Experiment No. 8: Measurement of Pressure Distribution over a Circular Cylinder in the Wind Tunnel

1. Objective:

i. Measure and Plot the C_p distribution over the cylinder and compare with theoretical Values.
ii. Calculate C_d distribution over the cylinder.
iii. Plot the variation in C_d Vs R_e

2. Apparatus:

i. **Low speed wind tunnel:** The open-circuit low turbulence wind tunnel consists of an axial fan driven by a 2HP AC electric motor. The fan acts as a suction device. The honeycomb structure after contraction chamber makes the flow in test section quiescent with a turbulence intensity as low as 0.1%.

The specifications of the low speed wind tunnel are

S. No.	**Property**	**Measurement**
1	Type	Open – Return Suction Type
2	No. Of Screenings in the settling chamber	6
3	Contraction ratio	16:1
4	Test section	dimensions 0.6 m X 0.6 m X 3 m 5
5	Velocity	Max. ~ 25 m/s
6	Motor	20 Hp AC

Figure 1: Wind tunnel

ii. **Model:** The model is circular cylinder mounted vertically in the test section. It has 24 ports at equal angles along the circumference.

iii. **Electronically Scanned Pressure sensor:** 32-HD ESP scanners are differential pressure measurement units housing an array of 32 piezo-resistive sensors, one for each pressure port consisting of a Wheatstone bridge diffused onto a single silicon crystal. These scanners have two-position manifold, one is run-mode and other one is cal-mode. The manifold position can be changed by applying a momentary pulse of control pressure. Run-mode is used to acquire a pressure data and cal-mode is used for calibration of pressure ports. In cal-mode position, all sensors are connected to a common calibration pressure port. The accuracy of the scanners is maintained within ±0.05% of full scale pressure range through their periodic calibration. The frequency of calibration is dependent on ambient conditions and it changes with time. Calibration performed immediately before a set of data is acquired assures the highest accuracy of the scanners. The voltage output from the pressure sensors is connected to multiplexers which can acquire data at rate up to 20,000 Hz.

iv. **Multiplexer Unit:** Each sensor output is selectively routed to the onboard instrumentation amplifier by applying its unique binary address to the multiplexers. The multiplexed and amplified analog outputs of the scanners are capable of driving long lengths (up to 30fts) of cable to the remote A/D converter of DAQ board. Scanners require 12V DC power supply for the operation of built-in analog/digital devices and a +5V DC power supply as the excitation voltage source for the sensors

v. **Digital Interface and Line Driver (DILD) unit for ESP Scanners:** The DAQ board provides 5-volts (TTL) logic level signals through its digital I/O lines, whereas the pressure scanners require 12-Volt (CMOS) logic level signals for binary addressing. Thus, there is a logic (TTL-CMOS) level mismatch between DAQ board and scanners. The logic level shifters of the DILD unit compensates for this logic level mismatch. The DILD unit also provides digital fan-out to drive up to 8 pressure scanners, and long cable (30 ft) drive capability. The regulated DC power (12V and 5V) required for the operation of pressure scanners are also supplied by this unit.

vi. **Data Acquisition Board:** A 14-bit high speed data acquisition board from National Instruments is used for the pressure measurement, which acts as an interface between sensors and computer. The data acquired is digitized and transferred to computer by the DAQ board.

vii. **Pressure Data Acquisition and Analysis Software:** Data acquisition and controlling is done by the Lab VIEW 12.0 application software. In-house developed pressure data acquisition and analysis software is capable of acquiring the data at desired data acquisition parameters, analysis, and presenting in the engineering units.

viii. **Pitot Static tube:** The Pitot static tube is used to measure the fluid velocity.

3. Procedure:

a) Measure the cylinder diameter and note down the ambient temperature and pressure which will be used for calculating Reynolds number.
b) Mount the pitot static in the test section to measure the flow velocity.
c) Connect the pitot static tube and static measurement port of the cylinder to the digital manometer.
d) Run the data acquisition VI and take the no wind readings.
e) Increase the speed to the desired value, and after the flow stabilizes, save the wind data.
f) Repeat the same for another set of speed.
g) Run the data analysis VI to write the data to a spreadsheet file.

4. Calculations:

The flow pattern and the drag on a cylinder are functions of the Reynolds number $R_{eD} = \frac{UD}{\nu}$, based on the cylinder diameter D and the undisturbed free-stream velocity U.

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

$$C_d = -\frac{1}{2}\int_0^{2\pi} C_p \cos\theta \, d\theta$$

Sample Graphs

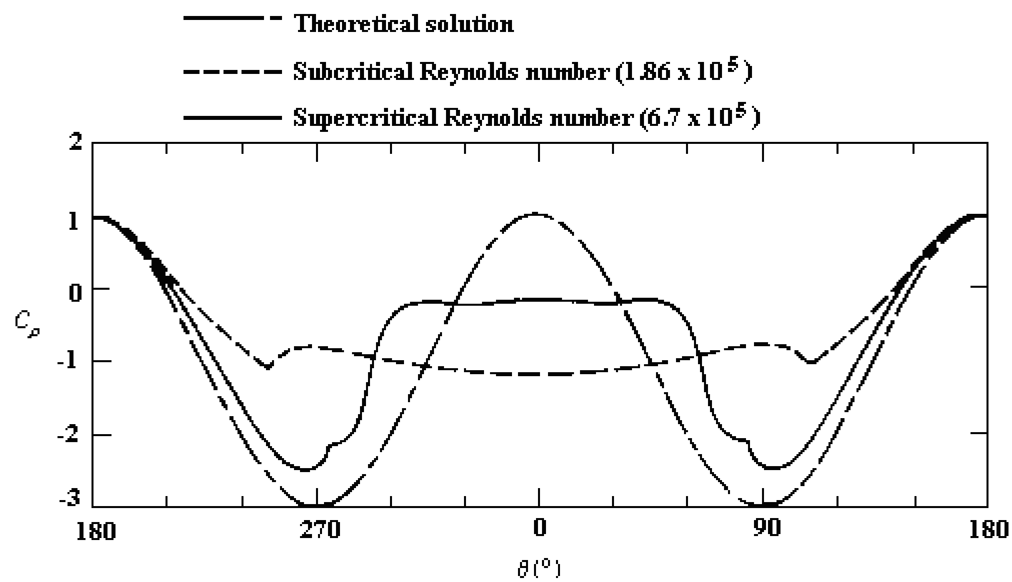

Figure 2. Measured Pressure distribution on circular cylinder compared with theoretical distribution

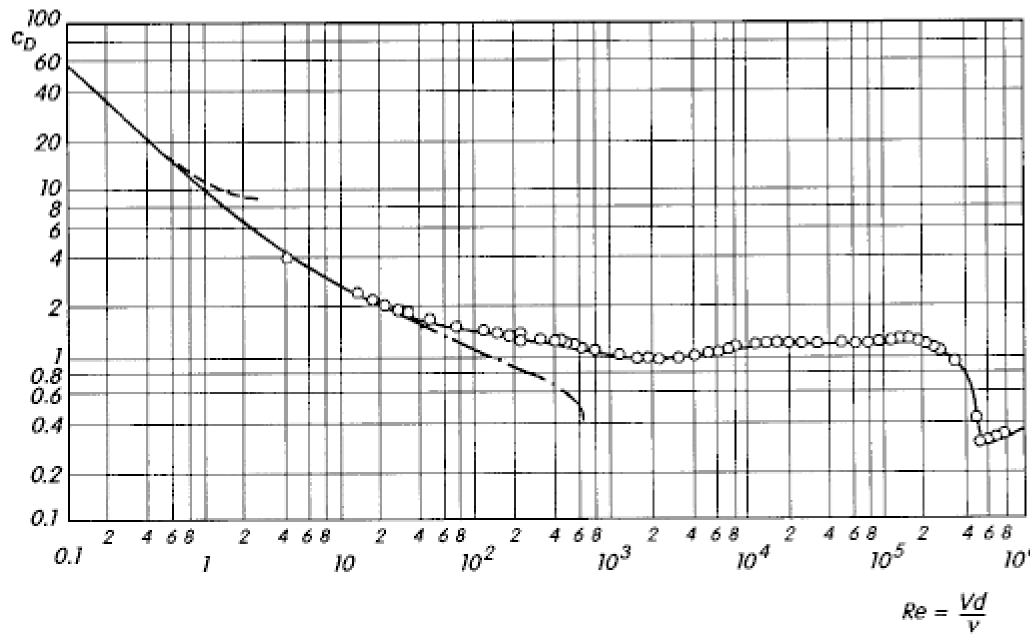

Figure 3. Drag coefficient on a circular cylinder as a function of Reynolds Number

5. Error Analysis

The error in measurement can be classified as:-

a) Systematic Error: These arise due to improper calibration of instruments or some other unknown reasons. They can be eliminated by proper calibration of instruments or rectifying the fault. This defines the accuracy of the measurement made. The lesser the bias, the higher the accuracy. These are biased in nature.

b) Random Error: These occur due to the natural disturbances that occur during the measurement process. These cannot be eliminated. This defines the precision of the measurement made. These are statistical in nature.

6. Results

a) Calculate and plot the coefficient of pressure over the cylinder using the measured calibration coefficients (From Experiment No.6), port map and wind data at different wind velocities. Plot the graph Cp vs location for at least 3 data cases as given in **respective BATCH of "DATA for Students.xls".**

b) Calculate the coefficient of drag and the Reynolds numbers at which experiment is conducted. Plot the Graph Cd Vs Re.

c) Compare the Cd Vs Re of the present experiment with that of smooth cylinder from literature.

d) Comment on the nature of the results and explain inconsistencies, if any.

e) Calculate the percentage error in the measurements. (based on experiment No.6)

7. References:

1. Schlichting, ``Boundary Layer Theory," McGraw Hill Book Co., New York, 1960.

2. Morkovin, ``Flow Around Circular Cylinder - A Kaleidoscope of Challenging Fluid Phenomena," Symposium on fully separated flows, ASME, 1964.