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Theoretical, Numerical Prediction of Viscous Coefficient of Venturi Meter Under Non Iso Standard Conditions

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Abstract: There are many pipelines where flows need to be accurately measured. Meters having a high level of accuracy and relatively low cost are a couple of the most important parameters when deciding on the purchase of a flow meter. Most differential pressure flow meters meet both of these requirements. Many of the most common flow meters have a specified range where the discharge coefficient may be considered constant and where the lower end is usually the minimum recommended Re number that should be used with the specified meter. With the additional knowledge of this study it will enable the user to better estimate the flow through a pipeline over a wider range of Reynolds numbers. The research completed in this study on discharge coefficients focused on Venturi meter with varying beta ratios and diameters. In the present work CFD tool Fluent is to describe the behaviour of flow meters from very low to high Reynolds numbers. In particular, the CFD predictions of discharge co-efficients were verified through comparison through results available in the literature. Results are presented in terms of predicted discharge co-efficients. Reynolds numbers deserve excessive observation when it comes to analyzing the capabilities of Venturi Meter. The value of the Reynolds number for a particular pipe flow can be decreased by either decreasing the velocity, or increasing the viscosity.Venturi flow meter models were created to determine their discharge coefficient data for a wide array of Reynolds numbers. The different beta(β) values used for the models were 0.60, 0.56,0.52,0.48, 0.44, and 0.4 to observe if there was any significant difference in results based on pipe diameter.
Keywords: Venturimeter, Throat, Co-efecient of discharge, CFD, Reynolds number

1. INTRODUCTION

Among the differential pressure flow meter, Venturi Meter stands out and dominates in flow measurement field because of its simple and well understood concept, accurate and economical compared to other sophisticated flow meter.Still, study has been made to further understand the performance of Venturi Tube and its accuracy. Accurate flow measurement is one of the greatest concerns among many industries, because uncertainties in product flows can cost companies considerable profits.

Differential pressure flow meters such as the Venturi, standard concentric orifice plate, V-cone, and wedge are popular for these applications at higher Reynolds numbers, because they are relatively in expensive and producer liable results. However, little is known about their discharge co-efficient (Cd) values at low Reynolds numbers (Miller) of the Venturi Meter. The calibrations for the semesters are generally performed in a laboratory using cold water which, at low Reynolds numbers, results in extremely small pressure differentials that are difficult to accurately measure. Consequently, there is a need for accurate low Reynolds number flow measurements for Venturimeters.

Industrial flow measurements include measuring of flow rate of solids, liquids and gases. There are two basic ways of measuring flow; one on volumetric basis and the other on weight basis. Solid materials are measured in terms of either weight per unit time or mass per unit time. Very rarely solid quantity is measured in terms ofvolume. Liquids are measured either in volume rate or in weight rate. Gases are normally measured in volume rate. In this chapter, the flow measurements of liquids and gases will be discussed in detail rather than that of solids.

Prasanna M A et al [1], In the present work, an attempt is made to study and develop a computational model of a Venturimeter, which can be used as an efficient and easy means for predicting the compressibility effect using Computational Fluid Dynamics (CFD) software. ANSYS FLUENT-14 has been used as a tool to perform the modeling and simulation of flow through Venturimeter. Analysis of flow through Venturimeter has demonstrated the capability of the CFD methodology for predicting accurately the values of Cd, ε and CPL over a wide range of operating conditions. CFD methodology also has been used to analyze the effect of various parameters like surface roughness, convergent and divergent angle as well as turbulent intensity of the incoming flow on the expansibility factor It has been demonstrated that the validated CFD methodology can be used to predict the performance parameters of a classical Venturimeter even under conditions not covered by ISO 5167-1 standards.

To predict the value of coefficient of discharge in theoretical method and numerical method under non ISO standard conditions such as Re < 2 x 10E5, D=25mm, beta =0.4, 0.44, 0.48, 0.52,0.56 and 0.6

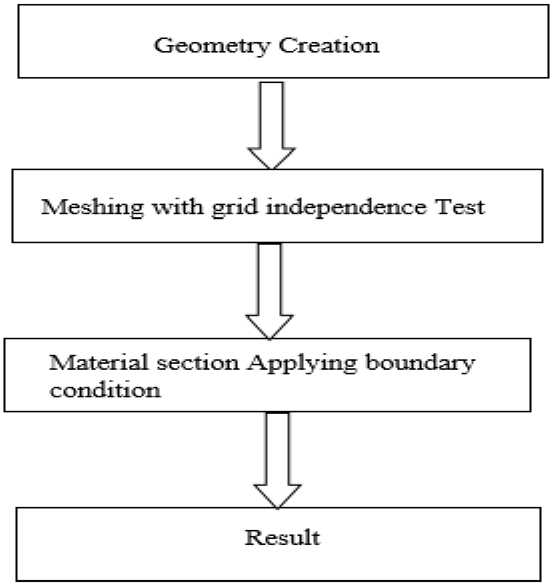


Fig 1: Methodolgy

Result and Discusion

There are many pipelines where flows need to be accurately measured. Meters having a high level of accuracy and relatively low cost are a couple of the most important parameters when deciding on the purchase of a flow meter. Most differential pressure flow meters meet both of these requirements. Many of the most common flow meters have a specified range where the discharge coefficient may be considered constant and where the lower end is usually the minimum recommended Re number that should be used with the specified meter. With the additional knowledge of this study it will enable the user to better estimate the flow through a pipeline over a wider range of Reynolds numbers. The research completed in this study on discharge coefficients focused on Venturi meter with varying beta ratios and diameters.

1.1 Theoretical Method

cd=$0.9559 + 0.312\,\beta^{2.1} - 0.184\,\beta^{2.1} + 91.71[\frac{\beta^{2.5}}{\mathrm{Re}^{0.75}}]$

Re=ρvd/μ

Diameter of pipe=25mm

Diameter of venture =10mm

Case 1: Beta Ratio 0.4

Beta Ratio (β) =d/D

=10/2=0.4

Reynolds Number (Re) =ρvd/μ

$$= \frac{1000 * 0.995 * 10 * 10\hat{} - 3}{1 * 10\hat{} - 4}$$

=99.5*10^3

Cd = $0.9559 + 0.312(0.4)^{2.1} - 0.184(0.4)^{2.1} + 91.71\left[\frac{(0.4)^{2.5}}{(99.5*10^{3})^{0.75}}\right]$

=0.974

Case 2: Beta Ratio 0.44

Beta Ratio (β) =d/D

=11/25

=0.44

Reynolds Number (Re) =ρvd/μ

$$= \frac{1000 * 0.995 * 11 * 10\hat{} - 3}{1 * 10\hat{} - 4}$$

=109.45*10^3

Cd= $0.9559 + 0.312(0.44)^{2.1} - 0.184(0.44)^{2.1} + 91.71\left[\frac{(0.44)^{2.5}}{(109.45*10^{3})^{0.75}}\right]$

=0.978

Case 3: Beta Ratio 0.48

Beta Ratio (β) =d/D
=12/25=0.48
Reynolds Number (Re) = ρvd/μ

$$= \frac{1000 * 0.995 * 12 * 10\hat{} - 3}{1 * 10\hat{} - 4}$$

=119.4*10^3

Cd= $0.9559 + 0.312(0.48)^{2.1} - 0.184(0.48)^{2.1} + 91.71\left[\frac{(0.48)^{2.5}}{(119.4*10^{3})^{0.75}}\right]$

=0.983

Case 4: Beta Ratio 0.52

Beta Ratio (β) =d/D

=13/25=0.52

Reynolds Number (Re) =ρvd/μ

$$= \frac{1000 * 0.995 * 13 * 10^{\wedge} - 3}{1 * 10^{\wedge} - 4}$$

=129.35*10^3

Cd= $0.9559 + 0.312(0.52)^{2.1} - 0.184(0.52)^{2.1} + 91.71\left[\frac{(0.52)^{2.5}}{(129.35 * 10^3)^{0.75}}\right]$

=0.988

Case 5: Beta Ratio 0.56

Beta Ratio (β) =d/D

=14/25=0.56

Reynolds Number (Re) =ρvd/µ

$$= \frac{1000 * 0.995 * 14 * 10^{\wedge} - 3}{1 * 10^{\wedge} - 4}$$

=139.3*10^3

Cd=$0.9559 + 0.312(0.56)^{2.1} - 0.184(0.56)^{2.1} + 91.71\left[\frac{(0.56)^{2.5}}{(139.3 * 10^3)^{0.75}}\right]$

=0.993

Case 6: Beta Ratio 0.60

Beta Ratio (β) =d/D

=15/25=0.6

Reynolds Number (Re) =ρvd/µ

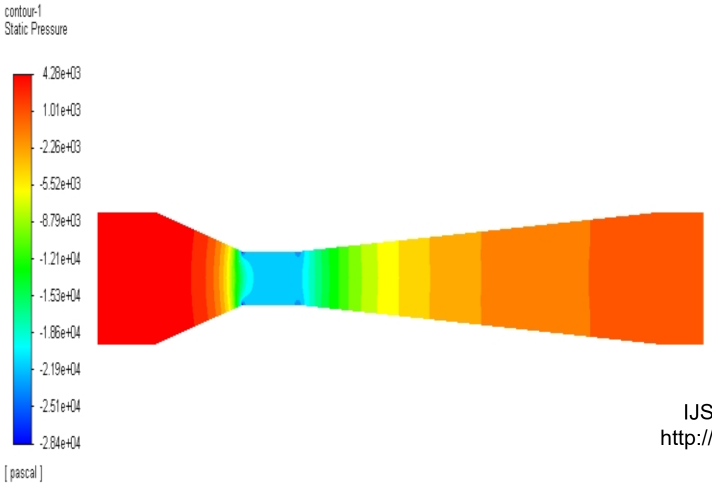
$$= \frac{1000 * 0.995 * 15 * 10^{\wedge} - 3}{1 * 10^{\wedge} - 4}$$

=149.25*10^3

Cd= $0.9559 + 0.312(0.6)^{2.1} - 0.184(0.6)^{2.1} + 91.71\left[\frac{(0.6)^{2.5}}{(149.25 * 10^3)^{0.75}}\right]$

=0.999

Numerical Method

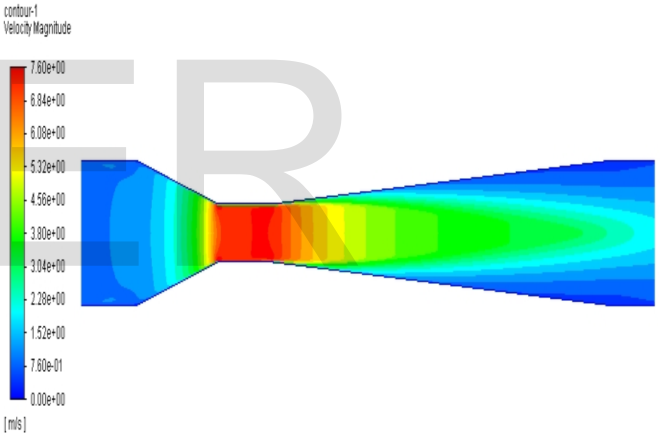


Case 1: Beta Ratio 0.4

Fig2: Static Pressure plot

Figure 2 shows static pressure plot, it is observed from figure pressure varies from -2.84e+04 to 4.28e+03. At the throat pressure is observed is -2.66e+04.

Fig 3: Velocity contour



4.2 Case: Analytical Calculation:

Diameter of the pipe = 25mm.
Diameter of the venturi meter = 10mm.
Area of the pipe is (A_1) = 4.9e-4mm^2.
Area of the venturi meter is (A_2) = 7.85e-5mm^2.
Velocity at the inlet = 6.08m/s
Q = A_2V_2 = (2.01e-4)*7.62 =4.7e-4 m^3/sec.
Pressure inlet p_1 =1.01e3 pascals
Pressure outlet p_2 =-2.66e4 pascals
Beta ratio (β) $= \frac{10}{25} = 0.4$

$$\mathbf{Q} = \frac{\mathbf{C_d A_2}}{\sqrt{\mathbf{1-\beta^4}}}\sqrt{\frac{\mathbf{2\times(p_1-p_2)}}{\boldsymbol{\rho}}}$$

$$4.7\text{e-}4 = \frac{Cd \times 7.85e-5}{\sqrt{1-(0.4^4)}}\sqrt{\frac{2\times(1.01e3-(-2.66e3))}{1000}}$$

4.7e-4 = C_d× 8.056e-5×7.431

$\mathbf{C_d} = \frac{4.7e-3}{0.0005}$

$\mathbf{C_d}$ = 0.94

Case 2: Beta Ratio 0.44

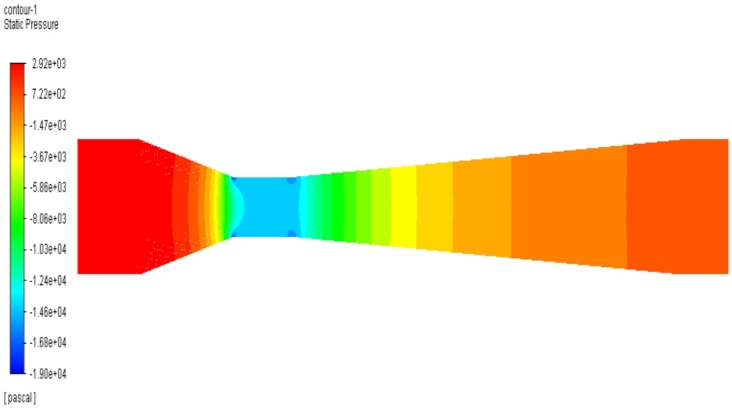


Fig 4: Static Pressure plot

Figure 4 shows static pressure plot, it is observed from figure pressure varies from -1.90e+04 to 2.92e+03. At the throat pressure is observed is -1.47e+04.

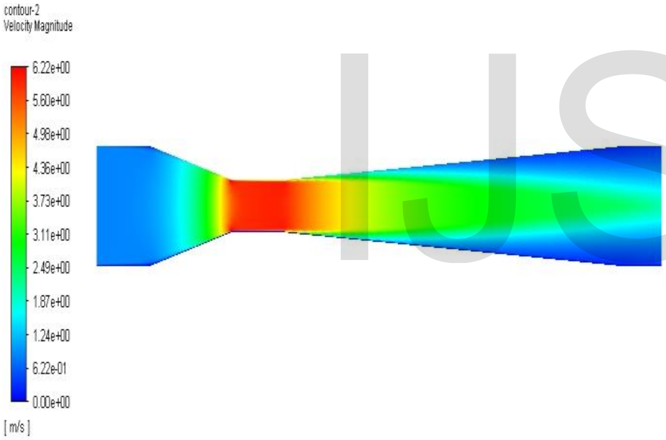


Fig 5: velocity plot

Calculations:

Analytical Calculation:

Diameter of the pipe = 25mm.
Diameter of the venturi meter = 11mm.
Area of the pipe is (A_1) = 4.9e-4mm^2.
Area of the venturi meter is (A_2) = 9.50e-5mm^2.
Velocity at the inlet = 5.60 m/s
$Q = A_2V_2 = (2.01e-4)*7.62$ =0.000532 m^3/sec.
Pressure inlet p_1 =7.22e2 pascals
Pressure outlet p_2 =-1.68e4 pascals
Beta ratio (β) $= \frac{11}{25} = 0.44$

$$\mathbf{Q} = \frac{C_d A_2}{\sqrt{1-\beta^4}}\sqrt{\frac{2\times(p_1-p_2)}{\rho}}$$

$$0.000532 = \frac{Cd\times 9.50e-5}{\sqrt{1-(0.44^4)}}\sqrt{\frac{2\times(7.22e3-(-1.68e3))}{1000}}$$

$0.000532 = C_d\times 9.870e\text{-}5\times 5.9192$

$\mathbf{C_d} = \frac{0.000532}{0.00055}$

$\mathbf{C_d = 0.9467}$

Case 3: Beta Ratio 0.60

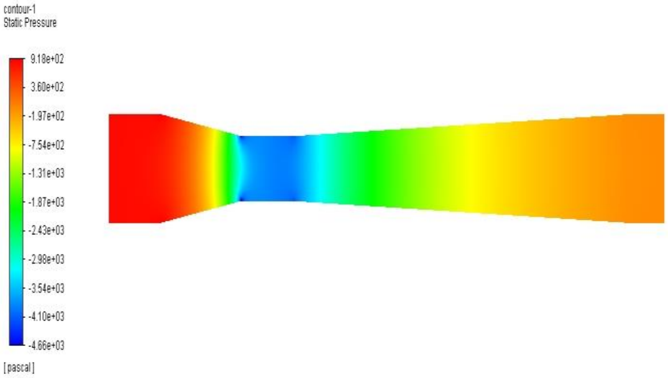


Fig 6: Pressure plot

Figure 6 shows static pressure plot, it is observed from figure pressure varies from -4.66e+04 to 9.18e+03. At the throat pressure is observed is -1.97e+04.

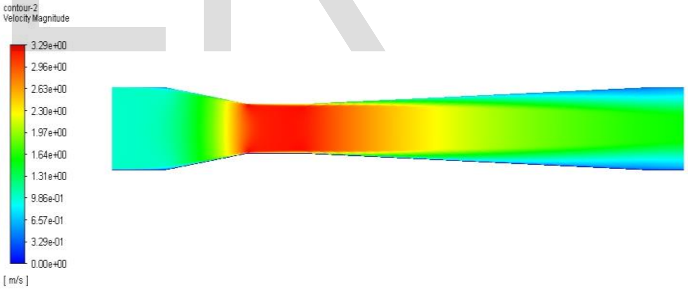


Fig 7: Velocity Contour

Analytical Calculation:

Diameter of the pipe = 25mm.
Diameter of the venturi meter = 15mm.
Area of the pipe is (A_1) = 4.9e-4mm^2.
Area of the venturi meter is (A_2) = 1.76e-4mm^2.
Velocity at the inlet = 3.195m/s
$Q = A_2V_2 = (2.01e-4)*7.62$ =0.00056 m^3/sec.
Pressure inlet p_1 = 3.6e2 pascals
Pressure outlet p_2 =-4.1e3 pascals
Beta ratio (β) $= \frac{15}{25} = 0.60$

$$\mathbf{Q} = \frac{C_d A_2}{\sqrt{1-\beta^4}}\sqrt{\frac{2\times(p_1-p_2)}{\rho}}$$

$$0.00056 = \frac{Cd\times 1.76e{-4}}{\sqrt{1-(0.60^4)}}\sqrt{\frac{2\times(3.6\mathrm{e}2-(-4.1e3))}{1000}}$$

$$0.00056 = \mathrm{C_d}\times 0.000188\times 2.9866$$

$$\mathbf{C_d} = \frac{0.00056}{0.00056}$$

$$\mathbf{C_d = 0.997}$$

Conclusion

- It is concluded that from theoretical method for the beta ratio 0.6 has yield good coefficient of discharge.
- It is observed that from numerical analysis maximum pressure can be observed at the entrance and pressure reduces from entrance to exit.
- It is also identified by numerical and theoretical method that beta ratio 0.4, 0.44,0.48, 0.52,0.56,0.60 within the range I e is 0.96 to 0.99 coefficient of discharge can be achieved.
- It seen from theoretical analysis beta ratio more than 0.64 is not desirable

RECOMENDATIONS/FURTHER RESEARCH

The results from this study could be expanded with future research of discharge coefficients of Venturi Meters. In this study only performing test over a wide range of beta values and classical Venturi Meters to obtain a more complete understanding of discharge coefficient relationship. An area of potential interest is performing tests over a wide range of beta values and different diameters of Eccentric type of Venturi Meters and Rectangular type of Venturi Meters.

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