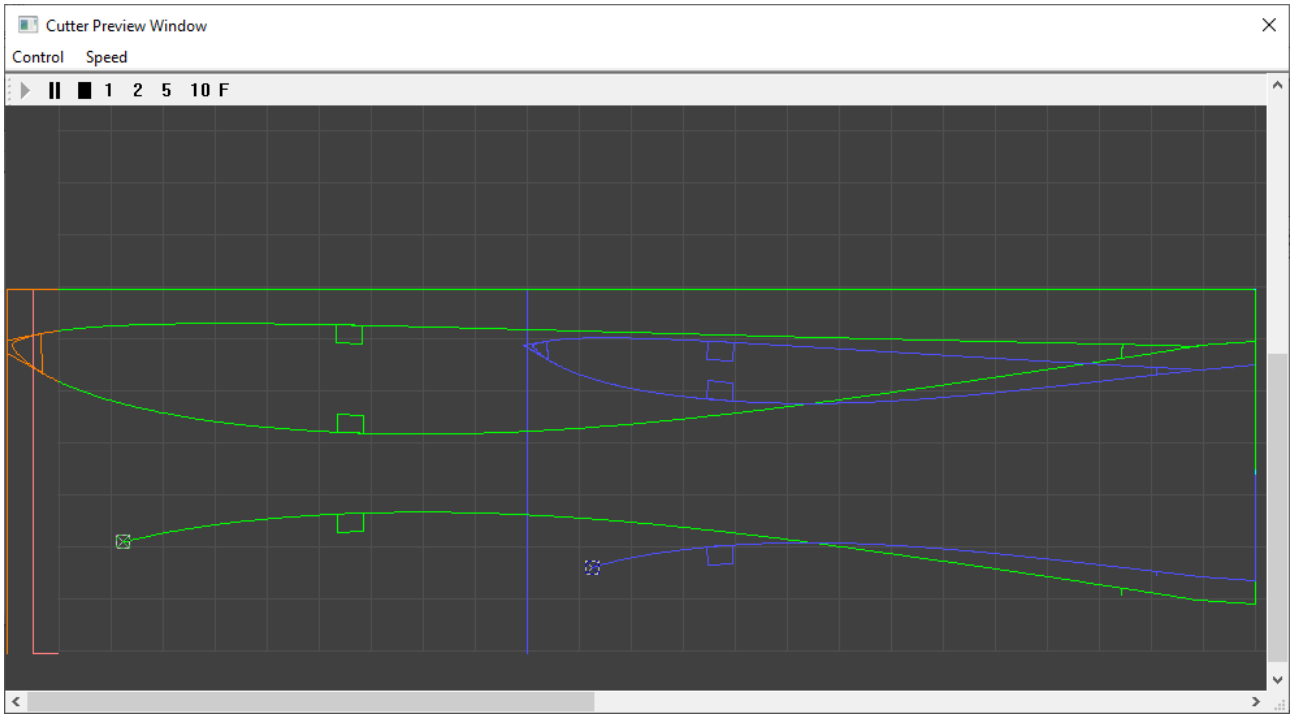
To set up the cutter geometry select *Cutter/Cutter Geometry* from the main menu. You will then see a dialog like the one shown below.



Cutter Geometry allows you to set the horizontal and vertical travel as well as the cutter width. The left hand side of the block and its width then establish the relationship between the block and the cutter. Note that the block's left hand side and width must be less than the cutter width. All dimensions are in mm.

Previewing a Cut

Before sending the G-Code to the cutter it is worth previewing the cut. To do this select Cutter / Preview Cut Path. You'll see a dialog similar to the one below displayed and the cutting path will be animated. Note that this is showing the path the actual cutter takes – when cutting tapered wings this will not be the exact shape traced on the edges of the foam block by the wire.



The screenshot above shows the path of the cutter animation – it's already cut one core and is part way through the top surface of another. Note the colour coding:

- Green is the path taken by the root end of the cutter.
- Blue is the path taken by the tip end of the cutter.
- Cyan (not shown) where both axes are cutting exactly the same point at the same time.
- Red is where one or other path has gone out of limit – less than zero or greater than the cutter travel.

Red is usually the result of faulty programming, in particular cutting a tapered wing where an axis cannot travel far enough to ensure that the wire is in the correct position on the edge of the block.

The simulation can be started, stopped, paused and restarted. The simulation speed can also be changed using the 1-5 and F (full speed) buttons.

Loading and Saving

Drawings can be loaded and saved. On the *File* menu:

- *New* creates a new drawing or cut file.
- *Open* opens an existing (.plt) drawing file (or .cut cutter file).
- *Close* closes the current drawing.
- *Save* saves the current drawing to file.
- *Save As* saves the current drawing to file with a new filename.

It's worth noting that the save format is XML. There is no schema per se, but looking at saved files will give a good guide. These files can be edited by hand if necessary although it's not usually necessary. Once instance where this may be necessary is if the aerofoil data (.dat) files are moved so the saved drawing files no longer reference valid aerofoil files.

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- c) Convey individual copies of the object code with a copy of the written offer to provide the Corresponding Source. This alternative is allowed only occasionally and noncommercially, and only if you received the object code with such an offer, in accord with subsection 6b.
- d) Convey the object code by offering access from a designated place (gratis or for a charge), and offer equivalent access to the Corresponding Source in the same way through the same place at no further charge. You need not require recipients to copy the Corresponding Source along with the object code. If the place to copy the object code is a network server, the Corresponding Source may be on a different server (operated by you or a third party) that supports equivalent copying facilities, provided you maintain clear directions next to the object code saying where to find the Corresponding Source. Regardless of what server hosts the

Corresponding Source, you remain obligated to ensure that it is available for as long as needed to satisfy these requirements.

•e) Convey the object code using peer-to-peer transmission, provided you inform other peers where the object code and Corresponding Source of the work are being offered to the general public at no charge under subsection 6d.

A separable portion of the object code, whose source code is excluded from the Corresponding Source as a System Library, need not be included in conveying the object code work.

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“Installation Information” for a User Product means any methods, procedures, authorization keys, or other information required to install and execute modified versions of a covered work in that User Product from a modified version of its Corresponding Source. The information must suffice to ensure that the continued functioning of the modified object code is in no case prevented or interfered with solely because modification has been made.

If you convey an object code work under this section in, or with, or specifically for use in, a User Product, and the conveying occurs as part of a transaction in which the right of possession and use of the User Product is transferred to the recipient in perpetuity or for a fixed term (regardless of how the transaction is characterized), the Corresponding Source conveyed under this section must be accompanied by the Installation Information. But this requirement does not apply if neither you nor any third party retains the ability to install modified object code on the User Product (for example, the work has been installed in ROM).

The requirement to provide Installation Information does not include a requirement to continue to provide support service, warranty, or updates for a work that has been modified or installed by the recipient, or for the User Product in which it has been modified or installed. Access to a network may be denied when the modification itself materially and adversely affects the operation of the network or violates the rules and protocols for communication across the network.

Corresponding Source conveyed, and Installation Information provided, in accord with this section must be in a format that is publicly documented (and with an implementation available to the public in source code form), and must require no special password or key for unpacking, reading or copying.

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