Separation of flow around a bluff body

1 Introduction

This laboratory takes place in the Handley-Page wind tunnel at the Acre Road facility. This is a closed-return wind tunnel, with a 7 feet wide × 5 feet high working section and is capable of a maximum speed of some 50ms^{-1}. A circular cylinder model of diameter $D = 0.16$m is placed in the wind tunnel with its axis vertical, and this represents the bluff body. A series of pressure tappings are set at regular intervals around the model circumference at the mid-span. These are numbered, and make sure you know where they are relative to the 'leading edge' of the model. Each tapping is connected to a pressure transducer by a scanivalve, and a data acquisition system records the pressure transducer voltages. The wind tunnel speed U is determined from the dynamic pressure taken from a pitot-static probe upstream of the model in the working section.

The pressure coefficient C_p is given by

$$C_p = \frac{p - p_\infty}{\frac{1}{2}\rho U^2} \tag{1}$$

where p is the local pressure and p_∞ is the ambient pressure. Therefore correct measurement and analysis of the pressure readings from the model will allow you to calculate C_p for each pressure tapping position.

A traverse system is placed some distance behind the cylinder model. This moves a pitot-static across the wake of the cylinder so that the wake velocity $u(y)$ can be determined as a function of lateral distance y.

2 Conducting the laboratory

The purpose of the laboratory is to study separated flow behaviour around the circular cylinder. At low Reynolds number Re (based on wind tunnel speed and model diameter D) the separation is laminar, but at high enough Re the separated shear layer reattaches to form a turbulent boundary layer, with consequent turbulent separation. You will need to do some prior research work to find out the Reynolds number ranges. You will run the tunnel at a range of flow speeds to measure how the pressure distribution changes; what are the required tunnel speeds?

- You will need to take careful notes during the laboratory.
- Make sure you know the diameter of the model. How are the pressure tappings arranged around the model (the wind tunnel flow direction is from right to left)? How many of them are there, what is their angular separation?
- You will need to calculate the Reynolds number for the experiment. For this you require the wind tunnel speed, air density and air viscosity. A mercury barometer and thermometer are in the lab, so you can get the air density. For the air speed you use the digital manometer in the lab. Take care what units the manometer displays.
- What is the downstream distance of the wake probe from the model?
- Run the wind tunnel at a range of speeds that you specify. You need at least two runs as follows: one for laminar separation, and a higher speed where you think you should get reattachment and turbulent separation.
- Run the traverse across the wake for both speeds.
- The data acquisition system will supply you with raw voltage data from the pressure transducer, and traverse position with respect to some origin. Make sure you understand how the data are organised.

3 Data analysis

- Once you have your wind tunnel data you should find C_p for each pressure tapping location.
- Plot the pressure distribution over each hemisphere (plot $-C_p$ as a function of the angle θ of the pressure tapping position around the model circumference). It is standard practice to plot $-C_p$; why?
- Identify the locations of the separation points for each side of the cylinder.
- Calculate drag and lift coefficients for each hemisphere (use the notes provided).
- Compare the results for the Re values you tested for; what are the changes?
- Calculate drag coefficient from the wake traverse data; how does this compare to the drag from the pressure data?
- Expand on the above results for your lab report. What do they mean?