OBJECTIVES

To investigate the characteristics of the velocity distribution in a boundary layer on smooth and rough surfaces of plates.

LEARNING OUTCOMES

At the end of this lab session, students should be able to:

1. Determine pressure distribution for smooth and rough flat surfaces correctly for a plate length of 256mm.
2. Determine the velocity distribution for smooth and rough plate surfaces correctly for a plate length of 256mm.
3. Plot graph of distance against velocity profile over a smooth and rough surfaces.
4. Discuss the different between boundary layer phenomena over different surface conditions.
5. Write a clear and well-presented laboratory report that describes the nature of boundary layer experiments and its consequent results.

THEORY

Consider steady flow over a flat smooth plate as shown in Figure 1, where the streaming velocity, u is constant over the length of the plate. It is found that the thickness of the boundary layer grows along the length of the plate as indicated in the diagram. The motion in the boundary layer is laminar at the beginning, but if the plate is sufficiently long, a transition to turbulence is observed. The parameter which characterizes the position of the transition is the Reynolds number, Re_x based on distance x from the leading edge:

$$Re_x = U_x/v \qquad (1)$$

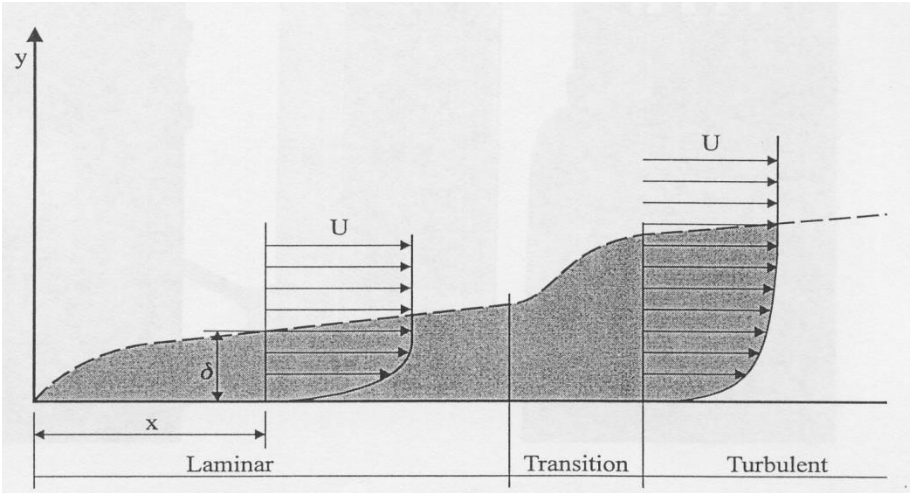

Figure 1 General Characteristics of the Boundary Layer over a Flate Plate

A little consideration will show that the boundary layer thickness δ*, shown in Figure 1 as the thickness where the velocity reaches the free stream value. Where,

$$\delta^* = \int_0^\infty \left(1 - \frac{u}{U}\right) dy \qquad (2)$$

To define the momentum thickness, θ of the boundary layer we use

$$\theta = \int_0^\infty \frac{u}{U}\left(1 - \frac{u}{U}\right) dy \qquad (3)$$

Integration or area under the curve can be evaluated in various ways such as by using Simpson's or the trapezium rule etc. (Hint: Refer to your Numerical Method notes on how to calculate area under a curve).

The ratio of displacement thickness δ* to momentum thickness θ is called shape factor H

$$H = \frac{\delta^*}{\theta} \qquad (4)$$

Theoretically, for a turbulent boundary layer along a smooth flat plate

$$\tfrac{1}{2}\rho U^2 = P \qquad (5)$$

$$Re_x = \frac{UL}{\nu} \qquad (6)$$

$$\delta^* = \frac{0.046x}{Re_x^{\,0.2}} \qquad (7)$$

$$\theta = \frac{0.036x}{Re_x^{\,0.2}} \qquad (8)$$

Common properties:

1. Air density, $\rho = \dfrac{P}{RT}$ (9)

   where P = atmospheric pressure, R = gas constant , T = air temperature [K]

2. Coefficient of kinematic viscosity, $\nu = \dfrac{\mu}{\rho}$ (10)

   where μ = coefficient of viscosity, ρ = air density.

3. Pressure in the manometer, $P_m = \rho_w g h$ (11)

   where ρ = density of water, g = gravity, h = different in height.

APPARATUS

1. The AF10 Airflow Bench
2. The AF14 Boundary Layer Apparatus

PROCEDURES

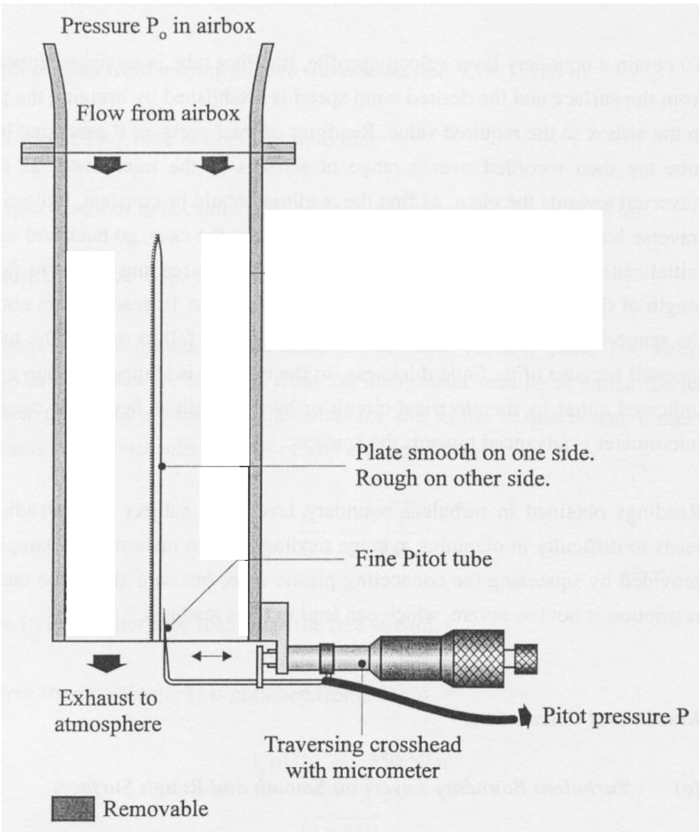

Figure 2 Test Section Arrangement

**Note: Length of plate, L = 0.265m and thickness of Pitot tube, = 0.40 mm.