PRACTICAL APPLICATIONS OF BERNOULLI'S EQUATION

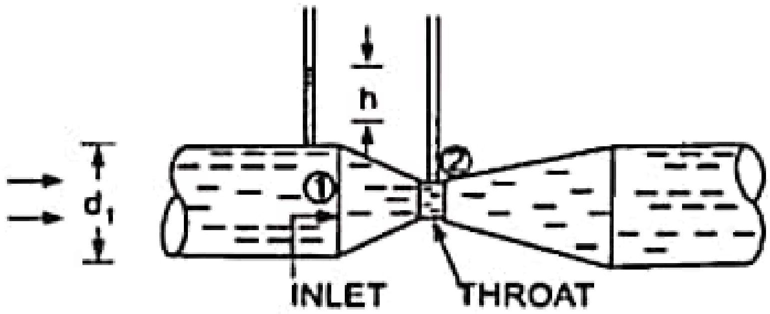
Bernoulli's equation is applied in all problems of incompressible fluid flow where energy considerations are involved. But we shall consider its application to the following measuring devices:

- Venturimeter
- Orifice meter
- Pitot-tube

VENTURIMETER:

A venturimeter is a device used for measuring the rate of a flow of a fluid flowing through a pipe. It consists of three parts:

(i) A short converging part, (ii) Throat, and (iii) Diverging part. It is based on the Principle of Bernoulli's equation



Venturimeter

Expression for rate of flow through venturimeter

Consider a venturimeter fitted in a horizontal pipe through which a fluid is flowing (say water), as shown in Fig.

Let d_1 = diameter at inlet or at section (1)

p_1 = pressure at section (1)

v_1 = velocity of fluid at section (1)

a_1 = area at section (1) = $\frac{\pi}{4} d_1^2$

and d_2, p_2, v_2 and a_2 are corresponding values at section (2). Applying Bernoulli's equation at sections (1) and (2),

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + Z_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + Z_2$$

As pipe is horizontal, hence $Z_1 = Z_2$

$$Q = \frac{a_1 \, a_2}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh}$$

The above equation gives the discharge under ideal conditions and is called, theoretical discharge. Actual discharge will be less than theoretical discharge.

$$Q_{act} = C_d \times \frac{a_1 \, a_2}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh}$$

where C_d = Co-efficient of venturimeter and its value is less than 1.

Value of 'h' given by differential U-tube manometer

Case I: Let the differential manometer contains a liquid which is heavier than the liquid flowing through the pipe. Let,

S_h = Sp. gravity of the heavier liquid

S_o = Sp. gravity of the liquid flowing through pipe

x = Difference of the heavier liquid column in U-tube

then,

$$h = x\left[\frac{S_h}{S_o} - 1\right]$$

Case II: If the differential manometer contains a liquid which is lighter than the liquid flowing through the pipe, the value of h is given by

$$h = x\left[1 - \frac{S_l}{S_o}\right]$$

where,

S_l = Sp. gr. of lighter liquid in U-Tube

S_o = Sp. gr. of fluid flowing through pipe .

x = Difference of the lighter liquid columns in U-tube.

Case III: Inclined Venturimeter with Differential U-tube manometer. The above two cases are given for a horizontal venturimeter. This case is related to inclined venturimeter having differential U-tube manometer. Let the differential manometer contains heavier liquid then h is given as

$$h = \left(\frac{p_1}{\rho g} + Z_1 \right) - \left(\frac{p_2}{\rho g} + Z_2 \right) = x\left[\frac{s_h}{s_o} - 1\right]$$

Case IV: Similarly, for inclined venturimeter in which differential manometer contains a liquid which is lighter than the liquid flowing through the pipe, the value of h is given as

$$h = \left(\frac{p_1}{\rho g} + Z_1 \right) - \left(\frac{p_2}{\rho g} + Z_2 \right) = x\left[1 - \frac{s_l}{s_o}\right]$$

A horizontal venturimeter with inlet and throat diameters 30 cm and 15 cm respectively is used to measure the flow of water. The reading of differential manometer connected to the inlet and the throat is 20 cm of mercury. Determine the rate of flow. Take C_d = 0.98.

Solution:

Given :

Diameter at inlet, d_1 = 30 cm = 0.3 m

Area at inlet , $a_1 = \frac{\pi}{4} d_1^2 = \frac{\pi}{4}(30^2) = 706.85 \text{ cm}^2$

Diameter at throat, d_2 = 15m = 0.15m

$a_2 = \frac{\pi}{4} d_2^2 = \frac{\pi}{4}(15^2) = 176.7 \text{ cm}^2$

C_d = 0.98

Reading of differential manometer = x =20 cm of mercury

Difference of pressure head is , $h = x\left[\frac{s_h}{s_o} - 1\right]$

Where,

S_h = Sp. gravity of mercury = 13.6

S_o = Sp. Gravity of water = 1

$h = 20\left[\frac{13.6}{1} - 1\right]$ = 20 x12.6cm = 252 cm of water

The discharge through venturimeter is given by eqn.

$$Q = C_d \times \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh}$$

$$= \frac{86067593.36}{\sqrt{499636.9} - 31222.9} = \frac{86067593.36}{684.4}$$

$$= 125756 \text{ cm}^3/\text{s} = \frac{125756}{1000} \text{ lit/s}$$

Q = 125.756 lit/sec