Class :2nd stage

Subject: Fluid Flow

Ministry of Higher Education and Scientific Research
Al-Mustaqbal University College

Chemical engineering and petroleum industries

(Fluid Flow Lab)

Experiment No. 7

(Flow Measurements Using Orifice)

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Number of Experiment: 7

Name of Experiment: Flow Measurements Using Orifice (Discharge Through an Orifice)

Purpose of Experiment:

1- To determine the discharge coefficient of orifice meter.

2- To determine the contraction coefficient (C_c) and velocity coefficients (C_v).

Introduction:

An orifice plate is a device used for measuring the rate of fluid flow. It uses the same principle as a Venturi nozzle, which states that there is a relationship between the pressure of the fluid and the velocity of the fluid.

When the velocity increases, the pressure decreases and vice versa. An orifice plate is a thin plate with a hole in the middle. It is usually placed in a pipe in which fluid flows. When the fluid reaches the orifice plate, with the hole in the middle, the fluid is forced to converge to go through the small hole; the point of maximum convergence actually occurs shortly downstream of the physical orifice, at the so-called vena contracta point. As it does so, the velocity and the pressure changes. Beyond the vena contracta, the fluid expands and the velocity and pressure change once again. By measuring the difference in fluid pressure between the normal pipe section and at the vena contracta, the volumetric and mass flow rates can be obtained from Bernoulli's equation.

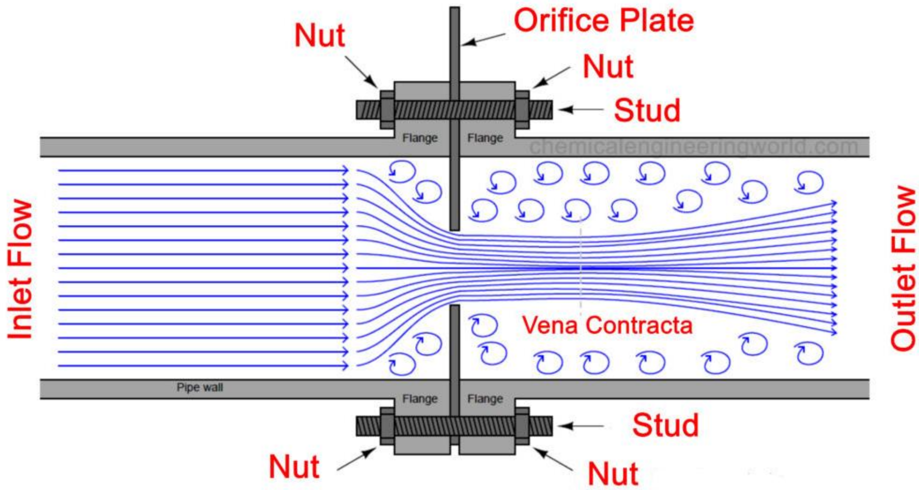

Figure 1. Schematic of Standard Orifice Meter

Theory:

An orifice meter is defined to be a plate having a central hole that is placed across the flow of a liquid, usually between flanges in a pipeline. The pressure difference generated by the flow velocity through the hole enables the flow quantity to be measured. As seen in Figure 2 the fluid flows through the left side of the pipe at the pipe diameter D and it is restricted down to Dc as it flows through the restricting plates, this is known as the orifice. The pressure difference is measured at P1 and P2. This pressure can be measured using any different measurement devices such as piezometer tubes or pressure gages.

The vena contracta is the location of the smallest cross-sectional diameter of the flow of liquid after the orifice of the meter. This is also shown in Figure 2. This Secondary flows phenomenon is the result of the inability of the fluid to turn the sharp 90 degree corner formed by the orifice plates. Some common properties of the vena contracta are: constant pressure across the cross-sectional area and all the streamlines of flow are parallel at this location (Fundamentals of Fluid Mechanics). To calculate the theoretical flow rate through the meter you multiply the velocity of the fluid by the area of the orifice. This value unfortunately will not match the actual flow rate through the orifice of the meter. This is due to two main sources of error. The first is the mechanical losses due to friction along the walls of the meter. The second is the reduction in area of flow due to the vena contracta phenomenon discussed above. To account for these sources of error, a discharge coefficient is introduced into the calculation.

A standard value for the discharge coefficient of an orifice meter is 0.6.

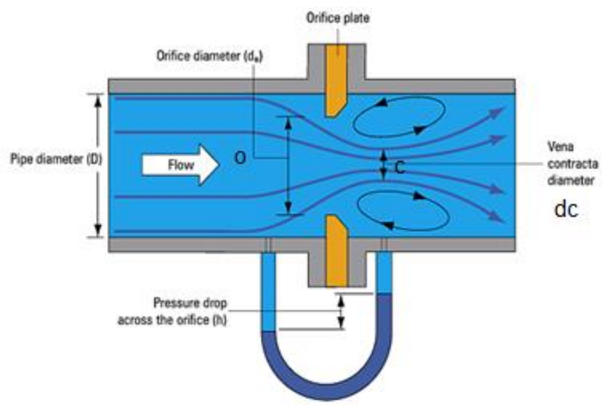

Figure 2. Illustration of Secondary Flows and Vena Contract That Occurs in Orifice Meter

The Equations:

Applying Bernoulli's theorem :

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_o}{\rho g} + \frac{V_o^2}{2g} + Z_o$$

However P1 = Po , $V_1 = 0$, $Z_1 - Z_o = H_o$

Where H_o = head over orifice.

hence substituting these into Bernoulli's equation gives:

$V_o = (2\, g\, H_o)^{1/2}$ ………(1)

Where:

V_o= the theoretical velocity of the water passing through the orifice (m/sec).

and hence the quantity of water being discharged through the orifice is given by:

$Q_{theo} = a_o\, V_o = a_o\, (2\, g\, H_o)^{1/2}$

$C_v = V_c / V_o$ ……(2)

Where: Cv= the coefficient of velocity.

And hence the velocity at the vena contracta is given by:

$V_c = C_v\, (2\, g\, Ho)^{1/2}$ ………..(3)

Where:

V_c= the actual velocity at the vena contracta (m/sec).

$C_c = a_c / a_o$……….(4)

Where: C_c= the coefficient of contraction.

a_o= the area at point (o) of the orifice (mm^2). $a_o = (\pi/4) d_o^2$

a_c= the actual area (point c) of water which flowing through the vena contracta (mm^2). $ac = (\pi/4)d_c^2$

Thus the equation (4) can be simplified to:

$C_c = (d_c / d_o)^2$…….(5)

d_o= the ideal diameter of flow (the diameter of the orifice) (mm).

d_c= the actual diameter of flow (the diameter of vena contracta) (mm).

$d_c = d_{out} + d_{in} /2$ ……..(6)

Where: d_{out} = the outer diameter of jet (mm).

d_{in} = the inner diameter of jet (mm).

$Q_{theo} = V_o\, a_o$ ……..(7)

$Q_{actual} = V_c\, a_c$……..(8)

$Q_{actual} = C_v\, V_o\, C_c\, a_o$……..(9)

$Q_{actual} = Cv\, Cc\, Q_{theo}$……..(10)

$C_d = \frac{Qactual}{Qtheo} = C_v\, C_c$ ……..(11)

Where: C_d = the coefficient of discharge.

Experimental Work:

Equipment and apparatus:

The experience consist of the device and tools following, (Figures 4):

1- The orifice meter.

2- Measuring tank.

3- Stopwatch.

Procedure:

1. Measure the (Q_{act}) by recording the time for takes the fixed volume of water in measuring tank, such as, (10, and 15 Liter).

2. Measure (H_o) by using piezometer tubes in orifice meter.

3. Measure the diameter of jet at the vena contract (d_c) by measuring (d_{out}, and d_{in}) by using the blade on the Pitot tube assembly.

Discussion:

Discuss your results, focusing on the following:

1- Derive equations (11).

2- What is the difference between venture meter and orifice meter?

3- What is vena contracta?

4- Why there is a greater loss of energy in orifice meter?

5- An orifice meter with diameter 30 cm is inserted in a pipe of 50cm diameter. The water flows at a rate of (Q_{actual} =250L/sec). Coefficient of velocity & coefficient of contraction for orifice meter is given as 0.97 & 0.65,respectively. What is the head over orifice (H_o)?