

From LEPARAGLIDING to XFLR5 Wing Analysis in Minutes

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13/07/2020

## Method to get the geometry of paraglider wing defined in LEPagliding into the wing analysis mode inside xflr5

### Introduction

There are various ways to analyze the aerodynamic behavior of a wing defined with LEPagliding (**LEP**) and the method described below is to convert the data already available in **LEP** in an exact and very accurate way for use in xflr5 wing analysis.

When it comes to wing analyses using the software xflr5 it is important to understand the limitations of the various solving methods. Studying the xflr5 guidelines pdf document downloadable from <https://sourceforge.net/projects/xflr5/files/> is a good starting point. The wing design and analysis capabilities are based on the Lifting Line Theory, the Vortex Lattice Method and the 3D Panel Method

It is important to note that **LEP** is a paraglider geometric layout program, and that no aerodynamic calculations are performed inside the program and needs to be done externally either with something like computational fluid dynamic (**CFD**) software or as in this case xflr5. **LEP** can export the 3-dimensional wing to STL format and methods exist to convert this to surfaces/solids for use in conventional **CFD** software but not described here. During the early stages of design, the use of Xflr5 is a great tool to use in conjunction with **LEP** firstly to define and understand the aerodynamic profiles used in **LEP** wing definitions and then secondly to understand the wing and its aerodynamic behavior. The final step is to use **CFD** and structural finite element (**FEM**) software to study and optimize the paraglider aerodynamic and structural behavior which includes the effect of the inlets at the leading edge.

There are four modes of analyses inside xflr5 and the one referenced here is the last listed below namely that of “Wing and Plane Design”

- Direct Foil Design
- XFoil Inverse Design
- XFoil Direct Analysis
- Wing and Plane Design

The method described here assumes that you know how to define a paraglider wing in LEP and that you are familiar with the **LEParaglider.txt** file that contains the geometry data.

## Method

The external part of the wing required for aerodynamic analyses is defined by the following sections in the input file named leparagliding.txt and output file lepout.txt

Description	File
Section 1 - Geometry	Leparagliding.txt
Section 2 - Airfoils	Leparagliding.txt
Section 30 - Airfoil thickness modification	Leparagliding.txt
Section 3 - Rib properties	lepout.txt

The section 1 and section 3 above are copied into a spreadsheet and manipulated slightly for input to xflr5 and written to a txt file. The whole process takes only a few minutes and can then be manually input into or imported to the wing section in xflr5.

See <http://www.laboratoridenvol.com/leparagliding/manual.en.html#6.1> for definition of variables in the sections listed above.

### Section 1 - Geometry (leparagliding.txt)

```
*****
*                               1. GEOMETRY                               *
*****
* Brand name
"LABORATORI D'ENVOL"
* Wing name
"gnu-test-3.19"
* Drawing scale
1.
* Wing scale  0.980762046
0.980762046
* Number of cells
29
* Number of ribs
30
* Alpha max and parameter
4.5 1
* Paraglider type and parameter
"ds" 1
* Rib geometric parameters
* Rib  x-rib  y-LE  y-TE  xp  z  beta  RP  Washin
1  22.65  0.16  309.25  22.64  0.40  1.95  33.33  0.00 0.0 50.0
2  67.75  1.39  308.60  67.62  3.53  6.06  33.33  0.00 0.0 50.0
3  112.46  3.84  307.32  111.90  9.71  9.97  33.33  0.00 0.0 50.0
4  156.60  7.50  305.40  155.09  18.79  13.87  33.33  0.00 0.0 50.0
5  199.98  12.37  302.86  196.84  30.55  17.57  33.33  0.00 0.0 50.0
6  242.42  18.43  299.70  236.81  44.75  21.75  33.33  0.00 0.0 50.0
7  283.72  25.69  295.93  274.49  61.65  26.50  33.33  0.00 0.0 50.0
8  323.64  34.78  291.58  309.41  80.96  31.25  33.33  0.00 0.0 50.0
9  361.82  46.86  286.67  341.23  102.04  35.78  33.33  0.00 0.0 50.0
10 397.91  61.58  281.06  369.71  124.21  40.10  33.33  0.00 0.0 50.0
11 431.64  78.51  274.77  394.47  147.07  46.40  33.33  0.00 0.0 50.0
12 462.75  97.17  267.95  414.34  170.99  54.04  33.33  0.00 0.0 50.0
13 491.09  117.10  260.74  429.49  194.91  61.64  33.33  0.00 0.0 50.0
14 516.52  137.86  253.27  438.60  218.59  76.24  33.33  0.00 0.0 50.0
15 539.00  159.09  245.71  441.49  240.83  88.85  33.33  0.00 0.0 50.0
```

## Section 2 - Airfoils (leparagliding.txt)

```
*****
*                2. AIRFOILS                *
*****
* Airfoil name, intake in, intake out, open , disp. rrw
1      gnua.txt      1.6    6.3    1      0      1      15
2      gnua.txt      1.6    6.3    1      0      1      15
3      gnua.txt      1.6    6.3    1      0      1      15
4      gnua.txt      1.6    6.3    1      0      1      15
5      gnua.txt      1.6    6.3    1      0      1      15
6      gnua.txt      1.6    6.3    1      0      1      15
7      gnua.txt      1.6    6.3    1      0      1      15
8      gnua.txt      1.6    6.3    1      0      1      15
9      gnua.txt      1.6    6.3    1      0      1      15
10     gnua.txt      1.6    6.3    1      0      1      15
11     gnua.txt      1.6    6.3    1      0      1      15
12     gnua.txt      1.6    6.3    1      0      1      15
13     gnua.txt      1.6    6.3    0      0      1      15
14     gnua.txt      1.6    6.3    0      0      1      15
15     gnua.txt      1.6    6.3    0      0      1      1
```

## Section 3 - Airfoil thickness modification (leparagliding.txt)

```
*****
*                30. AIRFOIL THICKNESS MODIFICATION
*****
1
1      0.9
2      0.9
3      0.9
4      0.9
5      0.9
6      0.9
7      0.9
8      0.9
9      0.9
10     0.9
11     0.9
12     0.9
13     0.9
14     0.8
15     0.0
```

The last rib which is accentually a line have been replaced with also 0.8 to limit issues with convergence.

### Section 3 - Rib properties in the output file (lepout.txt)

#### 3. RIB PROPERTIES:

-----  
Ribs number = 30  
Cells number = 29

Rib - Chord - washin - beta - Rot\_z  
-----

1	303.14	0.000	1.95	0.00
2	301.30	0.027	6.06	0.00
3	297.64	0.082	9.97	0.00
4	292.17	0.163	13.87	0.00
5	284.90	0.271	17.57	0.00
6	275.86	0.405	21.75	0.00
7	265.04	0.566	26.50	0.00
8	251.86	0.761	31.25	0.00
9	235.20	1.009	35.78	0.00
10	215.26	1.305	40.10	0.00
11	192.48	1.643	46.40	0.00
12	167.49	2.014	54.04	0.00
13	140.88	2.409	61.64	0.00
14	113.19	2.820	76.24	0.00
15	84.95	4.500	88.85	0.00

The first column in Table 2 defines the variables to define a wing in xflr5 and the second column the LEP counterpart that needs to be used as is or calculated.

**Table 2**

Table in xflr5	LEP definition in section 1	Note
Span position	X Rib (flat span position)	Distance values to each rib Section 1 must be scaled with factor in geometry section 1  Distance values of the flat layout must be used.
Chord	Chord = Y-Te subtracted from Y-Le	Calculated and scaled with factor in geometry section 1 or extracted from Rib property section in LEPOUT.txt
Offset (distance of leading edge of rib behind first rib in the center)	Y - Le	Scaled with factor in geometry section 1
Dihedral	Calculate from beta angle of each rib	Calculated from section 1 or determined from cad. See explanation below.
Geometric Twist	There are few possibilities to define but available in the output file	Extracted from rib property section in LEPOUT.txt
Foil data	Already in xflr5	Listed in section 2. For the airfoil that are scaled in section 3 airfoil data must be generated in xflr5
Rest of columns	N.A	Panel sizing as per xflr5 guidelines

## Clarification of dihedral definition in Table 2

The dihedral angle used in xflr5 can simply be measured in the paragliding.dxf file for each cell as shown below e.g 3.9, 19.3 degrees or calculated from the beta angles. The definition of beta angle defined in section 1 is the orientation angle of each rib as shown below eg. 1.9 ,6.1, 17.6, 21.7 etc

Figure 1 Front view - Beta angles (lep) and dihedral angles (xflr5)

## Example (gnu6A)

### Leparagliding.txt

```

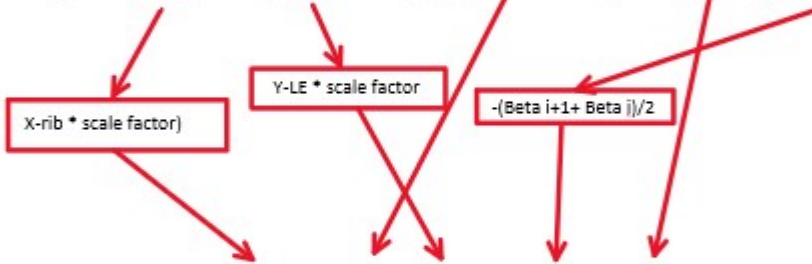
* Rib geometric parameters
* Rib   x-rib   y-LE   y-TE
1      22.65   0.16   309.25
2      67.75   1.39   308.60
3     112.46   3.84   307.32
4     156.60   7.50   305.40
5     199.98  12.37   302.86
6     242.42  18.43   299.70
7     283.72  25.69   295.93
8     323.64  34.78   291.58
9     361.82  46.86   286.67
10    397.91  61.58   281.06
11    431.64  78.51   274.77
12    462.75  97.17   267.95
13    491.09 117.10   260.74
14    516.52 137.86   253.27
15    539.00 159.09   245.71
  
```

### lepout.txt

```

3. RIB PROPERTIES:
-----
Ribs number =      30
Cells number =      29

Rib - Chord - washin - beta
-----
1   303.14  0.000  1.95
2   301.30  0.027  6.06
3   297.64  0.082  9.97
4   292.17  0.163 13.87
5   284.90  0.271 17.57
6   275.86  0.405 21.75
7   265.04  0.566 26.50
8   251.86  0.761 31.25
9   235.20  1.009 35.78
10  215.26  1.305 40.10
11  192.48  1.643 46.40
12  167.49  2.014 54.04
13  140.88  2.409 61.64
14  113.15  2.820 76.24
15   84.86  4.500 88.85
  
```



		span					
lep	xflr5	distance					
Ribs	Row Nr	y	chord	Offset	Dihedral	Twist	
0	1	0.000	3.031	0.000	0	0.00	
1	2	0.222	3.031	0.002	-4	0.00	
2	3	0.664	3.013	0.014	-7.9	0.03	
3	4	1.103	2.976	0.038	-11.9	0.08	
4	5	1.536	2.922	0.074	-15.7	0.16	
5	6	1.961	2.849	0.121	-19.6	0.27	
6	7	2.378	2.759	0.181	-24.2	0.41	
7	8	2.783	2.650	0.252	-28.9	0.57	
8	9	3.174	2.519	0.341	-33.5	0.76	
9	10	3.549	2.352	0.460	-37.9	1.01	
10	11	3.903	2.153	0.604	-42.7	1.31	
11	12	4.233	1.925	0.770	-50.3	1.64	
12	13	4.538	1.675	0.953	-57.7	2.01	
13	14	4.816	1.409	1.148	-69	2.41	
14	15	5.066	1.132	1.352	-82.6	2.82	
15	16	5.286	0.850	1.560		4.50	

Xflr5 table input (by hand or see below for import)



## Importing into xflr5

The table above now ready and should be formatted into a txt file that can be imported into xflr5 using the \*.xwimp extension

```
import_wing.xwimp - Notepad
File Edit Format View Help
gnuA6_wing
0.000 3.031 0.000 0 0.00 10 5 1 1 gnu-A18S90 gnu-A18S90
0.222 3.031 0.002 -4 0.00 10 5 1 1 gnu-A18S90 gnu-A18S90
0.664 3.013 0.014 -7.9 0.03 10 5 1 1 gnu-A18S90 gnu-A18S90
1.103 2.976 0.038 -11.9 0.08 10 5 1 1 gnu-A18S90 gnu-A18S90
1.536 2.922 0.074 -15.7 0.16 10 5 1 1 gnu-A18S90 gnu-A18S90
1.961 2.849 0.121 -19.6 0.27 10 5 1 1 gnu-A18S90 gnu-A18S90
2.378 2.759 0.181 -24.2 0.41 10 5 1 1 gnu-A18S90 gnu-A18S90
2.783 2.650 0.252 -28.9 0.57 10 5 1 1 gnu-A18S90 gnu-A18S90
3.174 2.519 0.341 -33.5 0.76 10 5 1 1 gnu-A18S90 gnu-A18S90
3.549 2.352 0.460 -37.9 1.01 10 5 1 1 gnu-A18S90 gnu-A18S90
3.903 2.153 0.604 -42.7 1.31 10 5 1 1 gnu-A18S90 gnu-A18S90
4.233 1.925 0.770 -50.3 1.64 10 5 1 1 gnu-A18S90 gnu-A18S90
4.538 1.675 0.953 -57.7 2.01 10 5 1 1 gnu-A18S90 gnu-A18S90
4.816 1.409 1.148 -69 2.41 10 5 1 1 gnu-A18S90 gnu-A18S90
5.066 1.132 1.352 -82.6 2.82 10 5 1 1 gnu-A18S80 gnu-A18S80
5.286 0.850 1.560 0 4.50 10 5 1 1 gnu-A18S80 gnu-A18S80
```

Regarding the format see below extra notes formulated by Jasonsh in 2013-05-28 - <https://sourceforge.net/p/xflr5/discussion/679398/thread/7db3809b/>

Some notes regarding the plain-text wing file:

- 1.)No blank lines please!
- 2.)Latin-1 character set only
- 3.)All values are space separated
- 4.)When specifying the airfoil names, if you wish for a space to be included in the name (AG 24) use the combination "/" instead of a space (AG/\_/24)
- 5.)The first line in the file give's the wing's name
- 6.)Each proceeding line represents one wing segment from root to tip and has the following values(expected units) in space separated columns  
y(m) chord(m) offset(m) dihedral(deg) twist(deg) nx-panels ny-panels x-panel-dist y-panels-dist right-foil-name left-foil-name
- 7.)Even if you don't yet know which airfoil you would like to use, you must still assign a left and right airfoil name; anything will do, NONE for example.
- 8.)file extension is .xwimp
- 9.)the xwimp file provides the wing geometry, you must provide the airfoil data via .dat file.

In xflr5 in the wing definition section, go to “other” and import as shown below in Figure 2

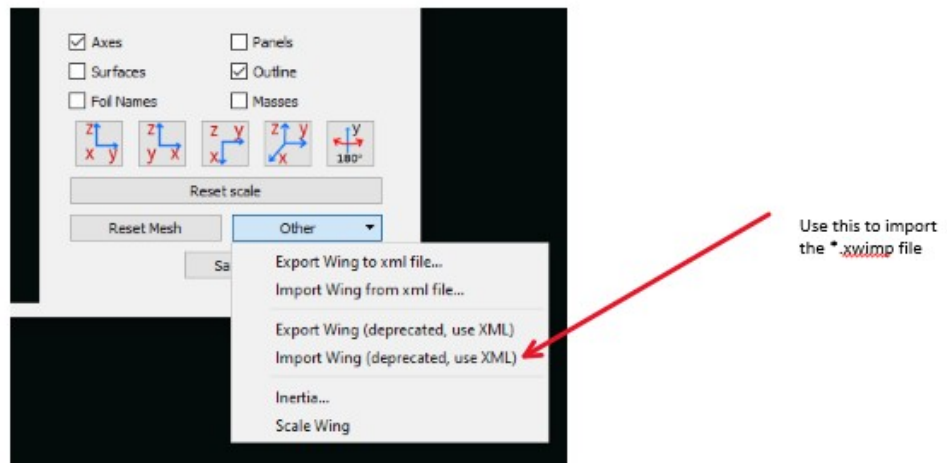
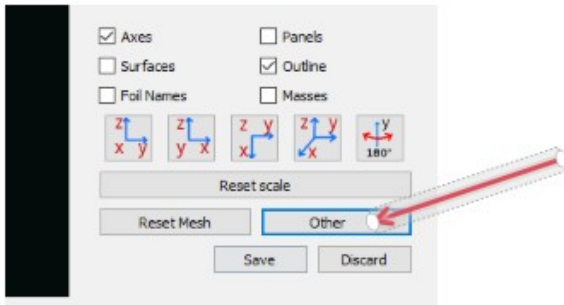


Figure 2 How to import \*xwimp file.

Finally, the exact geometry copy of the LEP exists inside xflr5 for Aerodynamic analyses.

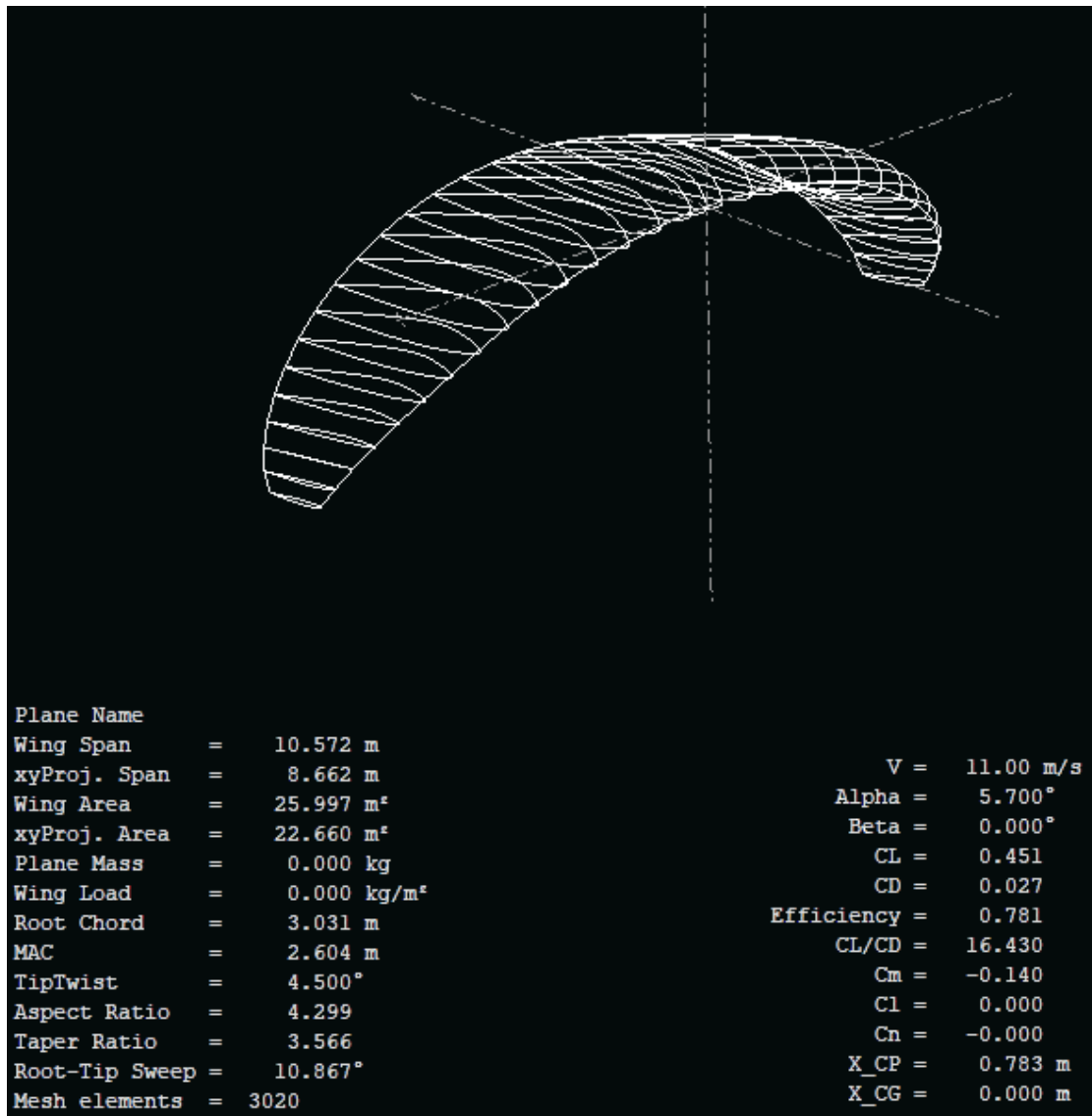


Figure 3 Presentation of wing and it's parameters with exact match of Lep-out.txt below

```

1. MAIN PARAMETERS:
-----
Flat area = 26.00 m2  279.8 ft2
Flat span = 10.57 m   34.7 ft
Flat A/R = 4.30

Projected area = 22.65 m2  243.8 ft2
Projected span = 8.66 m   28.4 ft
Projected A/R = 3.31
Flattening = 0.13

```

## Final Notes

- Some profiles might be scaled in thickness inside leparaglding.txt for instance in this case all the profiles have been scaled from 19.6 % to 18 % (0.9) and the second last rib to 15.68 % (0.8). The last profile is just a line meaning zero percent but have been replaced also with an 15.68 % (0.8) for this example. For each of the scaled profiles a profile must exist in xflr5 and the direct foil design module in xflr5 can be used to scale the foil.
- As a final verification the wing can be screen copied from xflr5 in front, top and side view and overlaid with views in paragliding.dxf using cad.
- Xflr5 Version 6.10 should be used to analyze geometry with larger Re nr of a million. The later versions are limited for low Re nr below a million. Once the polars have been generated it can be imported to a later version improved functionality and better graphics for e.g Version 6.57

## Various interesting plots

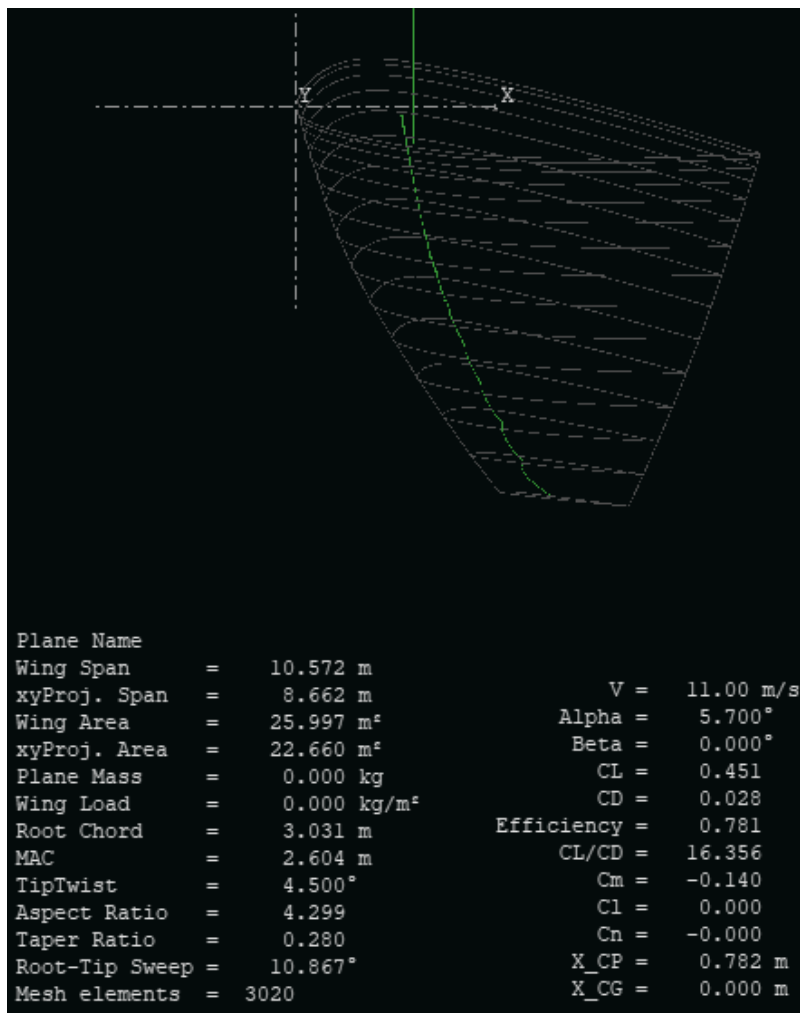
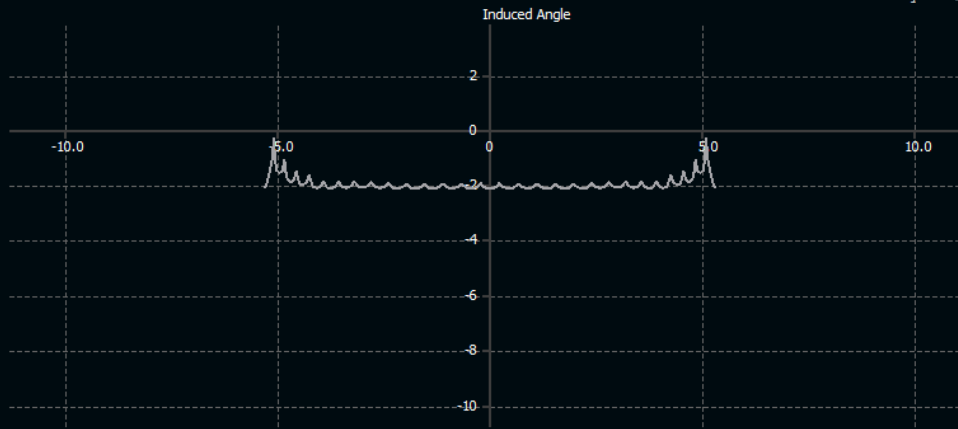


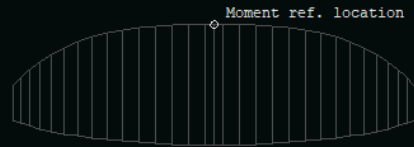
Figure 4 – Overall and span Xp position along the span

— Panels 5.7°-11.00m/s

x = 12.30506  
y = -11.38244



Plane Name  
Wing Span = 10.572 m  
xyProj. Span = 8.662 m  
Wing Area = 25.997 m<sup>2</sup>  
xyProj. Area = 22.660 m<sup>2</sup>  
Plane Mass = 0.000 kg  
Wing Load = 0.000 kg/m<sup>2</sup>  
Root Chord = 3.031 m  
MAC = 2.604 m  
TipTwist = 4.500°  
Aspect Ratio = 4.299  
Taper Ratio = 0.280  
Root-Tip Sweep = 10.867°  
Mesh elements = 3020



V = 11.00 m/s  
Alpha = 5.700°  
Beta = 0.000°  
CL = 0.451  
CD = 0.028  
Efficiency = 0.781  
CL/CD = 16.356  
Cm = -0.140  
Cl = 0.000  
Cn = -0.000  
X\_CP = 0.782 m  
X\_CG = 0.000 m

Figure 5 – Induced angle at 1.7 angle of attack

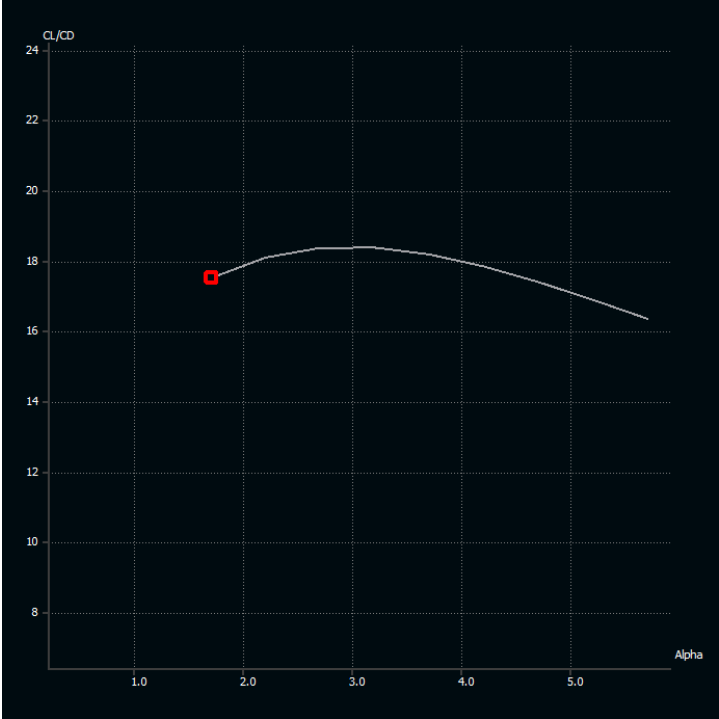


Figure 6 – CL/CD for the wing only. No line, pilot and harness drag and effect of inlets

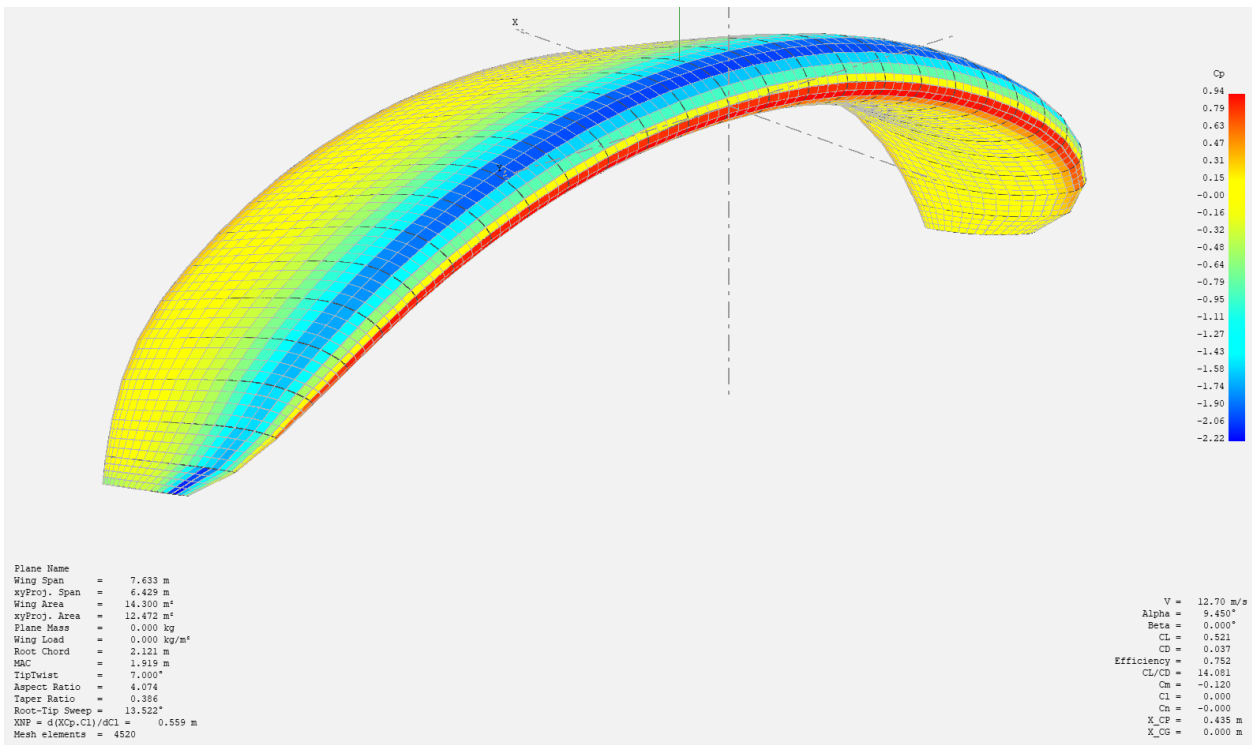


Figure 7 – Hegala Wing – Cp coefficient at 9.45 degree AOA

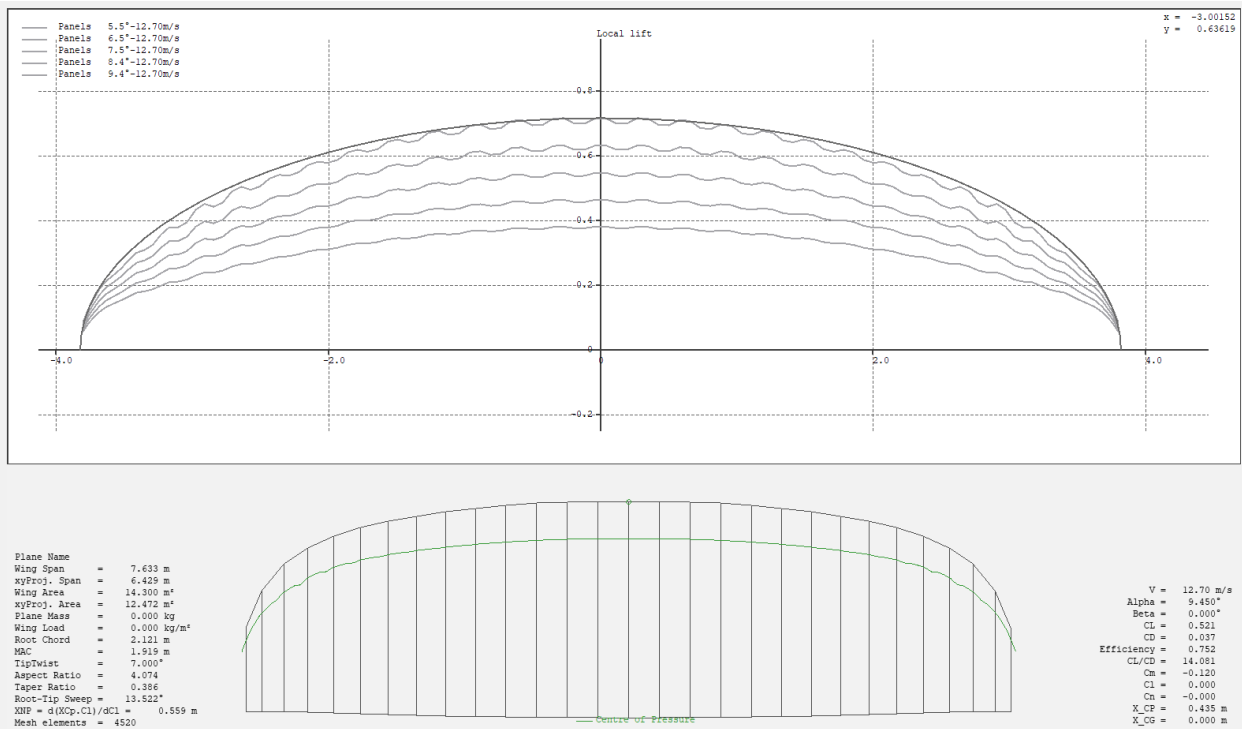


Figure 8 Hegala Wing – CL's vs Span and Elliptical vs 9.45 deg AOA

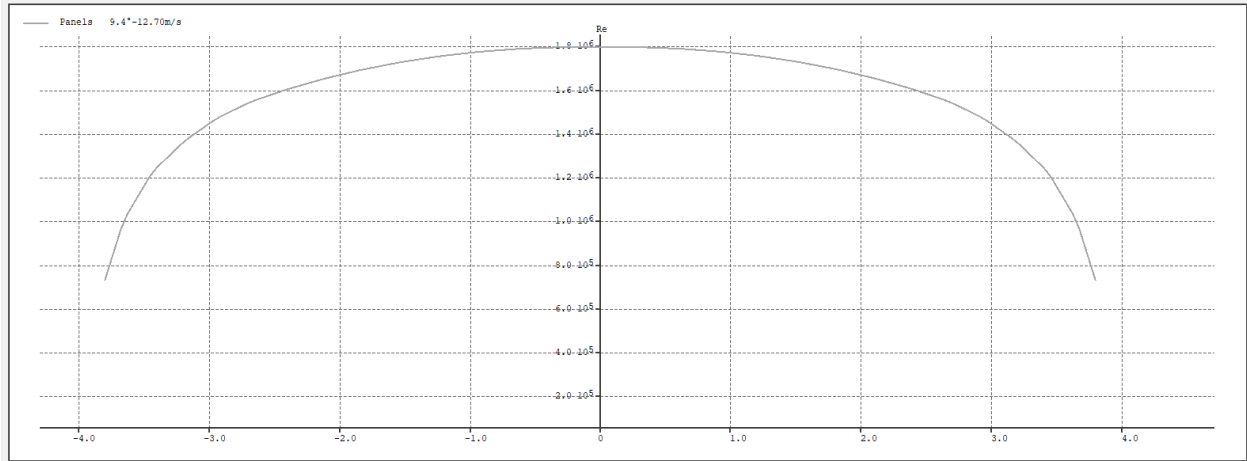


Figure 9 Hegala Wing - Reynold's Number vs Span at Trim Speed

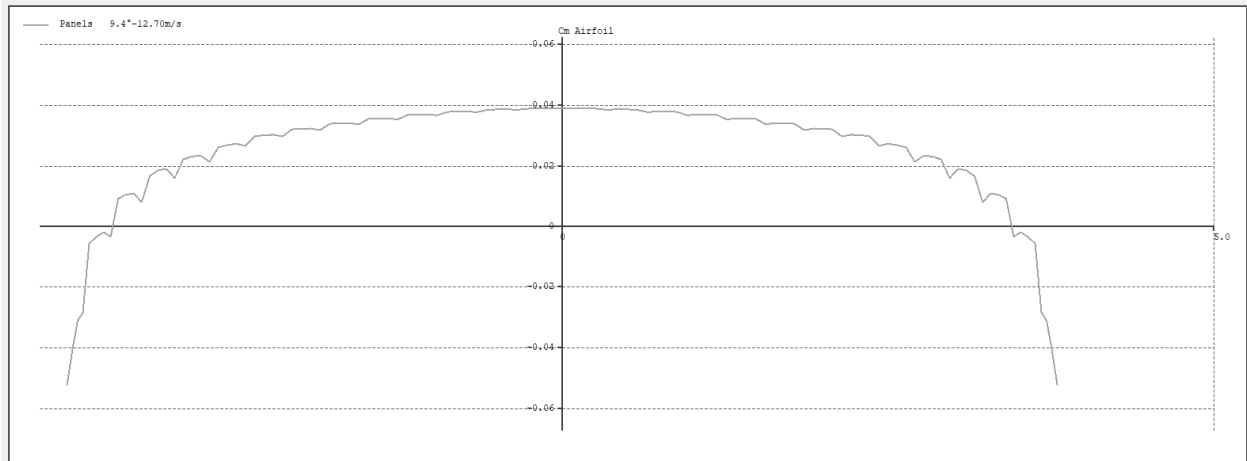


Figure 10 Hegala Wing – Cm vs span