Comparison of Experimental, Theoretical and Simulation result for Pressure Drop in Sharp Edged Orifice meter

[1]C. R. Sanghani, [1]D. C. Jayani, [2]A. H. Hingu, [2]M. Y. Jadav, [2]D. V. Jiyavia
[1]Lecturer, Mechanical Engg. Department, S.T.B.S. College of Diploma Engineering, Surat, India
[2]Diploma students, S.T.B.S. College of diploma Engineering, Surat, India

***Abstract* - An orifice meter is the most common type of flow measuring device used for measuring flow rate by creating pressure difference in pipe. It is widely used in process industry, chemical industry, oil and gas industry for flow rate measurement of steam, oil, gas, etc. In these types of flow meters, large amount of pressure drop occurs due to the restriction in flow path. This pressure drop depends on various parameters like shape of orifice pate, diameter ratio, properties of the fluid, etc. In this research work, experiments were conducted for various flow rate of water passing through sharp edged orifice meter. Computational Fluid dynamics (CFD) analyses were carried out in Ansys CFX 15.0 to find out pressure loss in orifice meter. Comparison of experiment, theory and simulation results have been done. From comparison of results, it was found that results of theory and simulation are in good agreement with experimental results.**

***Keywords* - CFD, Experiment, Pressure drop, Sharp edged orifice, Theory**

I. INTRODUCTION

Accurate measurements of fluid flow rate and pressure control in the pipe line are important requirements of many engineering industries when these parameters directly affect process efficiency and productivity. Among the available flow measuring devices, differential pressure based devices are extensively applicable due to their simple design and low cost [1]. Although orifice meters have higher pressure losses, they are the most commonly used flow measuring devices because of simple construction, ease of installation, low cost maintenance, no moving parts, economic as well as reliable measurement and it can be used for liquids, gases or slurries, etc. [2]. The fundament of the orifice plate operation consists of introducing a located obstruction in the path which changes the velocity of the flow and causes a differential of pressures that is proportional to the fluid flow [3]. Design of an orifice meter with a provision to track vena-contracta using CFD technique has been proposed by Shah et al. [4]. Different two-equation turbulence models were tested using Fluent software for a flow around an orifice meter and it was found that the k-ω model is the most promising candidate for simulating a flow around an orifice meter [5]. Few efforts have been made to simulate the pressure drop in orifice with the help of CFD analysis. So, in this paper, simulation of pressure drop in orifice meter at different flow rate has been done using CFD and compared with experimental and theoretical results.

II. EXPERIMENTAL ANALYSIS

The experimental analysis of pressure drop in orifice meter was carried out on the setup available at the college laboratory as shown in figure 1. A 45º sharp edged orifice plate having 14mm diameter hole in center is installed in pipe. Using water as a working medium, no. of experiments was conducted to investigate the pressure drop at various flow rates. Pressure difference across orifice plate was measured using differential u-tube manometer. The readings taken during these experiments are shown in Table 1. Experimentally,

ISSN: 2278 – 7798

the pressure drop in orifice meter can be found out using (2).

Fig. 1 Experimental setup

Table 1 Observation Table

Ex. No.	Measuring tank reading (m)		Manometer reading (m)	
	Initial (h1)	Final (h2)	Low (x1)	High (x2)
1	0.01	0.074	0.17	0.212
2	0.01	0.088	0.103	0.166
3	0.01	0.097	0.152	0.232
4	0.01	0.101	0.149	0.234
5	0.01	0.102	0.148	0.235
6	0.01	0.112	0.136	0.249
7	0.01	0.124	0.067	0.204
8	0.01	0.132	0.061	0.215

Orifice head, $H = \Delta X\,(13.6 - 1)$ (1)

Pressure drop, $\Delta P = \rho \times g \times H$ (2)

Where, ΔX = difference of manometer reading
ρ = density of water

III. THEORETICAL ANALYSIS

The calculation of flow rate of fluid based on pressure difference is most commonly used flow measurement technique. When any restriction is placed in fluid path, it will create pressure difference upstream and downstream from the restriction. This difference can be measured and used to provide the base for calculating flow rate of fluid. The theoretical analysis of pressure drop in orifice meter can be found from following method:

Discharge, $$Q = \frac{A_1 A_2 \sqrt{2gH}}{\sqrt{{A_1}^2 - {A_2}^2}} \quad (3)$$

Continuity equation, $$Q = A_1 V_1 \quad (4)$$

$$A_1 V_1 = \frac{A_1 A_2 \sqrt{2gH}}{\sqrt{{A_1}^2 - {A_2}^2}}$$

$$\sqrt{H} = \frac{V_1 \times \sqrt{{A_1}^2 - {A_2}^2}}{A_2 \sqrt{2g}}$$

$$H = \frac{{V_1}^2 \times ({A_1}^2 - {A_2}^2)}{{A_2}^2 \times 2g}$$

$$\rho \times g \times H = \rho \times g \times \frac{{V_1}^2 \times ({A_1}^2 - {A_2}^2)}{{A_2}^2 \times 2g}$$

$$\Delta P = \frac{\rho {V_1}^2 \times ({A_1}^2 - {A_2}^2)}{2{A_2}^2} \quad (5)$$

Where, A_1= cross section area of pipe
A_2= cross section area of orifice hole
V_1 = velocity at pipe inlet

IV. CFD ANALYSIS

Computational fluid dynamics (CFD) analyses of orifice meter for finding pressure drop were carried out using Ansys CFX 15.0 software. A 3D model of pipe with orifice plate was made as shown in Fig. 2. With automatic volume mesh generation tool in CFX, this model was meshed with 35690 tetrahedral elements as shown in Fig. 3.

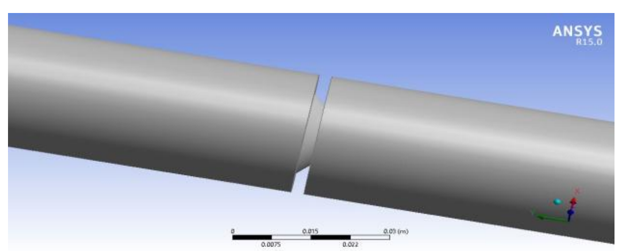

Fig. 2 3D model of orifice meter

ISSN: 2278 – 7798

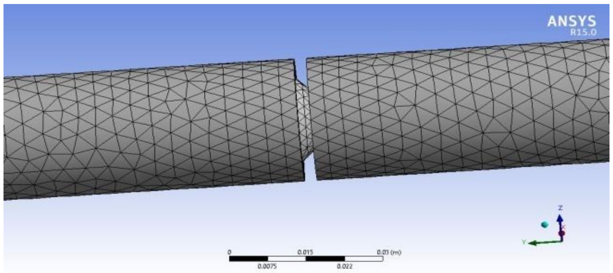

Fig. 3 Meshing of orifice meter

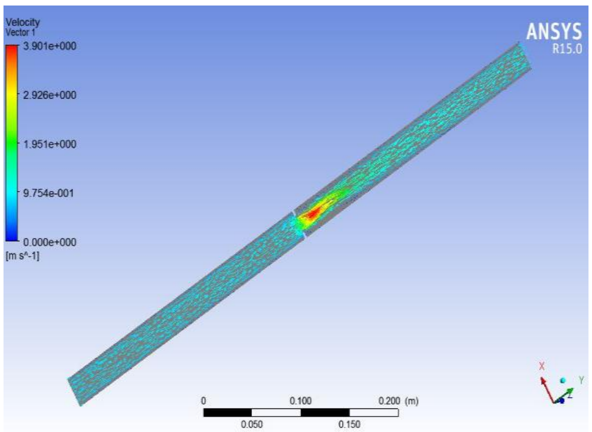

Fig. 4 Velocity vector plot
(For Q =5.12e-4 m^3/s)

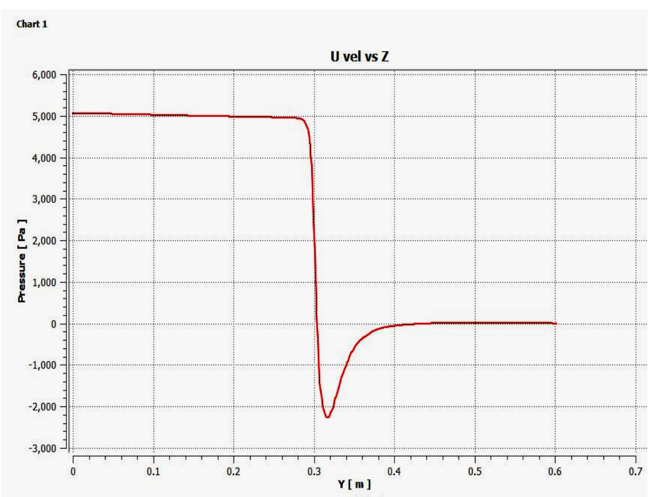

Fig. 5 Pressure plot
(For Q =5.12e-4 m^3/s)

V. RESULTS AND DISCUSSION

Pressure drops in orifice meter at various flow rate were calculated by experiments, theory and simulation. The comparison of pressure drop results from experiment, theory & simulation for orifice meter is shown in Table 2. Figure 6 shows graph of volumetric flow rate vs. pressure drop and it can be seen that the pressure drop increases with increase in flow rate. Based on this comparison, it was found that the results of theory and simulation are in good agreement with experimental results.

Table 2 Comparison of results

Ex. No.	Pressure Drop (Pa)		
	Experiment	Theory	Simulation
1	5175.88	5164.63	5187.71
2	7763.82	7671.29	7876.78
3	9858.81	9543.72	9856.50
4	10474.99	10441.48	10739.50
5	10721.46	10672.22	11031.30
6	13925.58	13118.36	13443.00
7	16883.22	16386.60	16893.90
8	18978.22	18767.18	19236.10

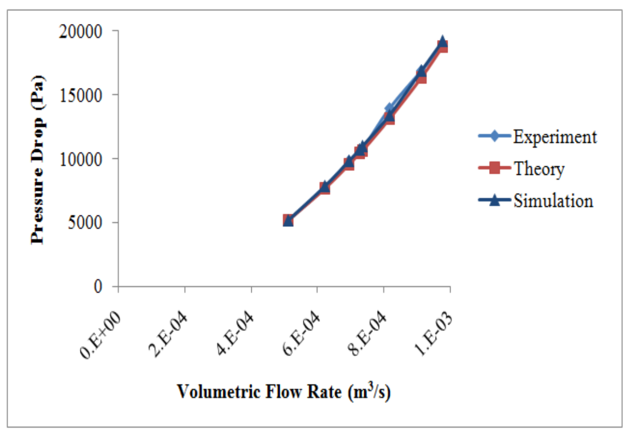

Fig. 6 Comparison of Pressure drop from Experiment, Theory and Simulation

VI. CONCLUSION

To find out pressure drop in sharp edged orifice meter, experiments were conducted at different flow rate using water as a working medium. Theoretical calculation of pressure drop was also done and Ansys CFX 15.0 was used to carry out

ISSN: 2278 – 7798

CFD analyses for each reading taken during experiments. The results of experiment, theory and simulation were compared for pressure drop and it was found that they are nearer to each other. It can be concluded that using theory and CFD analysis, pressure drop can be predicted and they can be substitute and economical tool instead of experiments.

VII. REFERENCES

[1] T. Sridevi , D. Sekhar , V. Subrahmanyam, “Comparision of flow analysis through a different geometry of flow meters using Fluent software”, International Journal of Research in Engineering and Technology, Vol. 03, Issue: 08, pp. 141-149, Aug-2014.

[2] Z.D.,Husain, “Theoretical uncertainty of orifice flow measurement”, Daniel Measurement and Control White Papers, 2010. (www.daniel.com)

[3] R. Kis, M. Janovcova , M. Malcho , J. Jandacka, “The impact of the orifice plate deformation on the differential pressure value”, EPJ Web of Conferences, 45, 01049, 2013.

[4] M. S. Shah , J. B.Joshi, A. S. Kalsi, C. S. R. Prasad, D. S. Shukla, “Analysis of flow through an orifice meter: CFD simulation” Chemical Engineering Science, Vol. 71, pp. 300–309, 2012.

[5] S. H. Kim and J. Yoon, “Comparison of Turbulence Models for Simulation of Flow around an Orifice Flowmeter”, Transactions of the Korean Nuclear Society Autumn Meeting, Gyeongju, Korea, November 2-3, 2006.

ISSN: 2278 – 7798