Instant Journal of Mechanical Engineering
Short Communication Open Access

Actual Discharge on Venturimeter - A Literature

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***Received Date:** Feb 18, 2021 / **Accepted Date:** Mar 01, 2021/ **Published Date:** Mar 04, 2021*

Abstract
Venturi meter is a device which is used for measuring the rate of flow of fluid flowing through the pipes. The applications of these are found in various fields like Water House Department, Aviation, Automotive, Chemical, Petro-chemical industries, etc. In automotive industry venturimeter is used to measure the fuel and air distribution in carburetor. Similarly, in the water houses, venturimeter device is used to calculate the velocity of flow in the pipelines [1]. In this paper we have to discuss about the working principle and set up the study of experimental calculations on venturimeter. In the present paper, an attempt was made to study a computational device of a venturimeter, which can be used as an efficient and easy means for predicting the discharge coefficients for the flow lines.
Keywords: Venturi meter; Discharge; Heads; Co-efficient of Discharge

Cite this article as: Amit Rakshit, Sumana Ghosh. 2021. Actual Discharge on Venturimeter - A Literature. I J Mech Eng. 3: 01-04.

Introduction

Venturi meter

A Venturimeter is a device used for measuring the rate of flow of a flowing fluid through a pipe. Venturimeter has been named after the 18th century Italian Engineer Venturi [2]. Venturimeter can be classified into three types which as follows-
a) Horizontal Venturimeter
b) Vertical Venturimeter
c) Inclined Venturimeter
The device consists of three sections namely-
a) Short Converging section
b) Throat
c) Long Diverging section

Discharge Expression

Consider a schematic diagram of the Venturimeter which shows that the device is fitted in a horizontal pipe through which a fluid is flowing say water as shown in the figure. Assume that the water is flowing steady flow, streamline flow, laminar flow and incompressible fluid. So, is the fluid is incompressible, then the fluid is inviscid in nature [3].

DOI: https://doi.org/10.36811/ijme.2021.110004 **IJME: March-2021: Page No: 01-04**

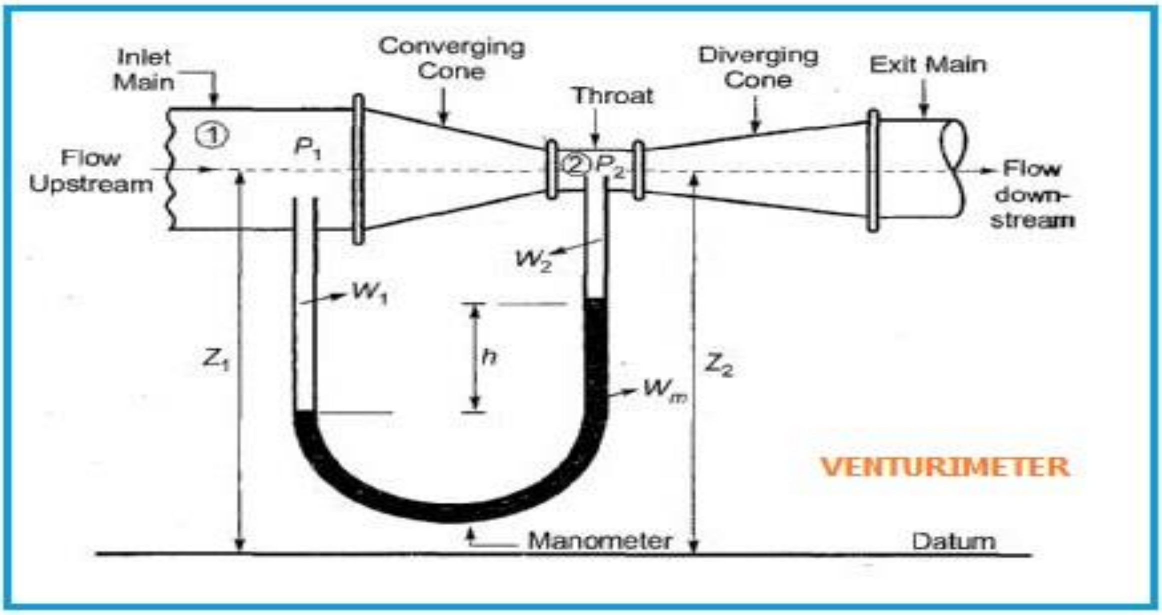

Figure 1: Set up of Venturimeter.

Consider, the two sections (1) and (2) at the convergent portion and throat respectively. Therefore,

d_1 = diameter at inlet section (section 1)
p_1 = pressure at inlet section (section 1)
v_1 = velocity at inlet section (section 1)
a_1 = area at inlet section (section 1) = $\frac{\pi}{4} d_1^2$
z_1 = datum head at (section 1)
Similarly, in the section (2),

d_2 = diameter at inlet section (section 2)
p_2 = pressure at inlet section (section 2)
v_2 = velocity at inlet section (section 2)
a_2 = area at inlet section (section 2) = $\frac{\pi}{4} d_2^2$
z_2 = datum head at (section 2)

Now, applying Bernoulli's Theorem at section (1) and section (2), we get

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + z_2 \ldots\ldots \text{(i)}$$

As the pipe is horizontal situation, so, therefore,

$$z_1 = z_2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(ii)}$$

So,

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(iii)}$$

Or,

$$\frac{p_1}{\rho g} - \frac{p_2}{\rho g} = \frac{v_2^2}{2g} - \frac{v_1^2}{2g} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(iv)}$$

But $\frac{p_1}{\rho g} - \frac{p_2}{\rho g}$ is the difference of pressure heads at section 1 and section 2 and it is equal to h. Substituting this value of h in the above equation (iv), we get

$$h = \frac{v_2^2}{2g} - \frac{v_1^2}{2g} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(v)}$$

Now, applying the continuity equation at section 1 and section 2

$$a_1 v_1 = a_2 v_2$$

$$v_1 = \frac{a_2}{a_1} v_2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(vi)}$$

Substituting the value of v_1 in equation (v), we get

$$h = \frac{v_2^2}{2g} - \frac{v_1^2}{2g}$$

$$h = \frac{v_2^2}{2g} - \frac{(\frac{a_2}{a_1} v_2)^2}{2g}$$

$$h = \frac{v_2^2}{2g}[1 - \frac{a_2^2}{a_1^2}]$$

$$h = \frac{v_2^2}{2g}[\frac{a_1^2}{a_1^2} - \frac{a_2^2}{a_1^2}]$$

$$\text{or, } v_2^2 = 2gh\frac{a_1^2}{a_1^2 - a_2^2}$$

$$\text{or, } v_2 = \sqrt{2gh\frac{a_1^2}{a_1^2 - a_2^2}} = \sqrt{2gh}\,\frac{a_1}{\sqrt{a_1^2 - a_2^2}}$$

Therefore, theoretical discharge or rate of flow at section 2,

$$Q_{Th} = a_2 v_2$$

$$Q_{Th} = a_2 \frac{a_1}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh}$$

DOI: https://doi.org/10.36811/ijme.2021.110004 IJME: March-2021: Page No: 01-04

$Q_{Th} = \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh}$……………(vii)

Equation (vii) gives the theoretical discharge. But practically actual discharge is less than that of theoretical discharge.

Corollary: The ratio of actual discharge upon theoretical discharge is reckoned as coefficient of discharge (C_d). Therefore, $\frac{Q_{act}}{Q_{Th}} = C_d$

So, $Q_{act} = C_d \times \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh}$……… (viii)

C_d is always less than one.

This equation (viii) only shows the actual discharge when the fluid is ideal fluid (i.e., non – viscous fluid). But, practically the fluid is an ideal fluid where the viscous force is acted on the fluid. Thus, the Bernoulli's equation of section (1) and section (2) is

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + z_2 + h_L$$

Value of h given by differential U-tube manometer:

Case 1: Let the differential manometer contains a liquid which is heavier than the liquid flowing through the pipe. Consider,

S_w = Specific gravity of the heavier liquid

S_o = Specific gravity of the lighter liquid

Δh = difference of the heavier liquid column in U - tube manometer

Then, h = Δh $[\frac{S_w}{S_o} - 1]$

Case 2: Let the differential manometer contains a liquid which is lighter than the liquid flowing through the pipe. Consider,

S_w = Specific gravity of the lighter liquid

S_L = Specific gravity of the flowing liquid

Δh = difference of the heavier liquid column in U - tube manometer

Then, h = Δh $[1 - \frac{S_w}{S_L}]$

Case 3: Let the differential manometer of inclined venturimeter contains a liquid which is heavier than the liquid flowing through the pipe. Consider,

S_w = Specific gravity of the heavier liquid

S_L = Specific gravity of the flowing liquid

Δh = difference of the heavier liquid column in U - tube manometer

Then, h = $(\frac{p_1}{\rho g} + z_1) - (\frac{p_2}{\rho g} + z_2)$ =Δh $[\frac{S_w}{S_L} - 1]$

Case 4: Let the differential manometer of inclined venturimeter contains a liquid which is lighter than the liquid flowing through the pipe. Consider,

S_w = Specific gravity of the lighter liquid

S_L = Specific gravity of the flowing liquid

Δh = difference of the heavier liquid column in U - tube manometer

Then, h = $(\frac{p_1}{\rho g} + z_1) - (\frac{p_2}{\rho g} + z_2)$ =Δh $[1 - \frac{S_w}{S_L}]$

Conclusion

Here the paper gives the overview of the working condition of venturimeter. The value of the Bernoulli's principles and continuity equation in the analysis of flow discharge through Venturimeter. The device will be effective applied in the control and measurement of flow alone pipeline in oil field, for irrigation purposes, automotive industry, wastewater collection systems, water houses and treatment plants. This flow system is valuable for practical demonstration of fluid measurement and control in Fluid mechanics studies in Mechanical Engineering Laboratory [4,5]. But this device is most costly as compared to the others flow rate measurement devices like orifice meter, rotameter and so on.

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