Aerodynamics Naïve #3– a brief intro to Xflr5, a virtual wind tunnel

by George Lungu

- The previous section charted the ping-pong polar diagrams and showed them side by side with a set of simulated ones. A reasonable similarity of shape was noticed for moderate angles of attack.
- This section contains a brief introduction to Reynolds numbers and the use of an aerodynamic simulator called XFLR5.
- In the next series of tutorials we will use this freeware to simulate various airfoils (for both the wing and the horizontal stabilizer), export data as .csv to Excel, do polynomial interpolations on the polars and use the extracted equations to model the 2D dynamics of an airplane built using the simulated airfoils.

Reynolds numbers:

- Reynolds numbers are used to characterize viscosity effects in aerodynamics. As the formula below shows, the number is proportional to the product between the relative speed of the air [m/s] with respect to the body, the length of the body in [m] (airfoil chord in this case) and inversely proportional to the air viscosity which below 4000 meter is roughly constant.

$$\mathrm{Re} = \frac{Speed \cdot Length}{Viscosity}$$

- It can be simply expressed as:

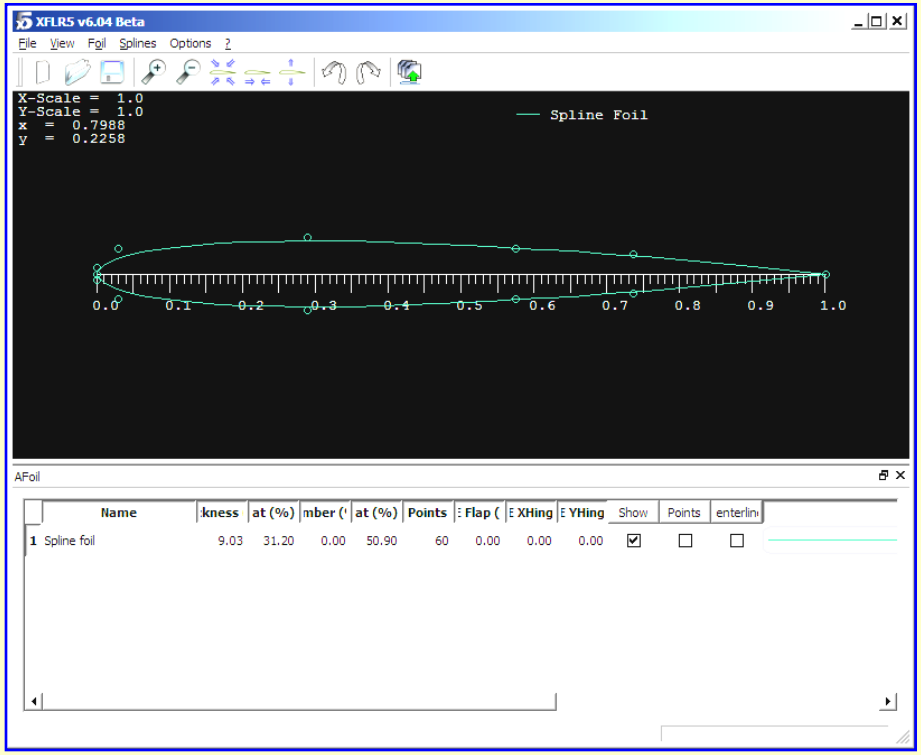
$$\mathrm{Re} = Speed \cdot Length \cdot 70000$$

where the speed is measured in [meter/second] and the length is in meters

The plug for the composite flying wing Atlantica - www.wingco.com

A very brief introduction to Xflr5:

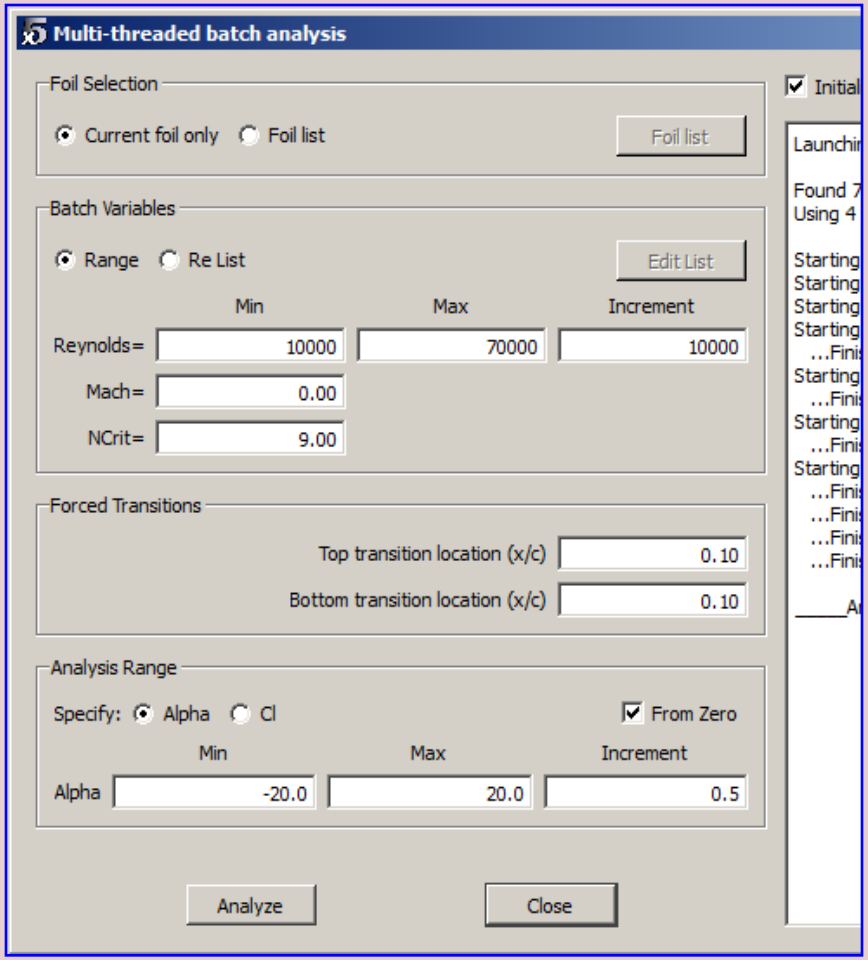
- XFLR5 is an aerodynamic software you can download for free at: http://xflr5.sourceforge.net/xflr5.htm
- After download you can pick up the "application" file, create a shortcut and place it on your desktop
- Let's model an airfoil using this program:
- Bring up the application by double clicking the XFLR5 desktop icon
- File => Direct Foil Design. You can experiment with changing the shape dragging the splines (the little circles) in the design pane.



- Save the foil: Splines => Export Splines to File => choose a folder and a name => Save
- Open the saved foil: File => Open => navigate to the file => Open, go into Direct Foil Design mode and you could change the thickness: Foil => Change Camber and Thickness => change whatever you like there and then save it
- The program is not very intuitive to use and sometimes it's just plain frustrating. When you get stuck close it, don't save anything and reopen again. After that: File => Open navigate to the file => Open
- Only after you open a saved file you will be able to perform analysis otherwise it will simply not display the analysis setup menu (due to its speed I like to use Analysis => Multi-threaded Batch Analysis).

Airfoil analysis with Xflr5:

- Launch the program => File => Open => select a file name (I chose the default symmetric foil that I previously saved under the name "Normal.dat" in a dedicated directory) => Open.
- Let's set up an analysis: Analysis => Multi-threaded Batch Analysis (the menu below will pop up).
- I chose a Reynolds number sweep between 10000 and 70000 in seven steps. You can use a different range of Reynolds numbers to your preference, making the speed to Reynolds number conversion by using the formula in the first page. You obviously must have in mind a wing chord size (foil length) and a speed range. I chose a small and slow model airplane (flying at low Reynolds numbers).
- Analysis range: "Specify Alpha" and I also like to select "From Zero". Set up the range of angle of attacks you like (-20 to +20 would be a reasonable number but this angle usually stays below 10 degrees absolute value in normal flight.
- I also found out that changing top and bottom laminar to turbulent transition points from 1 to 0.1 will make to curve look much smoother maintaining a similar shape.



- After this hit "Analyze" and wait for the program to execute the simulation

Plotting, formatting and exporting the polar diagrams:

- These are some results I got from running the previous simulation. You can easily change how many graphs are plotted and the content of each plot. The program is finicky, you might have to reopen it to get what you want but for the most part it works all right.
- After the simulation is finished you can go to "Polars" menu and choose "Polar Graphs". Experiment with various settings. You can have, one or two or even five polars displayed at the same time.
- You can also hover above any of the charts, then right click => Current Graph => Define Graph Settings and change the variables displayed on either axis but also adjust some formatting (such as scale values and some colors for instance).
- You can also hover above any chart, then right click => Current Graph = Export Graph, and you will be offered the option to save the points of the chart as .csv file which is a very useful option which we will use later to extract polynomial approximations for this curves to later use in more precise whole-airplane modeling.