Institute for Aerospace Studies
UNIVERSITY OF TORONTO

AER303F
Aerospace Laboratory I

Aerodynamic Forces on Airfoils

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1 Objectives

The teaching objectives of this laboratory are two folds:

- allow students to apply knowledge gained about airfoil aerodynamics in AER307 to a real-life experiment and experiment with an airfoil model in a low-speed wind tunnel
- apply knowledge gained in this course on the gathering, analysis and reporting of experimental data to a real experiment

The practical objectives of the laboratory are to:

- measure the pressure distribution around an airfoil model at different angles of attack
- measure the velocity profile in the wake of an airfoil model at different angles of attack
- calculate the C_L, C_M and C_D curves as a function of α for the airfoil
- compare different method of measuring pressure and velocity in a quantitative manner, including a detailed uncertainty analysis of each measurement systems

2 Preparation

The following questions need to be considered and answered before arriving at the laboratory. The answer are to be submitted to the lab instructor.

1. What is your interpretation of airfoil stall?
2. How would you expect the stalled condition to manifest itself when you perform the experiment?
3. Suggest some other methods that might be used to determine the lift of an airfoil.

3 Apparatus

The experiment will be performed in an open-return, Eiffel wind tunnel with a maximum speed of approximately 50 m/s (ELD Model 402B). The 0.61 m long test section has a cross-section that is 304.8 mm by 304.8 mm. The airfoil model for this experiment is the Clark Y airfoil. A total of 19 pressure tap are distributed along the surface of the model and connected via PVC tubes to different pressure measurement devices. The coordinates for the shape of the Clark Y model used for this work are given in the comma delimited ASCII file 'Clark Y airfoil.csv'. Table 1 list the location of each pressure taps, which are numbered clockwise starting from the leading edge

Table 1: Static pressure tap locations

Top		Bottom	
Tap number	x/c	Tap number	x/c
1	0	13	0.90
2	0.03	14	0.60
3	0.06	15	0.40
4	0.10	16	0.30
5	0.15	17	0.20
6	0.20	18	0.10
7	0.30	19	0.05
8	0.40		
9	0.55		
10	0.70		
11	0.85		
12	1.00		

tap. The wind tunnel speed can be monitored from a pitot-static tube located in the free-stream of the flow and connected to a Betz manometer. A rake of total pressure tubes is located at 27 cm downstream of the model trailing. The relative location of each pressure tube is given in Appendix B. For measurements that require better spatial resolution, the rake can be traversed using a manual traversing system.

Pressure differences in this experiment will be measured using two different pressure measurement devices. The first one is a 36-tube inclined water manometer. The second system is a pressure sensor mounted on a multi-channel Scanivalve system. The Scanivalve allows the pressure tube connected to the pressure to be changed rapidly, thus enabling the single pressure sensor to be used for all pressure ports in this experiment.

The only analog signal to be sampled in this experiment is the output of the pressure transducer connected to the Scanivalve. This signal will be sampled using a PC through a data acquisition card. Data acquisition programs were develop for this laboratory using MatLab.

4 Procedure

1. Determine the sampling frequency and sampling time required to obtain accurate measurements from the pressure transducer. To do so, set the speed of the wind tunnel to the value provided by the lab instructor, then take some representative samples of the pressure transducer output. Using the provided MatLab routines, determine the frequency content and time constant of the signal. Set the sampling time to provide $\pm 1\%$ accuracy on the transducer

signal.

2. Assume that there is no technical information available for the pressure transducer. It must therefore be calibrated first. This can be done by developing a calibration curve of the pressure transducer output against readings from the Betz manometer for 10 different pressure difference. These can be generated by changing the wind tunnel speed.

3. Once the calibration of the pressure transducer is completed, set the wind tunnel speed to the value provided by the lab instructor. Record the actual speed from the Betz manometer reading of the pitot-static tube pressure difference. Note also the degree of fluctuations in the pressure if significant.

4. Manually change the angle of attack of the airfoil until the stall angle in the positive and negative values are found. Given these findings, decide which are the most appropriate angles of attack to investigate in order to properly define the airfoil properties up to and just past stall. A maximum of 15 angles is suggested given the time allocated for the lab.

5. Collect the pressure distribution using the inclined manometer and pressure transducer over the airfoil and from the wake rake for all the angles of attack that you have determined. If you deem necessary based on your best engineer judgement, translate the wake rake to acquire the wake profile with more precision.

5 Presentation of Results

In your lab report, present plots of typical pressure distribution around the airfoil for important cases, as well as velocity profiles of the wake downstream of the airfoil. Plot both sets of pressure measurements with their respective uncertainties. Discuss any difference between the different measurements and state which one you believe to be the most accurate and why. Also, discuss any features of interest in the pressure distribution and the implications versus the performance of the airfoil.

Use the trapezoidal rule to calculate the lift, moment (relative to the leading edge), pressure drag and total drag. Only use the pressure measurements that you judged to be most accurate. Plot C_L, C_D and C_M versus α, as well as C_D versus C_L. Compare to theoretical predictions and computations from XFOIL. Obtain some comparative data from other experiments using this airfoil.

Compare the value of the measure pressure drag and total drag at different flow regimes. Discuss why these two drag measure are different, and why the relative difference may change depending on the flow regime.

Tabulate the pressure measurements in the Appendix of your report. In the Appendix, also include any MatLab program code, appropriately annotated, that you have used to arrive at the end results shown in the report. Also include the details of your uncertainty analysis in the Appendix.

In your conclusion, include a “recommendation for future experiment” subsection of paragraph. This can discuss suggestion for improving this laboratory and/or suggestions for answering questions that have arisen during your analysis.

A Pressure Rake

The pressure rake is made of 17 total pressure tubes arranged as per Figure 1.

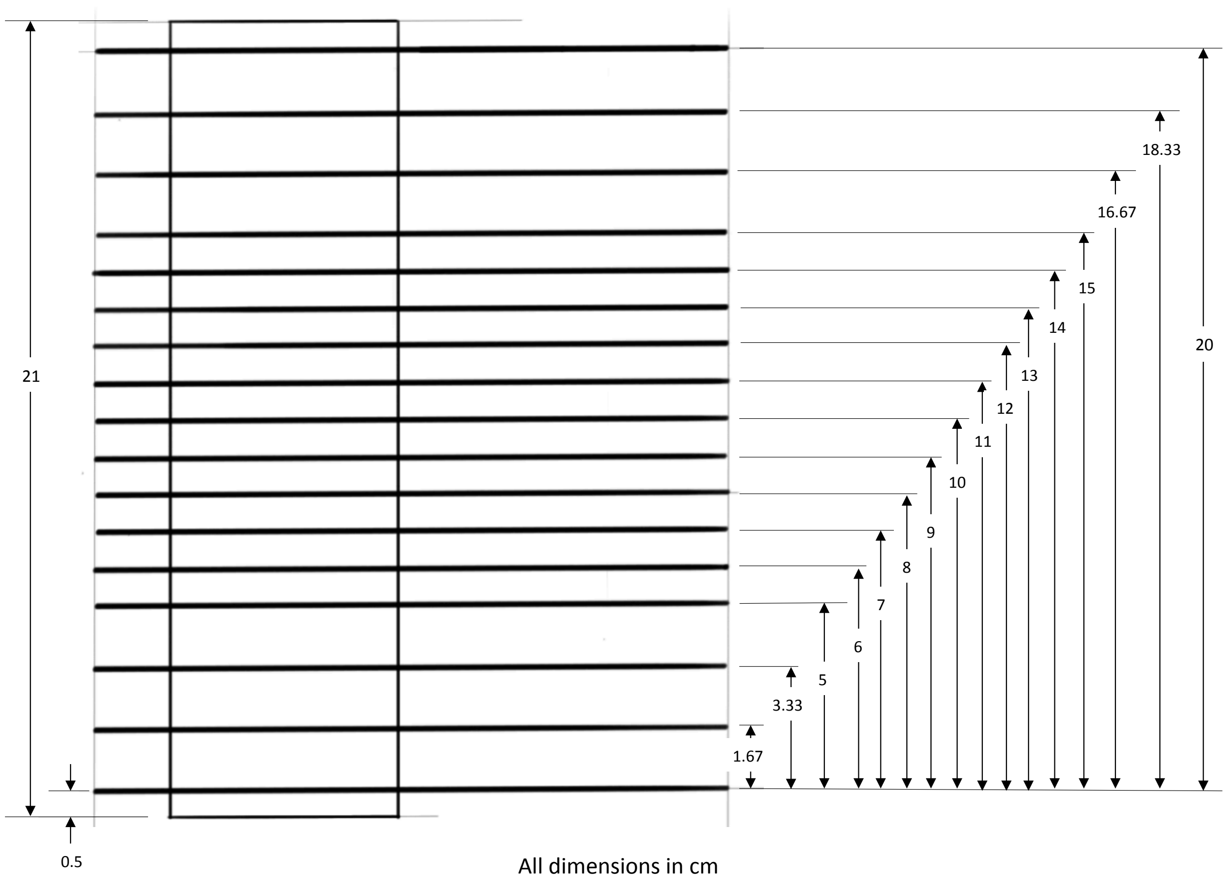

Figure 1: Total pressure tube rake for wake measurements.