

AerE 344: Undergraduate Aerodynamics and Propulsion Laboratory

Lab Instructions

Lab #04: Pressure Coefficient Distribution on the Surface of a Circular Cylinder

Purpose:

- To get “hands-on” experiences on how to make pressure measurements using Electronic Pressure Scanners.
- To learn how to determine the drag coefficient from the surface pressure measurements.
- To learn how to do raw data acquisition, experimental data reduction and processing, and final result analysis and discussion of an experimental study.
- To analyze the results and suggest possible reasons to explain the inconsistencies between theoretic predictions and the measurement results.

Instructor:

Dr. Hui Hu
Department of Aerospace Engineering
Iowa State University
Office: Room 2251, Howe Hall
Tel:515-294-0094
Email:huhui@iastate.edu

AerE344 Lab #04 Pressure Coefficient Distribution on the Surface of a Circular Cylinder

About the Pressure Measurement with Electronic Pressure Scanners

Always remember that pressure sensors most often measure *differences* in pressure.

The pressure sensor we will be using for this lab measures the difference in pressure between an input port and a reference port. We use the Scanivalve DSA 3217 shown below:



Tubes are connected from pressure taps in the walls of the wind tunnel to the ports on the DSA. One of the ports on the DSA is labeled “Reference.” The pressures that you will read in your data files will be pressure differentials as follows:

$$P_1 - P_{ref}$$

where P_1 and P_{ref} are the pressure at port #1 and the pressure at the reference port, respectively. Sometimes the reference port is left open to the atmosphere. Sometimes the reference port is connected to the static pressure in the wind tunnel. It is very important to know what reference pressure is used for a given test.

Data files:

The data files you will obtain by using the DSA are arranged in columns. The first column show the sample numbers. The next 20 columns are the pressures measured from each pressure port at many different instants in time. You will use the average pressure at each pressure port. This means you must find the average value for each column.

How to calculate the aerodynamic drag force acting on a circular cylinder based on the surface pressure measurements.

For an inviscid incompressible flow, the aerodynamic drag force acting on a circular cylinder can be determined by taking integration of the pressure distribution around the circular cylinder.

$$D = \int_{-\pi}^{\pi} P \cos \theta R d\theta$$

Since

$$C_p = \frac{P - P_{\infty}}{\frac{1}{2} \rho V_{\infty}^2}$$

Drag coefficient can be obtained by using the following equation:

$$C_D = \frac{D}{\frac{1}{2} \rho V_{\infty}^2 2R}$$

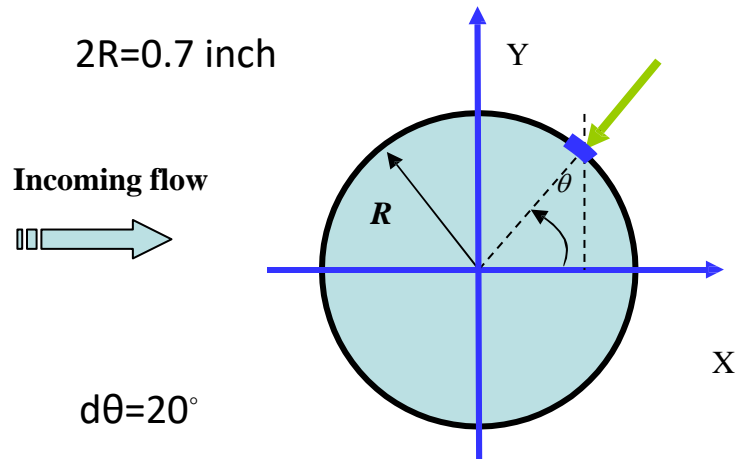
$$= \frac{1}{2} \int_{-\pi}^{\pi} C_p \cos \theta d\theta$$

$$= -\frac{\Delta\theta}{2} [f_1 + f_2 + f_3 + \dots + f_N]$$

Where $f_i = C_{pi} \cos \theta$

$$C_{pi} = \frac{(P_i - P_{\infty})}{\frac{1}{2} \rho V_{\infty}^2} = \frac{(P_i - P_E)}{K(P_A - P_E)}$$

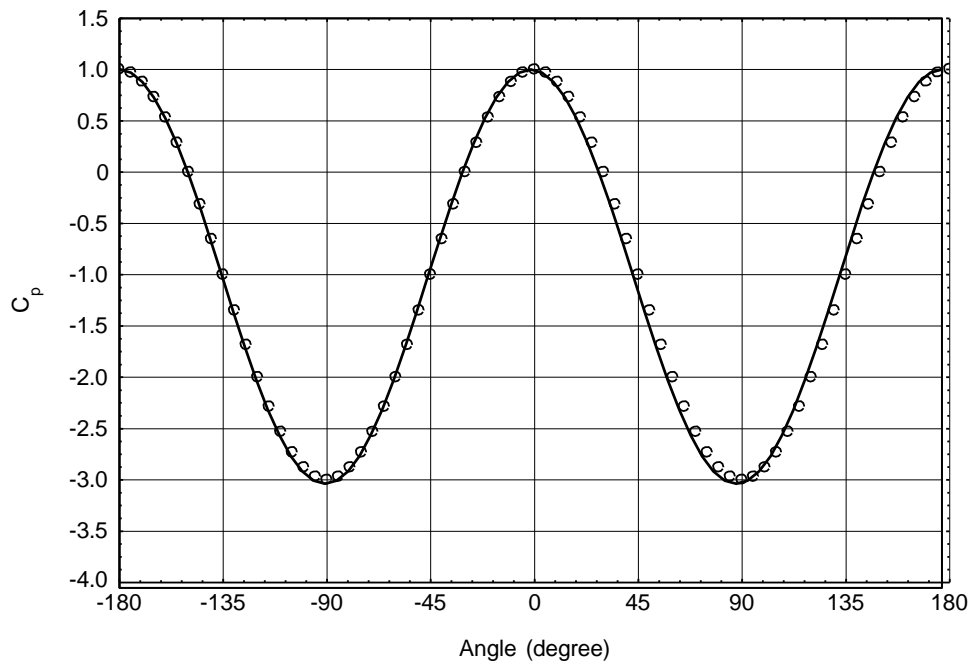
K is the calibration constant you obtained from Lab #2. [Use $K = 1.1$ in your calculation]



Theoretic prediction of the pressure coefficient distribution on the surface of a circular cylinder

According to potential flow theory, the pressure coefficient distribution on the surface of a circular cylinder can be expressed as:

$$C_p = \frac{(P - P_\infty)}{\frac{1}{2} \rho V_\infty^2} = 1 - 4 \sin^2 \theta$$



The Test Condition for the Experiments

Each group needs to do the experiments with the motor running at following 6 speed levels:

1. $f = 5\text{Hz}$
2. $f = 10\text{Hz}$
3. $f = 15\text{Hz}$
4. $f = 20\text{Hz}$
5. $f = 25\text{Hz}$
6. $f = 30\text{Hz}$
7. $f = 35\text{Hz}$

The Experimental Data You Need for This Lab Experiments

Atmosphere pressure in the lab, $P_{atm} = ?$

The temperature in the wind tunnel, $T = ?$

The density of air in the wind tunnel, $\rho = ?$

The pressure at the entrance of the contraction section $P_A = ?$

The pressure at the inlet of the test section $P_E = ?$

The velocity of the incoming flow, $V_\infty = ?$

The Reynolds number of the incoming flow $Re = \frac{\rho V_\infty D}{\mu} = ?$

The surface pressure data from the pressure taps around the circular cylinder.

$P_1 = ?$

.

.

.

$P_N = ?$

Requirements for the Lab Report

You are required to prepare a formal lab report with following results included:

- a. To make a table showing all the time-averaged data you obtained for all the cases you tested.
- b. To show all the calculation steps leading up to the final answer.
- c. To plot pressure coefficient C_p distribution on the cylinder for all the cases you tested.
- d. To make comments on the characteristics of the pressure distribution compared with the theoretic predictions.
- e. To calculate the drag coefficients C_D of the circular cylinder for all the cases you tested.
- f. To plot the drag coefficients C_D of the circular cylinder as a function of the Reynolds numbers.