Pressure Drag and Lift on an Airfoil Model

1. Introduction and Experimental Setup

When an airplane moves through the air, the air exerts a force on the plane. The total force on the plane can be broken into two components: the drag force (F_D) in the direction of the flow and the lift force (F_L) in the direction normal to the flow. Both of these forces change with the angle of attack as well as with the speed.

In this experiment, we will use a 12-in by 12-in wind tunnel in Thermal-Fluids Instructional Lab to examine the pressure drag and lift force on the NACA 4412 model airfoil. The dimensions of the wind tunnel test section are 12-in high, 12-in wide, and 24-in long. The air flow speed covers a range from 0 to 40 m/s. The airfoil is two-dimensional in shape and covers the entire width of the test section. The chord length of the airfoil is 10 cm and there are 14 pressure taps on the surface of the airfoil as shown in Fig. 1. The airfoil coordinates and tap locations are included in the Appendix.

All 14 pressure taps are connected to a 16-channel data acquisition logger (DSA), which reads all static pressures relative the atmosphere pressure (Channel #1). The tap # and its corresponding Channel # are shown in the Appendix. An extra pressure tap on the bottom wall of the wind tunnel just before the test section is connected to Channel #16 and used to estimate the incoming wind speed.
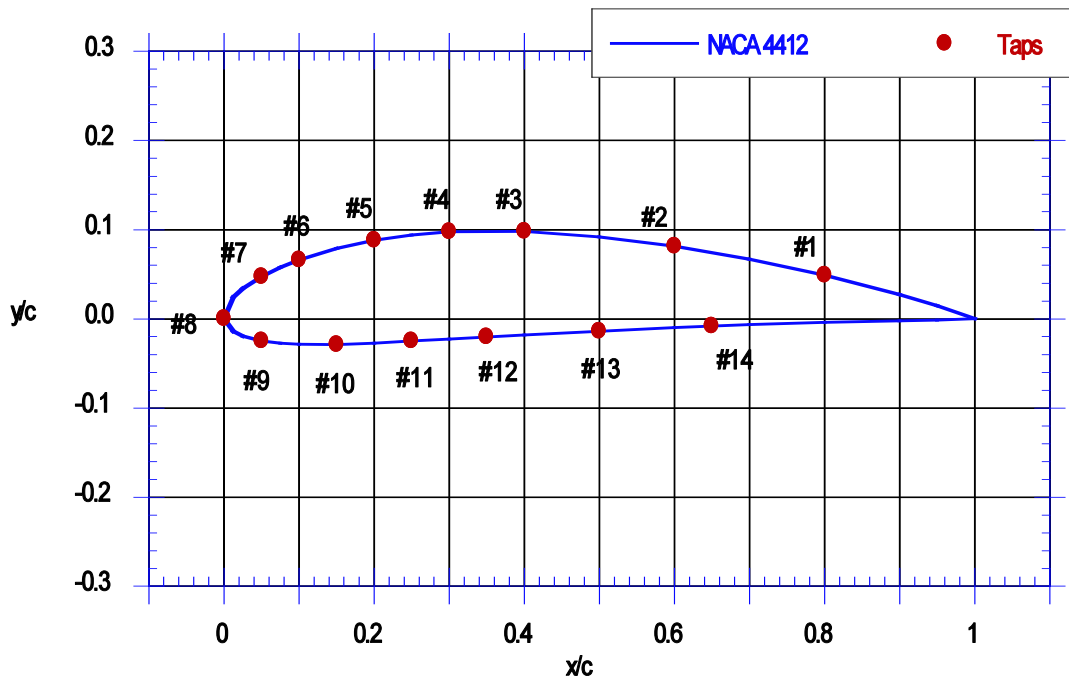

Fig.1 The schematic of a model airfoil with 14 pressure taps on the surface

2. Experimental Procedure

- Operate the wind tunnel at the specified setting for your group. More specifically, your group will be assigned one of the following frequency settings for controlling the wind tunnel fan speed: 30 Hz, 35 Hz, and 40 Hz.
- Set the airfoil at zero angle of attack and measure the pressure at Tap #8 (Channel #9), which corresponds to the stagnation point. Also, measure the static pressure from the extra pressure tap on the bottom wall of the test section (Channel #16). These readings will be used to determine the incoming air flow speed.

Figure 2. Angle-of-attack control for airfoil

- Set the airfoil at a desired angle of attack. Save the pressures from the 14 different Taps on the surface of the airfoil to the computer.
- Change the angle of attack of the airfoil, and repeat the previous step. Each group should make measurements at minimum ten different angles of attack ranging between -12° and 18°. Your measurements will be used to determine the angle of attack at which the airfoil stalls and to estimate the maximum lift coefficient for this model airfoil.
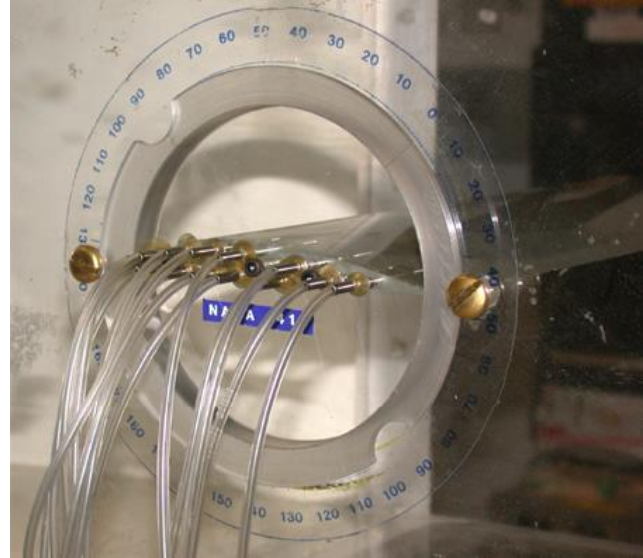
3. Report

Write a technical report. Your report should include the following items:

1. Calculations of the incoming wind velocity (U_∞) and the Reynolds number for the airfoil flow.
2. A table of the pressure coefficient, $C_p = 2(P-P_\infty)/\rho U_\infty^2$, over the airfoil on both upper and lower surfaces for each angle of attack. (One table with multiple columns of data.)
3. A plot of C_p on both upper and under surfaces versus non-dimensional distance, x/c, for each angle of attack. Your plot should also include a plot of the airfoil surface. See table below for surface coordinates (as well as tap locations).
4. An estimate of the pressure drag and lift force at each angle of attack.
5. One plot of drag coefficient, $C_D = 2F_D/\rho U_\infty^2$, versus C_L.
6. One plot of lift coefficient, $C_L = 2F_L/\rho U_\infty^2$, versus the angle of attack.
7. An estimate of the maximum value of C_L and the angle of attack at which the airfoil stalls.
8. Compare max CL and max angle of attack to published NACA data for this airfoil. Do you get good correlation? Explain any discrepancies.
9. Compare the lift curve slope with published NACA data. Do you get good correlation? Explain any discrepancies.
10. Compare your drag polar with published NACA data. Do you capture the same trends?

Are there any regions where they disagree? Explain any discrepancies.

4. Appendix

Table 2. NACA 4412 airfoil coordinates and
the corresponding Tap locations on the model airfoil

x/c	y/c	Tap #	DSA Channel #
1	0		1 (open to atmosphere)
0.95	0.0147		
0.90	0.0271		
0.80	0.0489	1	2
0.70	0.0669		
0.60	0.0814	2	3
0.50	0.0919		
0.40	0.0980	3	4
0.30	0.0976	4	5
0.25	0.0941		
0.20	0.0880	5	6
0.15	0.0789		
0.10	0.0659	6	7
0.075	0.0576		
0.05	0.0473	7	8
0.025	0.0339		
0.0125	0.0244		
0	0	8	9
0.0125	-0.0143		
0.025	-0.0195		
0.05	-0.0249	9	10
0.075	-0.0274		
0.10	-0.0286		
0.15	-0.0288	10	11
0.20	-0.0274		
0.25	-0.0250	11	12
0.30	-0.0226		
0.35	-0.0203	12	13
0.40	-0.0180		
0.50	-0.0140	13	14
0.60	-0.0100		
0.65	-0.00825	14	15
0.70	-0.0065		
0.80	-0.0039		
0.90	-0.0022		
0.95	-0.0016		
1	0		16 (Static pressure)