B.Eng. in Mechanical Engineering

Fluid Mechanics

(PHYS M7Z02)

Laboratory: Venturi Flowmeter

To Find the Coefficient of Discharge for a Venturi Flowmeter

Objective

To show by experiment the validity of the *continuity equation* and the *Bernoulli Equation* as it applies to the measurement of liquid flow in a horizontal pipe.

Theory

A venturi meter is a device that can be used to measure the average velocity of an incompressible fluid through a pipe, see Figure 1. The device consists of a pipe reducer followed by a throat of diameter, d_2 and then a gradual transition segment back to the original pipe size.

$D_A = 26$

D_B

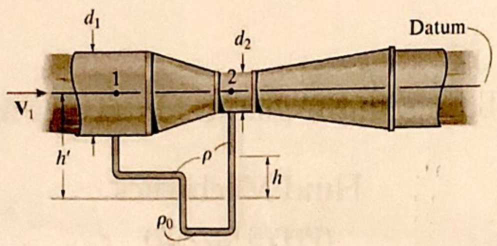

Figure 1: Venturi Meter.

Applying the Bernoulli equation along the centre streamline between point 1 in the pipe and point 2 in the throat, gives

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2$$

$$\frac{p_1}{\rho} + \frac{V_1^2}{2} = \frac{p_2}{\rho} + \frac{V_2^2}{2}$$

The continuity equation can be applied at points 1 and 2, giving

$$A_1 V_1 = A_2 V_2$$

Rearranging for V_1

$$V_1 = \frac{A_2}{A_1} V_2$$

or

$$V_1 = \frac{\pi d_2^2/4}{\pi d_1^2/4} V_2 = \frac{d_2^2}{d_1^2} V_2$$

Now substituting the new expression for V_2 into the Bernoulli equation

$$\frac{p_1}{\rho} + \frac{\left(\frac{d_2^2}{d_1^2} V_2\right)^2}{2} = \frac{p_2}{\rho} + \frac{V_2^2}{2}$$

After some mathematical manipulation

$$V_2 = \sqrt{\frac{2(p_1 - p_2)}{\rho\left[1 - \left(\frac{d_2^2}{d_1^2}\right)^2\right]}}$$

Thus, the theoretical flowrate, $\dot{V}_{th}$, can be written as

$$\dot{V}_{th} = A_2 V_2 = A_2 \sqrt{\frac{2g(H_1 - H_2)}{\left[1 - \left(\frac{d_2^2}{d_1^2}\right)^2\right]}}$$

The pressure drop is often measured using a pressure transducer or a manometer. For example, a manometer is used in Figure 1. The ratio of actual flowrate, $\dot{V}_{act}$, and theoretical flowrate, $\dot{V}_{th}$, is called the coefficient of discharge, C_{dis}. Thus

$$C_{dis} = \frac{\dot{V}_{act}}{\dot{V}_{th}}$$

Methodology

General Description

Below is a general description of the laboratory methodology:

- Water is pumped through the Venturi meter and the valves are adjusted so that the water levels in each of the two tappings lie between the zero and maximum mark on the vertically graduated scales of a water column manifold unit.
- The water column height readings corresponding to the full bore diameter and the throat section are recorded for different flowrates.
- The actual water flowrate is found by using the weighted counterbalance unit.
  - This is done by firstly adding weights to the hanger of the beam unit so that it is in balance, thereby offsetting the weight of the fibreglass measuring bucket.
  - Then a further suitable mass is added to the hanger, e.g. – $10kg$.
  - This means that the balance will tip when the bucket has collected $10kg$ of water from the discharge pipe, and the time taken for this to happen can be measured with a stopwatch.
  - This can be done several times to obtain an average reading of the time taken.
  - The fibreglass bucket is emptied at the end of each timing via a drain plug in its base, and this plug is raised or lowered by rotation of a wheel at the side of the bench.

Repeat the experiment and take note of all required readings for up to six different flowrate settings.

Readings

Table 1: Readings

Settings	H_1 (mm)	H_2 (mm)	Time (for $10kg$)	Diameter 1 (mm)	Diameter 2 (mm)
1	240	36	22.7	26	16
2	225	27	23.32	26	16
3	235	30	23.102	26	16
4	250	19	24.083	26	16
5	240	34	20.413	28	16
6	235	19	22.27		16

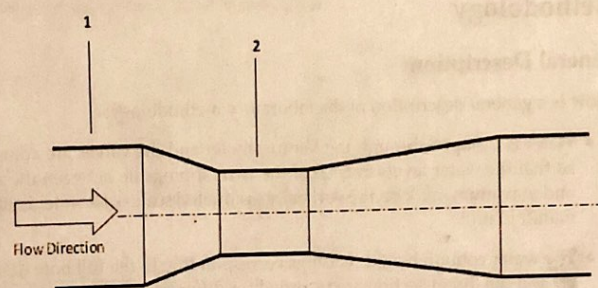

Figure 2: Laboratory schematic

Laboratory Output

In Your Report

- Present all readings and calculated results in table format. Use MatLab or Excel for calculation of results and for plotting of any graphs.
- Plot a graph of *theoretical flowrate* against *actual flowrate* measured and thus find the best estimate value for the Coefficient of Discharge for the flowmeter.
- Should the trendline go through the origin?

Analysis of Results

1. How precise is the experiment? Support your answer by referring to the graph you used to find the best estimate of the Coefficient of Discharge.
2. Compare your estimate of C_D against typical field values for Venturi meters.
3. Explain the Venturi effect. Apart from flow metering, give one other practical application of this effect.
4. If the theoretical flowrate for the venturi flowmeter is calculated to be 1.5 litres per second (according to the pressure difference measured) find the actual flowrate?
5. Show any calculation required.