Measurement of Pressure, Velocity and Volume Flow Rate by using Pressure Transmitter and Inclined Manometer

Inclined Manometer

For accurate measurement of small pressure differences by an ordinary u-tube manometer, it is essential that the ratio r_m/r_w should be close to unity. This is not possible if the working fluid is a gas; also having a manometric liquid of density very close to that of the working liquid and giving at the same time a well defined meniscus at the interface is not always possible. For this purpose, an inclined tube manometer is used.

If the transparent tube of a manometer, instead of being vertical, is set at an angle θ to the horizontal (Figure 1), then a pressure difference corresponding to a vertical difference of levels x gives a movement of the meniscus s = x/sinq along the slope.

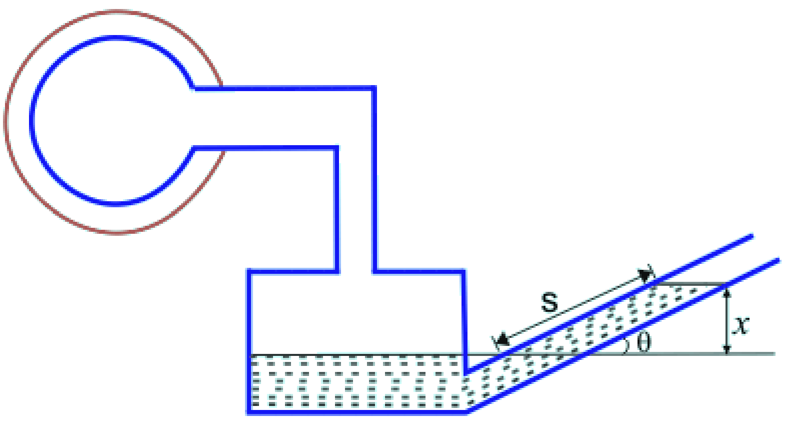

Figure 1. An inclined tube manometer

If θ is small, a considerable mangnification of the movement of the meniscus may be achieved. Angles less than 5^0 are not usually satisfactory, because it becomes difficult to determine the exact position of the meniscus. One limb is usually made very much greater in cross-section than the other. When a pressure difference is applied across the manometer, the movement of the liquid surface in the wider limb is practically negligible compared to that occurring in the narrower limb. If the level of the surface in the wider limb is assumed constant, the displacement of the meniscus in the narrower limb needs only to be measured, and therefore only this limb is required to be transparent.

Pressure Transducer:

The operation of this device is based on the principle of elastic deformation of a sensitive element. The commonly used transducer is the strain-gage base transducer. It converts pressure into an analog electrical signal by the physical deformation of strain gages. Pressure applied to the transducer produces a deflection of the diaphragm which introduces strain to the gages. The strain will produce an electrical resistance changes proportionally to the pressure.

Pitot tube:

A right angled glass tube, large enough for capillary effects to be negligible, is used for the purpose. One end of the tube faces the flow while the other end is open to the atmosphere as shown in Figure 1..

The liquid flows up the tube and when equilibrium is attained, the liquid reaches a height above the free surface of the water stream.

Since the static pressure, under this situation, is equal to the hydrostatic pressure due to its depth below the free surface, the difference in level between the liquid in the glass tube and the free surface becomes the measure of dynamic pressure.

Such a tube is known as a Pitot tube and provides one of the most accurate means of measuring the fluid velocity.

$$P_{dyn} = P_{stagnation} - P_{static} = \rho g h = \frac{\rho V^2}{2}$$

$$V = \sqrt{2gh}$$

For an open stream of liquid with a free surface, this single tube is sufficient to determine the velocity. But for a fluid flowing through a closed duct, the Pitot tube measures only the stagnation pressure and so the static pressure must be measured separately.

Measurement of static pressure in this case is made at the boundary of the wall (Figure 2). The axis of the tube measuring the static pressure must be perpendicular to the boundary and free from burrs, so that the boundary is smooth and hence the streamlines adjacent to it are not curved. This is done to sense the static pressure only without any part of the dynamic pressure.

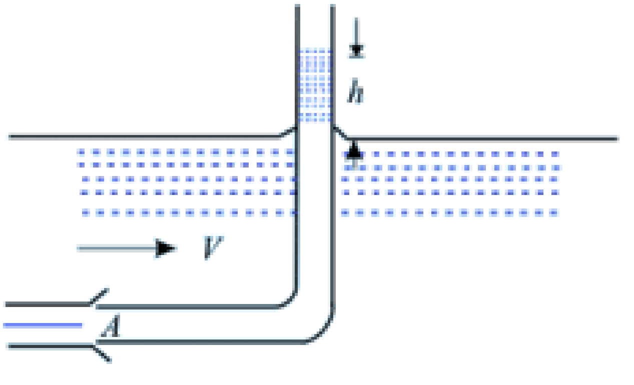

Figure 1. Tube for measuring the Stagnation Pressure

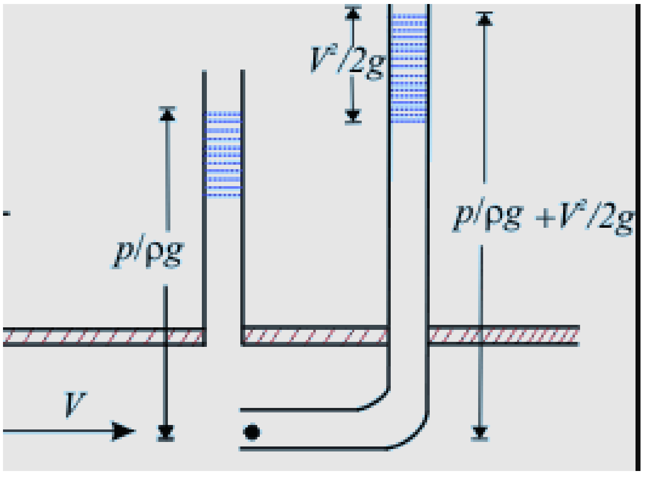

Figure 2. Static and Stagnation tubes together

A Pitot tube is also inserted as shown (Fig. 2) to sense the stagnation pressure. The ends of the Pitot tube, measuring the stagnation pressure, and the piezometric tube, measuring the static pressure, may be connected to a suitable differential manometer for the determination of flow velocity and hence the flow rate.

Objective of Experiment

The object of this experiment is to measure pressure by using inclined manometer and pressure transmitter. Also velocity and volume flow rate will be calculated by using measurement data.

Apparatus

Centrifugal fan controlled by frequency inverter

3" pipeline

Pitot tube

Inclined Manometer filled with alcohol

Pressure transducer

Data acquisition card

Computer

Labview Software

Procedure

Start the fan by adjusting the frequency converter to desired flow rate.

Connect one of the hose of inclined manometer to the Pitot tube to measure the total pressure, and connect the other hose of inclined manometer to the static pressure tap. Then record the total and static pressure.

Connect the pressure transmitters to the Pitot tube and static pressure tap to measure the total and static pressure respectively. Record the voltages via data acquisition card, The files which includes the data will be given to you..

Calculation

1-Calculate the dynamic pressure, mean velocity, volume flow rate and mass flow rate by using the inclined manometer.

2-Convert the voltage values to the pressure. Then find the arithmetic mean value of static and dynamic pressure.

3-Calculate the dynamic pressure, mean velocity, volume flow rate and mass flow rate by using the pressure transmitter,

4-Calculate the uncertainty of the pressure measurement for each instrument by using the equation below. Take the uncertainty of pressure, density and cross sectional area as %1, %0.5, %3. Find the % error of transmitter. Use the inclined manometer as calibration device.

$$\frac{w_Q}{Q_Q} = \left[\left(\frac{1}{2}\right)^2\left(\frac{w_{\Delta P}}{\Delta P}\right)^2 + \left(\frac{1}{2}\right)^2\left(\frac{w_\rho}{\rho}\right)^2 + (1)^2\left(\frac{w_A}{A}\right)^2\right]^{1/2}$$

5-Fill the table below.

Frequency ..Hz	Inclined Manometer	Inclined Manometer	Inclined Manometer	Inclined Manometer
	$H_{dynamic}$(m)	$P_{dynamic}$(Pa)	U (m/s)	Q(m3/s)

Frequency ..Hz	Transmitter		Transmitter		Transmitter	Transmitter
	V_{static}(Volt)	V_{total} (Volt)	P_{static}(Pa)	$P_{dynamic}$(Pa)	U (m/s)	Q(m3/s)

References:

http:((www-nptel.ac.iMcourses/112104118/lecture-16/16-3 pitot tube.htm

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