Experimental Investigation of Influence of Pipe Elbowon Coefficient of Discharge of Venturimeter

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Abstract— The performances of venturimeters with different throat diameter ratios have been evaluated experimentally and their influence on discharge coefficient for Reynolds number are studied. The experiments are conducted using water as working fluid for incompressible flow situation. The effects of locations of elbows at different upstream distances from venturimeter are investigated. Five different beta ratio (0.2, 0.3, 0.4, 0.5, and 0.6) venturimeters are considered. The upstream distance from the elbow to the venturimeter of 1D, 2D, 3D, 4D, 5D, 8D, 12D, 16D, and 20D are considered during the experimentation. From the study, it is seen that the discharge coefficient of a venturimeter is nearly independent of Reynolds number. The values of the discharge coefficient and Reynolds number are affected by the upstream length when the upstream length is of 1D & 2D.

Key words: Venturimeters, Flow through Elbows, Discharge Coefficient, Reynolds Number

NOMENCLATURE

- Q_{act}: Actual Discharge
- Q_{th}: Theoretical Discharge
- C_d: Co-efficient of Discharge
- D: Diameter of pipe
- d: Throat diameter
- A_1: Cross section area of pipe
- A_2: Cross section area of throat
- V: Volume of water collected
- g: Acceleration due to gravity
- h: Manometer Difference
- t: Time

I. INTRODUCTION

Venturimeter is a device used for measuring the rate of flow of a fluid through a pipe. The basic principle on which a venturimeter works is by reducing the cross sectional area of the flow of passage, a pressure difference is created and the measurement of the pressure difference enables the determination of the discharge through a pipe. It contains a converging section which gives an increase in the flow velocity and a corresponding pressure drop.

The venturimeter consists of three main parts viz.

- Converging part
- Throat
- Diverging part

The inlet section of the venturimeter is of the same diameter as that of the pipe, which is followed by a convergent cone. The convergent cone is a short pipe, which tapers from the original size of the pipe to that of the throat of the venturimeter. The throat of the venturimeter is a short parallel-sided tube having uniform cross sectional area smaller than that of the pipe. The minimum cross section diameter is called throat. The divergent cone of venturimeter is a gradually diverging pipe with its cross sectional area increasing from that of the throat to the original size of the pipe.

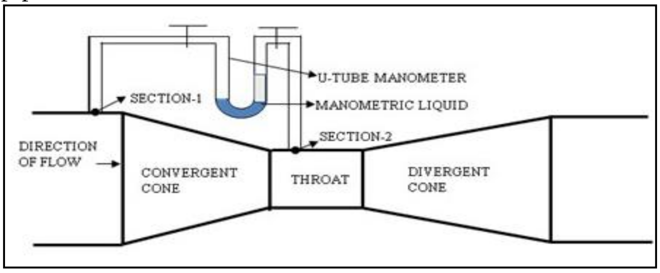

Fig. 1: Schematic representation of a Venturimeter

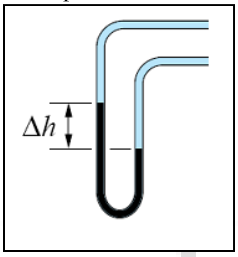

Fig. 2: U-tube Manometer

Dr. George Mattingly and Dr. T.T. Yeh (1993), performed installation effects on a typical orifice plate flow meter. This was part of a government-industry consortium to study such effects. The N.I.S.T. tests included three orifice plates in a 50 mm line. The Beta ratios tested were 0.363, 0.5 and 0.75. Flange connections were weld-neck flanges. The test fluid was water. Flow criteria for these tests were the same as the Micrometer tests. The positions of the orifice plate to the elbows were similar to the Micrometer tests. Single elbow effects on the V-Cone. The orifice plate showed significant effects from the single elbow. The maximum effect of the elbow (at 3D with b=0.750). Stephen A. Ifft and Eric d. Mikkelsen (1993), had worked on the elbow effects on the performance of V-Cone flow meter. Mc.Crometer introduced the V-Cone flow meter in 1986 as an alternative to traditional differential pressure flow meters. The Mc.Crometer tests included three 50 mm V-Cone flow meters with beta ratios of 0.363, 0.65 and 0.75. Beta ratios for V-Cones represent the same area ratio that standard orifice plate beta ratios represent. The meter was first placed at a maximum distance from the elbows. The data taken at this point was the baseline data for the particular meter. In this position the meter was 190 D away from the elbows. Each meter was then moved in intervals closer to the elbows. Six different positions relative to the elbows were tested. The positions were approximately 23D, 9D and 2 D away from the elbows. At each position, each meter was tested at five flow rates covering the range stated above. At each flow rate a repeat point was taken for verification. Thus for each position, a total of ten test points were taken. These ten points were then averaged. Colter L.Hollingshead (2011) investigated the relationship between the Reynolds number (Re) and discharge coefficients(C) through differential pressure flow meters. The focus of the study was directed toward very small Reynolds numbers commonly associated with pipeline transportation of viscous fluids. There is currently a relatively small amount of research that has been performed in this area for the venturi, standard orifice plate, V-cone, and wedge flow meters.

II. EXPERIMENTAL SET UP AND PROCEDURE

The designed and fabricated different beta ratio (d/D = 0.2, 0.3, 0.4, 0.5, 0.6) venturimeters are calibrated with water. Here the convergent side of the venturimeter is connected to the upstream length and 90ºelbow is connected to the inlet valve and the divergent side is connected to the gate valve and collecting tank. The pressure taps of convergent and throats are connected to simple U-tube mercury manometer. In the divergent side, the gate valve is fixed through which the flow is controlled. When the gate valve is in closed position the mercury level in the manometer is in balanced condition. Then the gate valve is open gradually till the required deflection occurs in manometer. The stop watch is used to measure the time required to collect the 40cm of water. Adjust the discharge and note down the pressure difference 'h' to calculate the theoretical discharge Q_{th} and determine the actual discharge Q_{act}. Calculate the coefficient of discharge C_d.

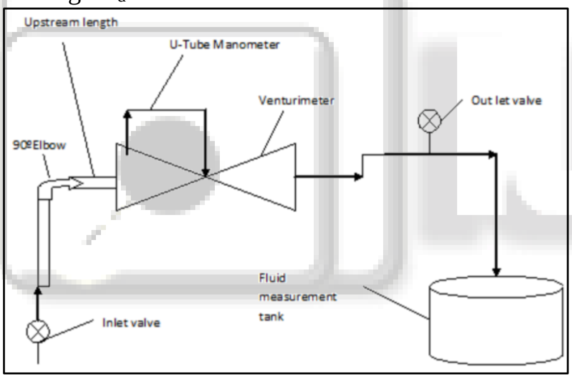

Fig. 3: Schematic Diagram of the Experimental setup with 90º Elbow

The actual discharge (Q_{act}) is calculated by the following eq

$$Q_{act} = \frac{V}{t}$$

The theoretical discharge (Q_{th}) is given by

$$Q_{th} = \frac{A_1 \times A_2 \times \sqrt{2gh}}{\sqrt{A_1^2 - A_2^2}}$$

$$C_d = \frac{Q_{act}}{Q_{th}}$$

The experimentation is continued for different deflections and start with minimum deflection to the maximum (15mm to 300mm), simultaneously the collecting time is recorded. Changing the upstream length and repeating the same procedure for the nine different upstream lengths (1D, 2D, 3D, 4D, 5D, 8D, 12D, 16D and 20D). The experiment is repeated for five different beta ratio venturimeters, for each beta ratio nine different upstream lengths set-up has made and calculated the actual water flow rate, theoretical flow rate and coefficient of discharge for collecting 40 cm of water. The calibration curves for the five different venturimeters are drawn for coefficient of discharge vs. Reynolds number.

Fig. 4: Photography of Manufactured Five Different Beta Ratio Venturimeters.

Fig. 5: Photography of Nine different upstream pipe lengths.

III. RESULTS AND DISCUSSIONS

The experimental investigation carried out to study the discharge coefficients, focused on five different types of venturimeters with varying beta ratios with 90º elbow is considered with different experimental set-ups. The venturimeters are manufactured for five different geometries to determine the significant effect on the discharge coefficients of venturimeter. The experiment is done for five different venturimeters having the beta ratio of 0.2, 0.3, 0.4, 0.5, and 0.6 for a 1 inch pipeline with nine different upstream lengths (1D, 2D, 3D, 4D, 5D, 8D, 12D, 16D, and 20D) are used and calculated the actual water flow rate, theoretical flow rate, coefficient of discharge and Reynolds number.

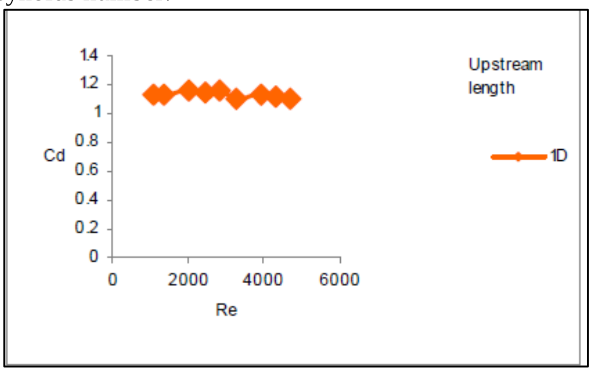

Fig. 6: C_d V/s Re with Beta ratio 0.2

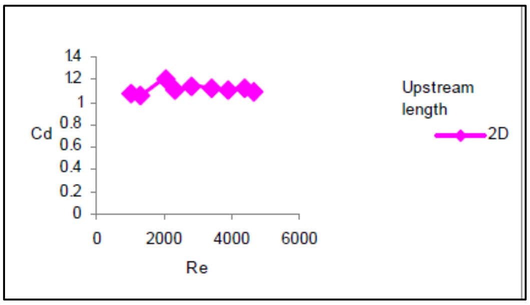

Fig. 7: C_d V/s Re with Beta ratio 0.2

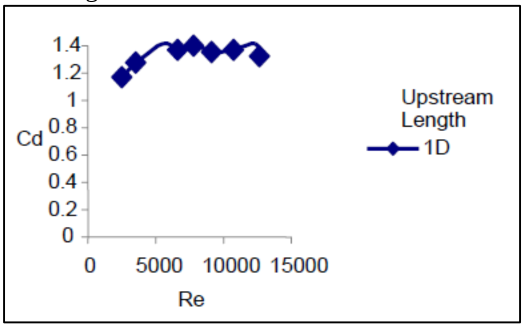

Fig. 8: C_d V/s Re with Beta ratio 0.3

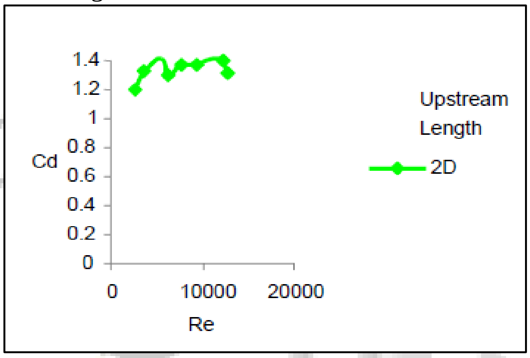

Fig. 9: C_d V/s Re with Beta ratio 0.3

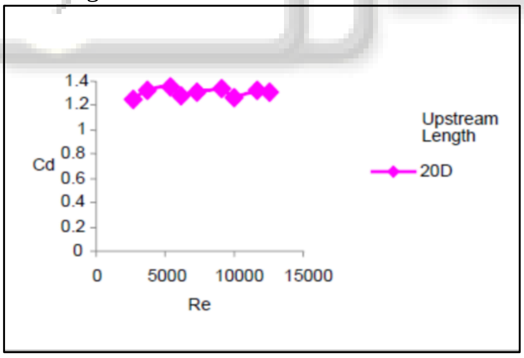

Fig. 10: C_d V/s Re with Beta ratio 0.3

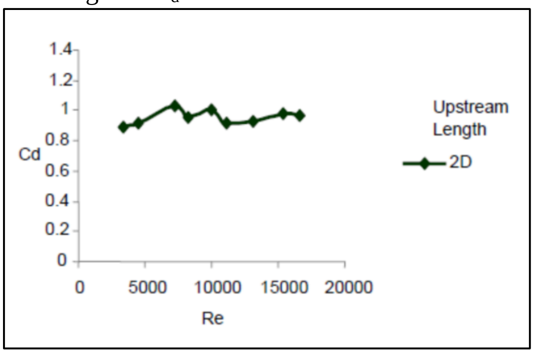

Fig. 11: C_d V/s Re with Beta ratio 0.4

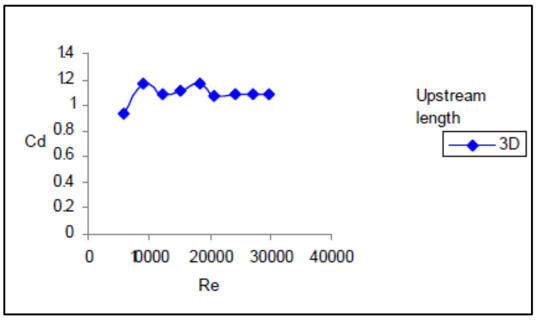

Fig. 12: C_d V/s Re with Beta ratio 0.5

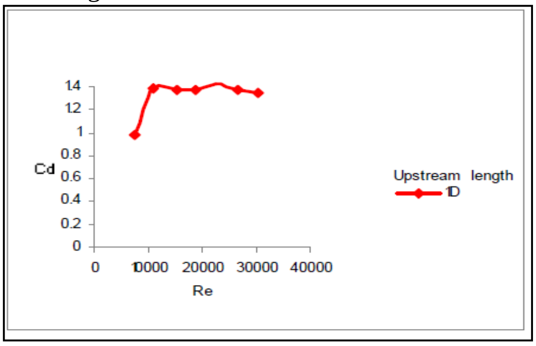

Fig. 13: C_d V/s Re with Beta ratio 0.6

It is found that there is an influence of upstream length on coefficient of discharge if the upstream length is placed at 1D, 2D and 3D as shown in Figures. However, discharge coefficient C_d remains non-linear and varies with Reynolds number and Beta ratio. This may be due to effect of elbow results in boundary layer separation which leads to turbulence.

As the upstream length increases the flow once again stabilizes.

IV. CONCLUSIONS

The experimental investigation is performed to study the "Influence of pipe elbow on coefficient of discharge of venturimeter". The experiment is conducted for 90° elbow using water for five different beta ratios venturimeters and varying the upstream length by elbow.

- Graphs are plotted for coefficient of discharge (C_d) versus Reynolds number (R_e). It is found that C_d is having a positive non-linear relationship with all five different beta ratios.
- Co-efficient of discharge (C_d) increases with increase in Reynolds number.
- Co-efficient of discharge (C_d) is increased for beta ratios 0.2 and 0.3 and, is decreased for beta ratios 0.4, 0.5 and 0.6.
- Reynolds numbers are small for beta ratio of 0.2 and 0.3 and large for beta ratio of 0.4, 0.5 and 0.6.
- The discharge coefficient is increasing for the distance 2D, 3D, 4D, 5D, 8D, 12D, 16D, 20D.
- It is found that there is an influence of upstream length on coefficient of discharge if the upstream length is placed at 1D or 2D. Therefore there is a variation of results for different beta ratios.

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