AerE 344: Undergraduate Aerodynamics and Propulsion Laboratory

Lab Instructions

Lab #06: **Airfoil Wake Measurements and Calibration of a Hot Wire Anemometer**

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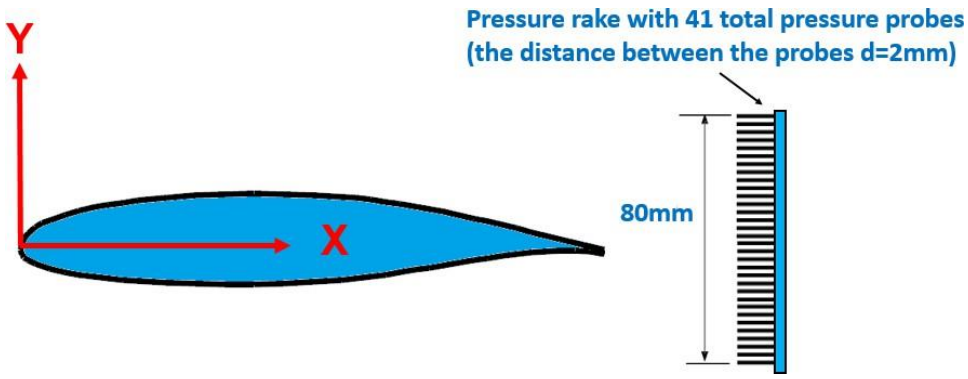
AerE344 Lab 06: Airfoil Wake Measurements and Calibration of a Hot Wire Anemometer

For this lab, you will measure the dynamic pressure in the wake behind the GA(W)1 airfoil you used last time. You will use the distribution of pressure behind the airfoil to estimate the drag and compare this drag with your measurements from the last lab. You will also calibrate a hot wire probe to be used in coming labs to measure turbulence characteristics.

Part 1: Airfoil Wake Measurements

What will be available to you in the lab?

- A thermometer and barometer for observing ambient lab conditions (for calculating atmospheric density).
- Three 16-channel Scanivalve DSA electronic pressure sensors for a total of 43 channels of pressure sensors.
- A rake downstream of the airfoil containing total pressure probes at a spacing of 2.0mm. All of the 41 tubes are connected to the DSA Scanivalve scanners.



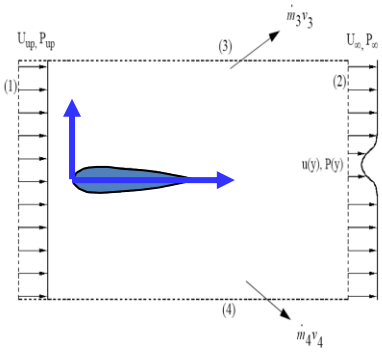
Steps:

- Choose a wind tunnel velocity at which to conduct your tests (incoming flow velocity =10~15m/s is recommended)
- Inspect the pressure difference between inlet and outlet of the contraction section of the wind tunnel for accurate measurement of dynamic pressure, so you can set the tunnel speed and normalize your pressure profiles.
- Conduct your wind tunnel experiments—acquire wake pressure distributions for the same angles of attack that you considered in the previous lab (i.e., AOA =, 0°, 4°, 6°, 8°, 10°, 12°). The idea here is that you will find the pressure across the wake to determine the drag of the airfoil.
- The rake can be moved up and down to cover the entire wake of the airfoil.
- During your tests, consider checking your profiles to see that you are sampling the entire wake.

Required Plots:

- C_p distribution in the wake (for each angle of attack)
- C_D vs angle of attack.

Determination of the drag coefficients of the airfoil model- based on the wake flow velocity measurements.



Forces on CV = Fluid momentum change

Forces on CV: $\sum F_X = -D + \int_{CS} (p\hat{n}dA)_X = -D + \int_1 p_{up} dA - \int_2 p(y) dA$

Since $p_{up} = p_\infty$, $p(y) \approx p_\infty$

$$\Rightarrow \sum F_X = -D$$

Momentum change: $\int_2 \rho U(y)\left(U(y) - U_\infty\right) dA_2 = \sum F_X = -D$

$$\Rightarrow D = \rho U^2{}_\infty \int_2 [\frac{U(y)}{U_\infty}(1 - \frac{U(y)}{U_\infty})] dA_2$$

$$C_D = \frac{D}{\frac{1}{2}\rho U_\infty{}^2 C} = \frac{\rho U^2{}_\infty \int_2 [\frac{U(y)}{U_\infty}(1 - \frac{U(y)}{U_\infty})] dA_2}{\frac{1}{2}\rho U_\infty{}^2 C}$$

$$\Rightarrow C_D = \frac{2}{C}\int_2 [\frac{U(y)}{U_\infty}(1 - \frac{U(y)}{U_\infty})] dy$$

Compare with the drag coefficients obtained based on airfoil surface pressure measurements at the same angles of attack!

Part 2: Hot Wire Anemometer Calibration

What you will have available to you in the lab:

- A thermometer and barometer for observing ambient lab conditions (for calculating atmospheric density).
- A computer with a data acquisition system capable of measuring the voltage from your pressure transducers.
- A Mensor manometer with a range of 10 inH2O.
- A pitot-tube used to measure the dynamics pressure.
- A hot wire anemometer
- A Dantec Mini-CTA constant temperature anemometer.

Steps:

- Choose a primary operator and have the TA record your choice.
- Orient the hot wire probe in an appropriate position for measuring the velocity of the flow coming out. Orient the Pitot-tube at the same position to measure the dynamic pressure.
- Measure the voltage from the hot wire anemometer for a range of flow velocities. You are trying to find a velocity versus voltage calibration curve for the hot wire anemometer.
- Measure the voltages over a range of velocities (i.e., dynamic pressures). The motor frequency ranges from 10 Hz to 40 Hz, with step = 2hz.
- Remember to move through the velocity range several times to determine precision uncertainty in your calibration.

Required Plots:

- Velocity versus voltage output of the hot wire anemometer (including a 4^{th} order polynomial fit)

Lab Exercise 06: Airfoil Wake Measurements and Calibration of a Hot Wire Anemometer

Writeup Guidelines

This lab writeup will be a typical formal lab report. You will need to make the required plots (as listed below) and provide discussions about the measurement results as a part of your lab report.

Required Plots:

- C_p distribution in the wake (for each angle of attack) for the airfoil wake measurements
- C_D vs. angle of attack (do your values look reasonable?) based on the airfoil wake measurements
- Your hot wire anemometer calibration curve: Velocity versus voltage output of hot wire anemometer (including a 4^{th} order polynomial fit)

Please briefly describe the following details:

- How you calculated your drag—you should show your drag calculations,
- How these drag calculations compared with the drag calculations you made in the previous experiment.
- Reynolds number of tests and the incoming flow velocity