**SESA2022 Laboratory Report**

**Abstract**

This report covers data obtained in Infinite-Span (Airfoil) Wing Experiment, Finite-Span Wing Experiments well as CFD lab and the boundary layer lab. The CFD lab, XFOIL and theory are used to compare the pressure distribution and lift coefficient to the airfoil experiment. The finite wing lab results are compared to XFLR5 and theory. The boundary-layer lab results are used to verify the zero-lift drag measurements in the finite-wing experiments as well as the viscous drag of the airfoil. Therefore, this lab should be viewed as a holistic report that assesses the content of 4 different labs. Moreover, writing this report provides you with a template to carry out a holistic design and determine the performance of a wing with a specific airfoil section.

The report should be no longer than **8 pages including appendices and references** (minimum font size 11 of any san-serif font such as Helvetica/Arial and use single-line spacing). Do not include a separate title page or table of contents. Just the name and Student ID number is sufficient. The report should be well-structured and present information with high-quality figures, appropriate text for description/discussion and suitable references. The presentation of the report will carry 10% of the marks. Please follow the style of this handout to structure your report (including references). Your report should contain at least the following sections (nominal marks for specific things to be addressed in the sections are included within parentheses).

A few general points of advice –

* All sources must be references
* When talking about a figure make sure you reference it in and that every figure is references in the text and figure has a suitable caption
* Do not write for the sake of making it the page limit it is a limit not a target, the easier the report is to read the more likely the marker is to understand your point.
* Presentation is very important. Make sure that the figures are clear and the axes are labelled correctly. Make sure that the symbols and lines in the figures are clear and legible. Presentation contributes 10% of the total mark.

**Introduction –** (5%)

This section should introduce the purpose of the report and the motivation for carrying out the experiment and CFD. It could be good to briefly introduce what the experiment what and what you hope to achieve in a few sentences. This introduction should also discuss the various theories involved. When discussing theories you may like to reference them to peer reviewed articles, these should be introduced in the introduction. It is also suggested that you come up with some aims and objectives which you will answer in the report.

**Experimental and CFD methods -** (10%)

This section should consist of details of the experiment. This include a description of the wind tunnel, airfoil, the equipment used to measure pressure and forces and the conditions under which the experiments were carried out (freestream speed, angle of attack etc). Diagrams should be included demonstrating the layout of the experiments in the labs (boundary layer, finite wing and infinite wing).

Discuss the uncertainty is making force and pressure measurements. Detailed uncertainty analysis is not needed for this report however discussing sources of error and how they may affect your results are required.

The section should also include an overview of the CFD including details of the mesh and conditions under which the calculation was performed. It is suggested to include a diagram of the mesh used so explain when it is designed like it is (i.e. cell spacing and shape)

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| Figure 1 – (edit captions as needed)  a) Boundary layer lab diagram  b) airfoil lab diagram  c) finite wing lab diagram  d) CFD mesh | |

**Results & Discussion-**

This section needs to be split in two subsections. One for the airfoil and the second for finite wing.

**Airfoil lab experiment -**

This subsection should contain results obtained in the infinite wing (or airfoil lab) experiment as well as some results from the CFD lab as well as XFOIL.

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| Figure 2 – (edit captions as needed)  a) Plot showing pressure distribution at 0 degrees (or another angle)  b) Plot showing pressure distribution at 6 degrees (or another angle)  c) Plot showing pressure distribution at 12 degrees (or another angle)  d) Cl - alpha plot and compare to theory | |

Plot the pressure distribution (in non-dimensional form, i.e. -Cp) for an angle of attack (for α= 0◦,α= 6◦ and α= 12◦) from the experimental data (alternately plot it for three angles of attack that you obtained measurements for). Also plot the pressure distribution from the CFD data at the same angles of attack in the same figure as experimental data. Add the XFOIL data at a similar Reynolds number to the one the aerofoil experiences during the lab and the CFD. Comment on the reasons for similarities and differences between CFD, XFOIL and experiments. The plots should be clearly labelled with legends to identify each data set. (15%).

Integrate the pressure coefficient to obtain a lift coefficient and plot it against angle of attack (you need several points going from angle of attack of -4 degrees to 14 degrees). Note that you need to use all the data across all angles of attack obtained by your group (or use the Master dataset). Use the lift coefficient against angle of attack to obtain the lift curve slope (remember to use the angle in radians). Following the same procedure, plot the lift coefficient computed from CFD results and from XFOIL in the same plot. Be careful when you obtain the fit and only use angles where the foil is not stalled. If you include higher angles of attack during the fitting, then the slope will be lower than expected. Compare the CFD and XFOIL to the experiments and to the theoretical values that can be obtained using thin aerofoil theory (discuss similarities and differences). Make sure you justify differences as well as sources of error and how they affect results. It is good practice to compare to peer reviewed articles to explain the results where possible, there are many papers on similar aerofoils discussing the results (15%)

Finally, estimate the viscous drag experienced by the airfoil section. For this, you are going to use the results from the Boundary layer lab. Your group took data for 4 cases (at two different speeds and two different plate lengths). First, find the Reynolds number based on airfoil chord length and then find the most similar Reynolds number of the 4 cases tested in the boundary layer lab. In this way, you assume that the airfoil is a flat plate of length equal to the chord length of airfoil. You need to get the drag by obtaining an estimate the momentum thickness (θ) – This is obtained through numerical integration of appropriate quantity derived from the velocity profile (see lecture Jupyter notebook for this).The Drag force per unit span D′=ρU∞2θ. (remember that there are two sides to the airfoil). You can compare this value against theory since you know the relationship between the momentum thickness and Reynolds number. (10%)

**Finite wing experiment -**

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| Figure 3 – (edit captions as needed)   1. CL alpha plot (compare 2D and 3D slope) 2. CD versus CL2 3. CL/CD against CL 4. Boundary layer profile as measured in lab and used to compare to the measured drag. | |

This subsection should show the results from finite wing part.

First plot the Lift coefficient (CL) against geometric angle of attack for a finite wing. Fit a Compare the lift curve slope obtained from the data to that of the theory and to XFLR5. Comment on similarities and differences. You can also compare that to the slope in the airfoil case and comment on the similarities/differences. You should comment on the causes that could lead to the differences with theory. If possible cite external sources such as peer reviewed papers. (10%)

Next plot the drag coefficient (CD) versus CL2 and use this plot to calculate the zero-lift drag coefficient (CD,0) for the finite wing. Compare this value to skin-friction coefficient obtained in the boundary layer lab at the highest Reynolds number. Note that the Reynolds number based on chord length of the finite wing is perhaps a bit higher than the highest Reynolds number in the boundary layer lab. However, you can also use theory to estimate the skin-friction coefficient with the Reynolds number based on the chord length of the wing. In this case, you will still assume that the wing is similar to a flat plate. Comment on the similarities and differences between the measurements and the theory (10%)

Finally plot the glide ratio (CL/CD) versus CL and compare to the theory and XFLR5. Find the the best glide ratio that can be achieved using this wing (see lecture slides). Comment on differences and the effect they have on the results, try and justify the differences using other sources to support your case. (10%)

**Conclusions (5%)–**

Write the major conclusions and the outcomes of this lab, these should be linked back to the aims and objectives of the experiment as set out in the introduction.

**References –**

List of references, IEEE or Harvard referencing techniques should be used see library resources for help if required.