XFLR5- Ver 6.32 Quick Start-up User Guide

XFLR5 is a comprehensive tool that combines XFOIL 2-D analyses as a base for 3-D model analyses. The inability of 3-D analyses alone to sufficiently capture viscous drag requires the reliance of XFOIL to estimate 2-D viscous properties that may then be accounted for under 3-D analyses.

• Installation

- The binaries for XFLR5 can be obtained from Blackboard
- Previous releases are also available at the XFLR5 website
- Save the downloaded to a location of your choosing and proceed to open the 'XFLR5.exe' application within to initialise XFLR5. A black workspace window will appear.

• Loading a 2-D aerofoil. Example: NACA 0010.

- Click 'File'- 'XFoil Direct Analysis'.
- Just above the workspace window, select 'OpPoint view' or alternatively click F5 on your keyboard to display the axes for a pressure distribution graph.
- Click the 'Design' tab from the toolbar at the very top of the window and select 'Naca Foils'.
- For demonstration purposes, the NACA 0010 aerofoil will be analysed, so enter the values '0010' for the '4 or 5 digits' section and click 'OK' when prompted to twice.
- An aerofoil outlined in red representing the specified aerofoil will now be displayed in the workspace window.
- To alter the number of panels for improved XFOIL analysis accuracy, navigate to the 'Design' tab and click 'Refine Globally.
- Enter a value of 130 for Number of Panels and apply this by selecting 'Overwrite' when prompted to 'Rename' the aerofoil.

Alternatively, aerofoils can also be imported into XFLR5. Navigate to:
http://m-selig.ae.illinois.edu/ads/coord_database.html
Download and save the desired .dat aerofoil. Within XFLR5, under the 'XFoil Direct Analysis' window, click 'open' and load the saved .dat aerofoil. It will now appear on-screen as before.

• XFOIL analysis of a NACA 0010 2-D aerofoil.

- With the NACA 0010 aerofoil loaded, 2-D analysis of the aerofoil can be run
- Select the 'Analysis' tab on the upper toolbar - Batch Analysis
- For 'Foil Selection', select 'Current foil only'. Alternatively, selecting 'Foil list' and selecting the NACA 0010 aerofoil will bear no difference.
- Ensure a 'Type 1' Analysis Type and for 'Batch Variables' click 'Range'
- For demonstration purposes, specify a Reynolds Number range from 6,000,000 to 7,000,000 with increments of 100,000.
- Ensure 'Forced transition' values are both at the trailing edge, so 1.00
- Under 'Analysis Range', specify 'Alpha' for a range of -5 to 15 in increments of 0.5 degrees. Ensure 'From Zero' box is ticked.
- Click 'Analyze'

- Upon completion, click ‘Close’ and switch view by clicking the ‘Polar view’ tab (alternatively click F8 on your keyboard) to view multiple graphs regarding the analysis of the NACA 0010.

NOTE: **1.)** Graph variables may be altered by double-clicking individual graphs.
2.) Scrolling with your mouse wheel allows zooming in on individual graphs.
3.) Clicking the ‘Graph’ tab at the top of the workspace window and selecting between Graphs 1-5 allows for further detailed viewing of individual graphs.
4.) Selecting ‘All Graphs’ under the ‘Graphs’ tab will reset to the default view of 5 graphs on-screen.

Further analysis on specific Reynolds Numbers cases can be carried out by following steps outlined in **Figure 1** below:

1.) Select the Reynolds number case to further analyse.

2.) Tick ‘Sequence’ and re-analyse the aerofoil for a new range of incidences

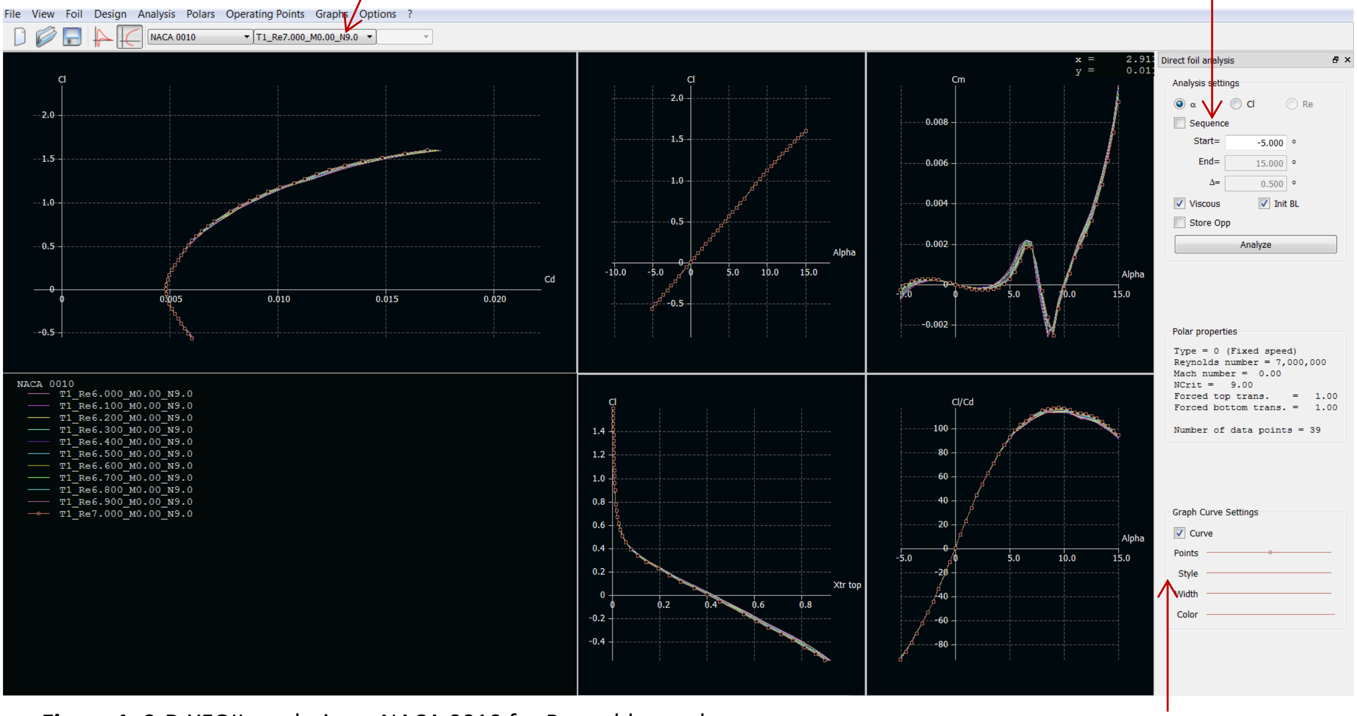


Figure 1: 2-D XFOIL analysis on NACA 0010 for Reynolds number range 6,000,000- 7,000,000 in increments of 100,000 Reynolds.

3.) Curves for specific Reynolds number analysis can be modified under this section menu

NOTE: Right clicking a graph and selecting ‘Current Polar’- ‘Export’ will allow the result data from the specific Reynolds analysis on-screen to be exported into a format of your choosing (.csv,.txt *etc)*

- **Test Case 1: Creating a 3-D ‘Plane’- Rectangular Wing.**
  - Once 2-D XFOIL analysis of the aerofoil is completed, click ‘File- ‘Wing and Plane Design’
  - A new window displaying dashed x,y,z co-ordinate axes will appear.
  - On the upper toolbar menu, click ‘Plane’
  - Click ‘Define a New Plane’
  - For ‘Plane Description’, enter: Rectangular Wing
  - UNCHECK the ‘Elevator’ and ‘Fin’ since the focus is primarily of a rectangular wing.
  - Under ‘Main Wing’, click ‘Define’
  - Enter the parameters as seen in **Figure 2** below:

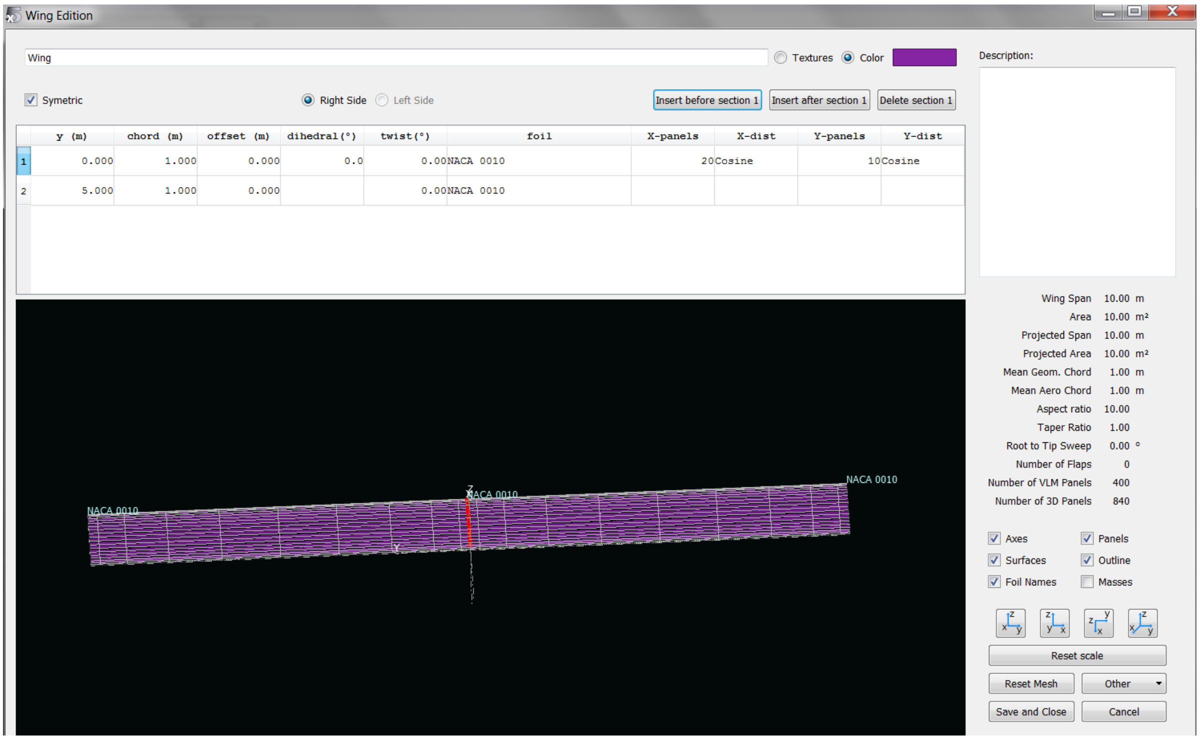


Figure 2: Wing creation parameters

  - Upon completion, click the ‘Save and Close’ tab
  - The Wing will not be offset from the origin, so ensure x=0.00m, z=0,00m
  - Click ‘OK’. A wing will now appear in the workspace window

- **Test Case 1: Analysing the 3-D Rectangular Wing.**
  - The process to analyse the 3-D wing is similar to that of the XFOIL 2-D analysis. Simply click on the ‘Polar View’ icon (alternatively press F8)
  - Four graphs by default will be displayed.
  - Click on the ‘Analysis’ tab- ‘Define an Analysis’.
  - Under the ‘Polar Type’ tab, ensure ‘Type 1’.
  - Enter a ‘Free Stream Speed’ of 102m/s (representing Mach 0.3)
  - Under the tab ‘Analysis’, select Ring Vortex VLM2).
  - Ensure ‘Viscous’ is ticked
  - Click ‘OK’

- Within the ‘Plane analysis’ dialog box, the ‘Polar properties’ menu will list the conditions for the analysis.
- Ensure ‘Sequence’ is ticked and enter an incidence range from -3 to +10 degrees in increments of 0.5 degrees

  NOTE: Similarly to the 2-D polar graphs, the 3-D polar graphs may also be exported to a .csv or .txt file by right clicking the graphs, selecting ‘Current Polar’ followed by ‘Export’

- Switching back to the 3-D Wing model view by clicking the ‘3D View’ icon (alternatively press F4), the wing at the specified incidence range can be visualized by selecting the various incidences as seen in **Figure 3**:

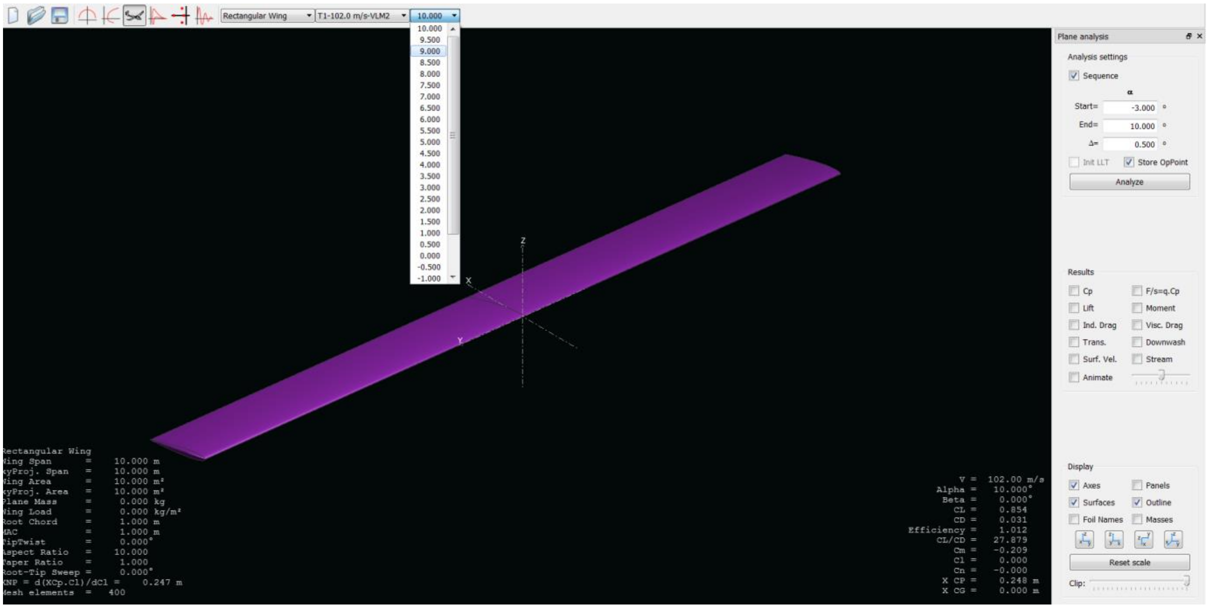


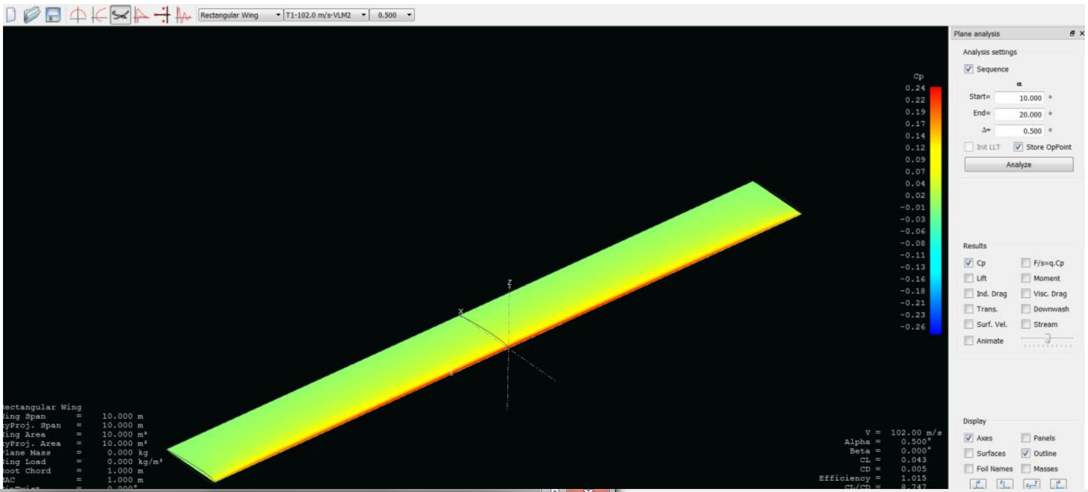
Figure 3: Note how the aerodynamic coefficients on the bottom right of the workspace window adjusts appropriately based on the selected incidence

- For further in-depth visualization, under the ‘Plane analysis’ dialog box, tick the boxes ‘Cp’,’Lift’,’Ind. Drag’ and ‘Animate’ in order to animate the wing through the specified incidence range and increment defined under the 3-D analysis.

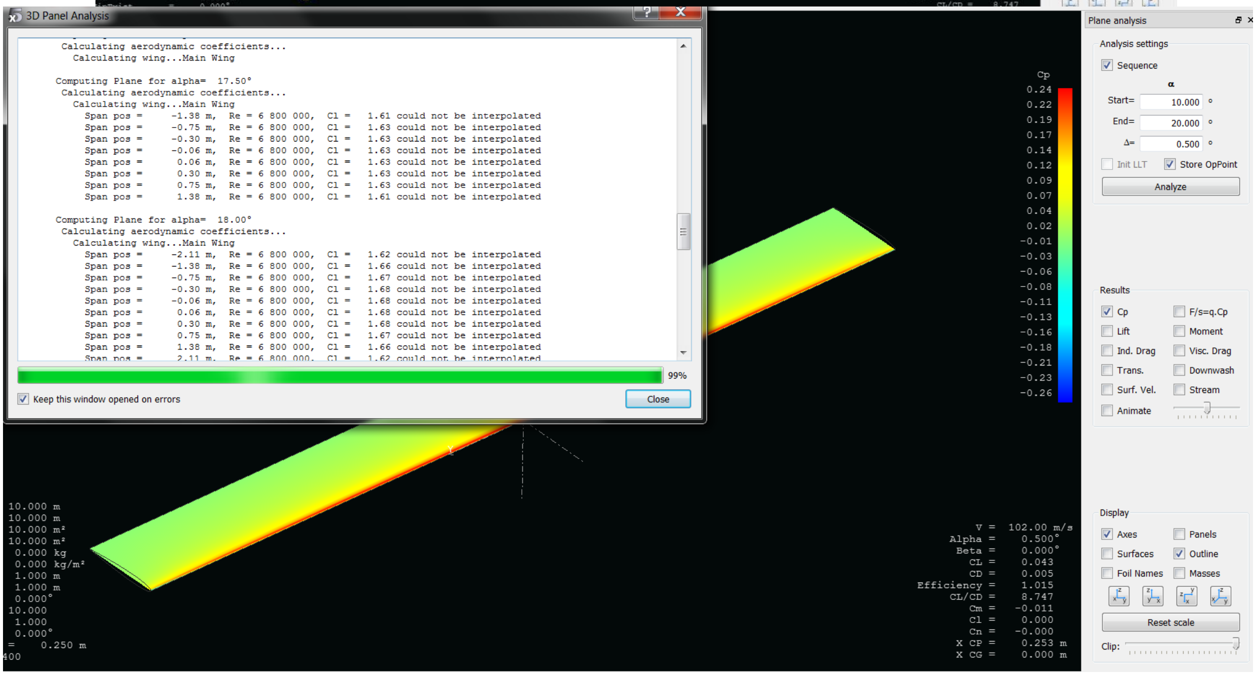
Trouble- Shooting

1.) **‘Cl = … could not be interpolated’**

- Continuing with Test Case 1 of the Rectangular Wing, if the incidence range for the 3-D analysis is now altered to include incidences above 10 degrees as seen below:



Upon clickin



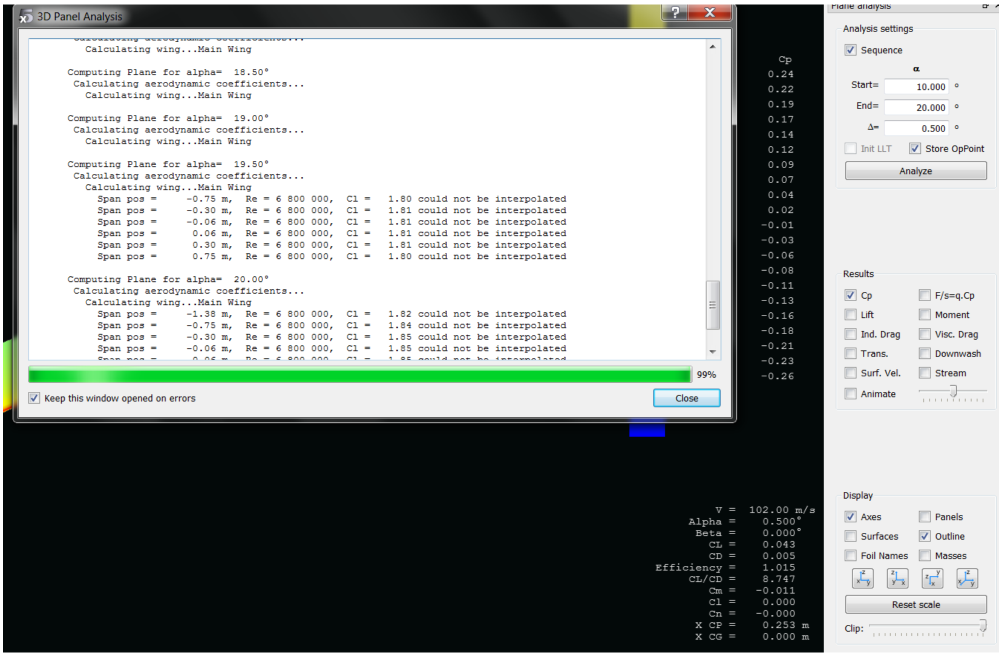
g ‘Analyze’, an error message will appear as follows:

As seen, at incidences 17.50 degrees and above, a Cl value cannot be interpolated. **This type of error is most common when ‘Viscous’ is included when initially defining the 3-D analysis.**

Navigating back to the 2-D foil analysis by clicking ‘File’- ‘XFOIL Direct Analysis’ it is clear that for the specified incidence range for the 2-D foil analysis, the upper limit of Cl is ≈1.6 therefore providing error messages for 3-D analysis that a Cl of eg: 1.61, 1.63 *etc* could not be interpolated.

NOTE: 3-D Plane analysis is firstly built upon the results from the 2-D XFOIL analysis in order to apply the 2-D viscous model for 3-D analysis. Viscous drag is poorly estimated in 3-D analysis alone hence the reliance on evaluating viscous drag from the initial 2-D foil analysis through XFOIL and applying this to the 3-D analysis. The neglect of viscous drag in 3-D analysis will result in overestimation in performance for 3-D planes.

1.) To attempt to resolve this error, re-analyze the NACA 0010 aerofoil for the same Reynolds number range but now for an additional incidence range from 15 to 20 degrees, preserving the initial increment of 0.5 degrees.
2.) Upon completion, navigate back to the 3-D plane analysis by clicking 'File'- 'Wing and Plane Design'
3.) Under the 'Plane analysis' dialog box, re-attempt to analyze the 3-D wing again for an incidence range between 10 and 20 degrees, increments of 0.5 degrees.



4.) The error message now shows that at incidence of 19.50 degrees and above, the corresponding lift coefficients could not be interpolated. 2-D XFOIL analysis suggest that the maximum Cl achieved for the NACA 0010 aerofoil is 1.795 before stall. Therefore 3-D plane analysis can achieve a maximum incidence of 19.00 degrees.
5.) Re-analyze the 3-D model from incidence range 10 to 19 degrees. This will now be successful.
6.) If 3-D plane analysis is required at higher incidences, consider altering the NACA aerofoil or 3-D wing Aspect Ratio to attempt to achieve successful Cl interpolations.

2.) 'Cl = … outside flight envelope'

- This error message may appear when performing either 3-D Viscous or Inviscid analysis and arises from an insufficient Reynolds number range when conducting initial 2-D XFOIL aerofoil analysis. This error message will provide the user with the 'missing' Reynolds number.

- Simply navigate to the 2-D aerofoil analysis by clicking ‘File’- ‘XFOIL Direct Analysis’ and re-analyze the aerofoil at a greater Reynolds number range to sufficiently include the specified value displayed in the error message.

- Return to the 3-D analysis by clicking ‘File’-‘Wing and Plane Design’ and re-analyze the 3-D model.

A useful Trouble shooting summary video may be found at:
https://www.youtube.com/watch?v=_8thw2CQCaI&list=PLtl5ylS6jdP6uOxzSJKPnUsvMbkmalfKg&index=11