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Effect of Geometrical Parameters of Venturimeter on Pressure Drop

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ABSTRACT

A Venturimeter is basically a differential pressure type flow meter which is used to measure the volumetric flow rate of fluids. Certain amount of pressure drop occurs in pipeline due to the reduction in flow passage in these types of flow meters. For designing flow meters, minimum pressure drop is a required condition. This pressure drop depends on various geometrical parameters of flow meters and properties of the fluid. In the present work, Computational Fluid Dynamics (CFD) has been used to investigate the effect of different geometrical parameters like convergent cone angle, divergent cone angle, diameter ratio and throat length on pressure drop in Venturimeter. Effect of each parameter has been checked by varying one parameter and keeping three parameters constant at a time. From simulation results, it was found that pressure drop fluctuates with increase in convergent cone angle, divergent cone angle and throat length while reduces with increase in diameter ratio.

Keywords: Venturimeter, CFD, Convergent Angle, Diameter Ratio, Divergent Angle, Pressure Drop

I. INTRODUCTION

In several industries like chemical, paper, minerals processing, oil and gas, etc., accurate flow measurement and control are an important task. A Venturimeter is one of the most accurate devices for measuring the fluid flow rate using Bernoulli's principle which states that the velocity of liquid increases in direct proportion to decrease in pressure. Researchers have studied venturimeter for different purposes. Elperin et al. [1] evaluated performance of a Venturimeter in gas–liquid flow in the presence of dissolved gases for pressure drop. The venturi of the carburettor was analyzed by Kumar et al. [2] using FLUENT software for pressure drop and velocity. They were taken three variations of 30º, 40º & 45º for discharge nozzle angle. Tamhankar et al. [3] analyzed the pressure variations across the venturimeter using CFD analysis and validated results by experimentation. Kumar and San [4] investigated the effects of convergent and divergent angles on discharge coefficient and over-reading in wet gas flow measurement. They found that divergent angles have significant effect on over-reading while convergent angles have influential effect on discharge coefficient. Huang et al. [5] used CFD technique to analyze relationship among the throat length, throat diameter, slot diameter and suction capacity of venturi injector. The results revealed that with keeping the inlet pressure and the slot position constant, the suction capacity of venturi injector increases with the decrease of throat diameter and throat length and the increase of slot diameter. Bharani et al. [6] evaluated performance characteristics of an eccentric venturimeter with elongated throat for flow measurement of solid-liquid mixture and it was found that discharge coefficient is slightly higher for slurry flow compared to pure water flow. Vijay and Subrahmanyam [7] compared four different models of venturimeter to analyze the velocity, pressure, turbulence and mass flow rate using CFD method. The performance evaluation of non-ISO standard venturimeter for viscous flow was done by Karthik and Seshadri [8]. They have predicted discharge coefficient for different Reynolds numbers using STAR CCM + CFD program. Literature shows lack of information for optimum dimensions of venturimeter for minimum pressure drop. So, in this work, effect of different geometrical parameters of venturimeter on pressure drop is analyzed using Ansys CFX 15.0 software.

II. METHODS AND MATERIAL

1. CFD Methodology

Computational Fluid Dynamics technique is used to analyze effect of different geometrical parameters on pressure drop in venturimeter. Water is used as a working fluid and flow is assumed as steady and incompressible.

A. Flow Domain

The venturimeter consists three basic parts: convergent cone, throat and divergent cone. The flow domain chosen for the analysis is shown in Fig. 1. It consists of a pipe of 28mm diameter in which a venturimeter is fitted at a distance of 100mm from the inlet. The geometrical parameters of venturimeter and their levels considered in this work are shown in Table 1. The meshing of the flow domain of venturimeter is shown in Fig. 2. Using automatic volume mesh generation tool, this domain was meshed with tetrahedral elements.

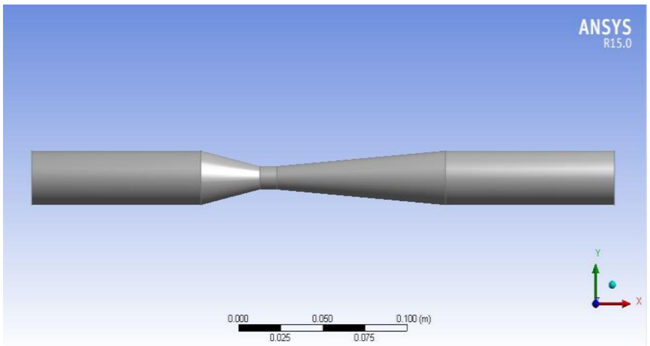

Figure 1: 3D Model of flow domain (For θ_1=17º, θ_2=11º, β=0.55, l=0.028mm)

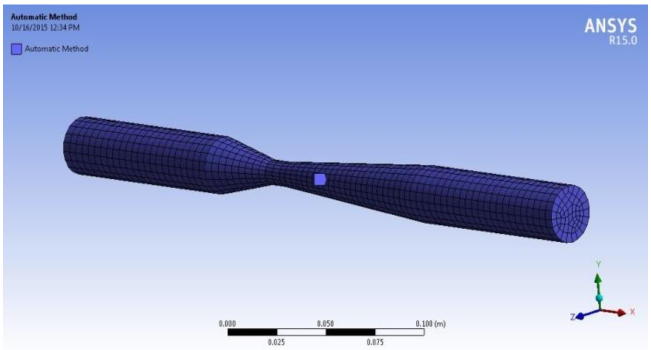

Figure 2: Meshing of flow domain (For θ_1=17º, θ_2=11º, β=0.55, l=0.028mm)

B. Boundary Conditions

The various boundary conditions specified for the flow domain are as follows:

- At the inlet of pipe, the constant velocity of 0.78 m/s was specified.
- On the pipe wall as well as orifice surface, “No Slip Wall” boundary condition was used.
- At the outlet of pipe, the gauge pressure was specified as zero.

III. RESULTS AND DISCUSSION

By varying one parameter and keeping three parameters constant at a time, different geometries were analyzed by CFD analysis to investigate their effects on pressure drop. The velocity vector plot and pressure drop graph are shown in Figure 3 and 4 respectively. Table 2 shows pressure drop results for all geometries of venturimeter. Figure 5, 6, 7 & 8 represents graph showing effect of convergent cone angle, divergent cone angle, diameter ratio and throat length on pressure drop respectively.

Table 1: Geometrical parameters and their levels

Sr. No.	Parameters	Units	Levels				
1	Convergent cone angle (θ_1)	degree	17	19	21	23	25
2	Divergent cone angle (θ_2)	degree	7	9	11	13	15
3	Diameter ratio (β)	-	0.35	0.45	0.55	0.65	0.75
4	Throat length (l)	mm	0.007	0.021	0.028	0.042	0.049

Table 2: Result of Analysis

Sr. No.	Convergent cone angle (θ_1)	Divergent cone angle (θ_2)	Diameter ratio (β)	Throat length (l)	Pressure drop (Pa)
1	17	11	0.55	0.028	153578.2
2	19	11	0.55	0.028	156567
3	21	11	0.55	0.028	153723
4	23	11	0.55	0.028	160428.2
5	25	11	0.55	0.028	158546.4
6	21	7	0.55	0.028	158805.6
7	21	9	0.55	0.028	158495.5
8	21	11	0.55	0.028	153723
9	21	13	0.55	0.028	158646.3
10	21	15	0.55	0.028	158598.8
11	21	11	0.35	0.028	1012448
12	21	11	0.45	0.028	361971.4
13	21	11	0.55	0.028	153723
14	21	11	0.65	0.028	78229.6
15	21	11	0.75	0.028	41925
16	21	11	0.55	0.007	160196.6
17	21	11	0.55	0.021	158317.8
18	21	11	0.55	0.028	153723
19	21	11	0.55	0.042	1583248
20	21	11	0.55	0.049	157969

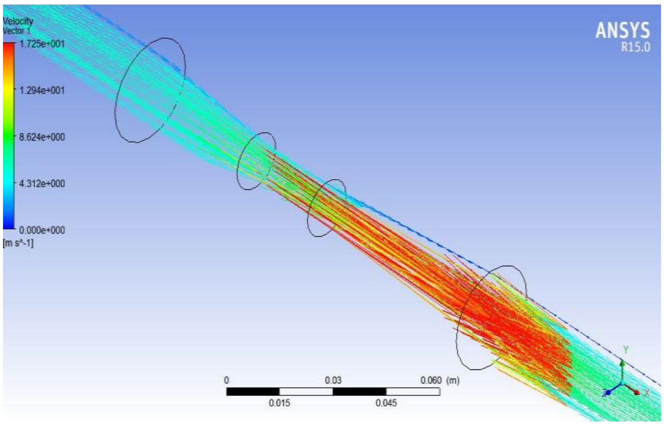

Figure 3: Velocity vector plot (For θ_1=17º, θ_2=11º, β=0.55, l=0.028mm)

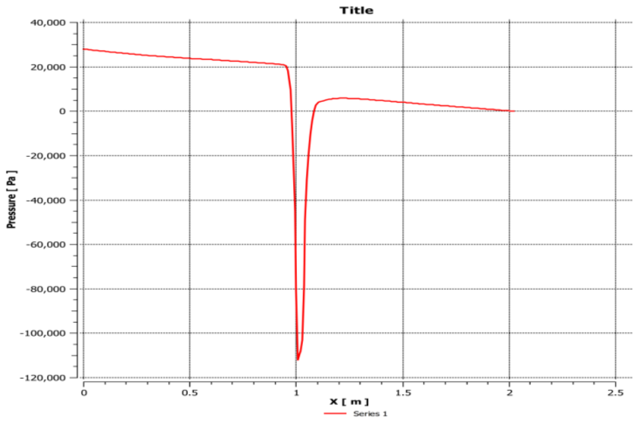

Figure 4: Pressure drop graph (For θ_1=17º, θ_2=11º, β=0.55, l=0.028mm)

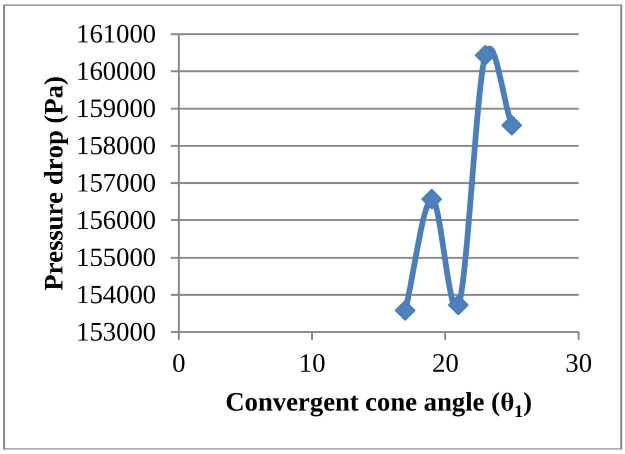

Figure 5: Effect of convergent cone angle on pressure drop

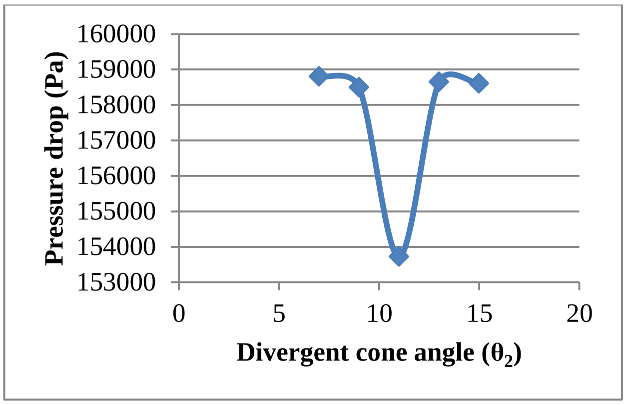

Figure 6: Effect of divergent cone angle on pressure drop

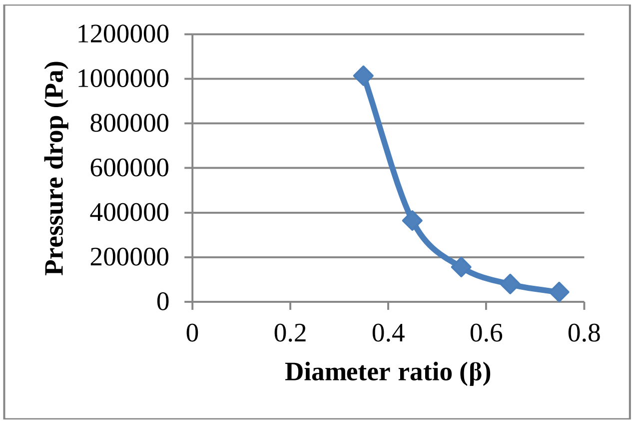

Figure 7: Effect of diameter ratio on pressure drop

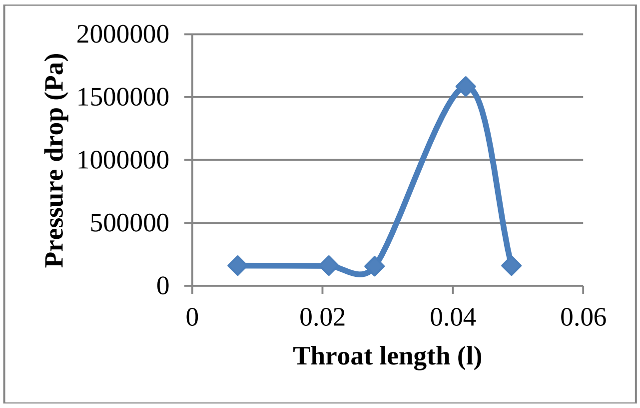

Figure 8: Effect of throat length on pressure drop

IV. CONCLUSION

Effect of different geometrical parameters of venturimeter like convergent cone angle, divergent cone angle, diameter ratio and throat length on pressure drop have been analyzed using Ansys CFX 15.0 commercial code. Different geometries of venturimeter were made by varying one parameter and keeping three parameters constant at a time. From simulation results, following conclusions can be drawn:

- By increasing convergent cone angle (θ_1), pressure drop fluctuates.
- Minimum pressure drop occurs at divergent angle (θ_2) of 11º.
- Pressure drop decreases with increase in diameter ratio (β).
- Maximum pressure drop occurs at throat length (l) of 0.042mm.

These results can be used in designing of venturimeter for particular application.

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