COMPARISION OF FLOW ANALYSIS THROUGH A DIFFERENT GEOMETRY OF FLOWMETERS USING FLUENT SOFTWARE

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Abstract

Flow meter or orifice meter are widely used in industry for flow measurement. A pressure loss takes place in the pipe line due to the restriction present in it. An amount of pressure loss occurs due to the thickness, shape and diameter of the plate. In the present paper, fluent software was used to plot the characteristics of the flow and gambit software was used to design the 2D model. Two phase computational fluid dynamics calculations, using k-Epsilon model were employed. This simulation gives the values of pressure, velocity and turbulence contour at various sections in which water as a media. The flow analysis is done on various types of flow meters namely round plate, nozzle, short tube and borda type plates. The numerical results were validated against experimental data from the literature and were found to be good agreement.

Keywords: *Gambit, Fluent, K-Epsilon model, restriction.*

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1. INTRODUCTION

Measuring the mass flow rate of a fluid running through a pipe is very important in many industries. Among the available flow metering devices, pressure differential based devices extremely applicable due to their simple design and low cost. A number of primary elements belonged to this class namely concentric orifice, eccentric orifice, wedge flow meter, venturi nozzle, and venturi meter. The selection of flow meter for given application depends upon the relative importance of measurement problems. Hence, it remains a matter of individual judgment based on engineer's knowledge and type of application. Based upon the simple principle of effect of pressure and velocity variations caused by reduction of the available area for flow in pipe. The flow meters are supplied with the discharge coefficient and the installation procedure. The discharge coefficient is defined as the ratio of actual flow to the theoretical flow. It is obtain from experimental results after regression, where in experiment are conducted in controlled condition of undistributed symmetric free velocity profile in the upstream of orifice.

Hence it is very important to understand the flow pattern of orifice meter to further improvement in its performance in terms of flow measurement with better accuracy and sensitivity.

2. DETAILED PROCEDURE

The current study used FLUENT, to solve the balance equation using control volume approach. These equations are solved by converting the complex partial differential equations into simple algebraic equations. The simple geometry is done in the GAMBIT software, a fine meshing is done by using successive ratio and later given the boundary conditions for the geometry and for the media. This file imported into Fluent software and has given the input values like velocity, mass flow rate, pressure, temperature etc.,

Two dimensional geometry was used to study the flow in the flow meters for solving the mass, momentum, and energy equations. The phase velocities were defined at the inlet boundary of the flow meters. The κ-ε turbulence models with standard wall functions were used to solve the problems. The gravitational acceleration of 9.81 m/s^2 in downward flow direction was used.

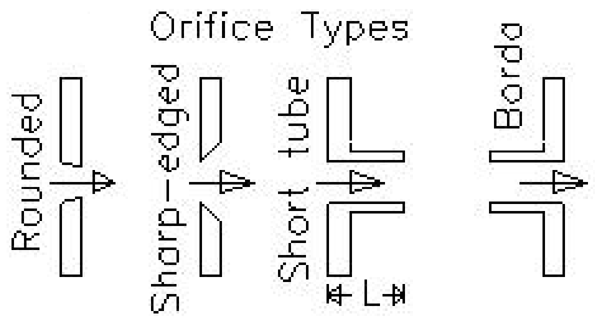

Fig-2.1: diagram of type orifice meter.

Two dimensional model is done for four different geometry namely round plate, nozzle, short tube and borda type in gambit software and simulations is done in steady state with inlet velocity of 3m/sec and at room temperature. Results are obtained for velocity, pressure and turbulence and graphs are plotted.

3. GEOMETRY DETAILS

The geometry was done in the GAMBIT with measurements, pipe diameter is 60mm, and thickness of the plate is 5mm and length of the pipe 150 mm. Defining required boundaries like inlet, outlet and wall of the geometry and mesh under tetrahedron. Defining the boundary conditions for the media as the water. The figure shows the geometry of the fluid flow through flow meters.

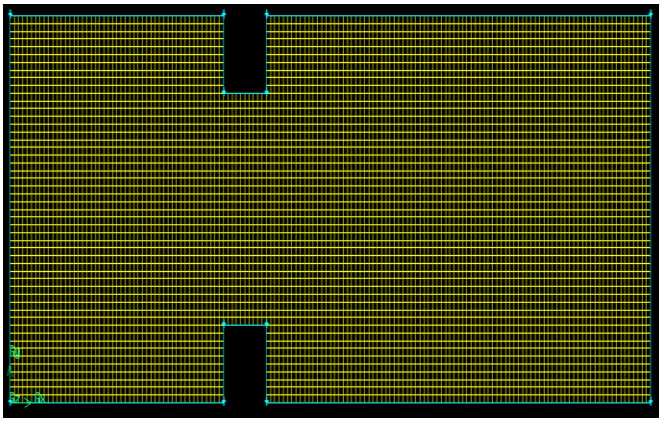

Fig- 3.1: mesh geometry of round type.

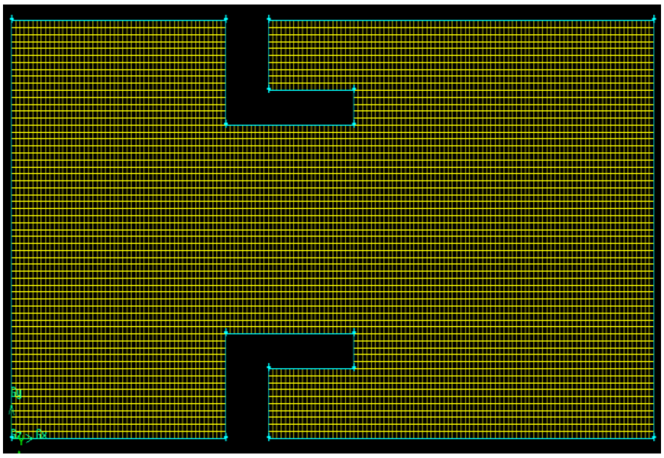

Fig- 3.2: mesh geometry of short tube.

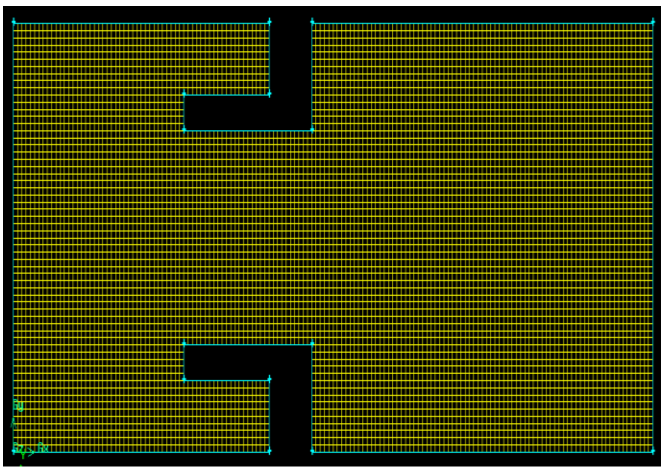

Fig- 3.3: mesh geometry of borda type.

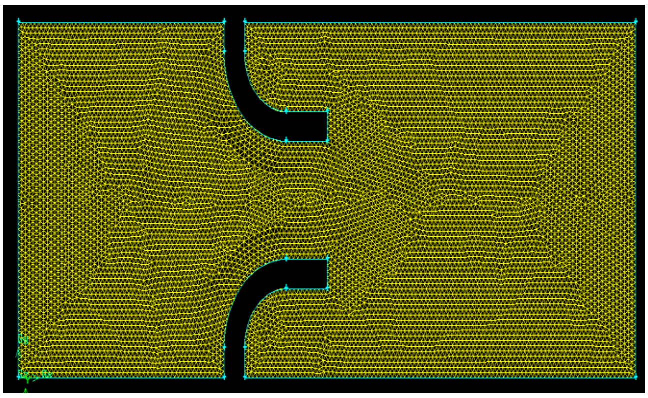

Fig- 3.4: mesh geometry of nozzle type.

4. SOLUTION STRATEGY AND CONVERGENCE

The simulation is done in the FLUENT based upon the governing equations. The steps followed in the fluent are define Model, define Material, define cell zone, boundary condition, solve, iterate, and analyze results. The governing equations used to solve this problem as below.

4.1. Continuity Equation

Continuity Equation also called conservation of mass. Consider fluid moves from point 1 to point 2.
The overall mass balance is

Input – output = accumulation

Assuming that there is no storage,

Mass input = mass output.

However, as long as the flow is steady (time-invariant), within this tube, since, mass cannot be created or destroyed then the above equation.

According to continuity equation, the amount of fluid entering in certain volume leaves that volume or remains there and according to momentum equation tells about the balance of the momentum. The momentum equations are sometimes also referred as Navier-Stokes (N-S) equation. They are most commonly used mathematical equations to describe flow. The simulation is done based on the N-S equations and then K-Epsilon model.

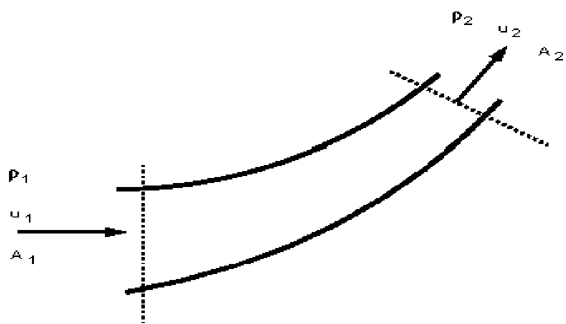

Fig- 4.1: continuity equation.

$$\dot{m_1} = \dot{m_1} \qquad (1)$$

$$\frac{dm_1}{dt} = \frac{dm_1}{dt} \qquad (2)$$

$$\rho A_1 u_1 = \rho A_2 u_2 \qquad (3)$$

$$A_1 v_1 = A_2 v_2 \qquad (4)$$

4.2. Momentum Equation and Bernoulli Equation:

It is also called equation of motion .According to Newton's 2nd law (the time rate of change of momentum of the fluid particles within this stream tube slice must equal to the forces acting on it).

F = mass x acceleration

Consider a small element of the flowing fluid as shown below, Let

dA : cross-sectional area of the fluid element,
dL : Length of the fluid element,
dW : Weight of the fluid element,
u : Velocity of the fluid element,
P : Pressure of the fluid element.

Assuming that the fluid is steady, non-viscous (the frictional losses are zero) and incompressible (the density of fluid is constant).

The forces on the cylindrical fluid element are,
1. Pressure force acting on the direction of flow (PdA).

2. Pressure force acting on the opposite direction of flow [(P+dP)dA].

3. A component of gravity force acting on the opposite direction of flow (dW sin θ).

Hence, Total force = gravity force + pressure force

The pressure force in the direction of low

Fp = PdA – (P+dP) dA = – dPdA (5)

The gravity force in the direction of flow

Fg = – dW sin θ {W=m g = ρ dA dL g}.
= – ρ g dA dL sin θ {sin θ = dz / dL}.
= – ρ g dA dz. (6)

The net force in the direction of flow

F = m a {m = ρ dA dL .
= ρ dA dL a.
= ρ dA u du. (7)

We have
ρ dA u du = – dP dA – ρ g dA dz {÷ ρ dA }
⇒ dP/ ρ + udu + dz g = 0 --------- Euler's equation of motion.

Bernoulli's equation could be obtain by integration the Euler's equation.
∫dP/ ρ + ∫udu + ∫dz g = constant.
⇒ P/ ρ + u2/2 + z g = constant.
⇒ ΔP/ ρ + Δu2/2 + Δz g = 0 -- Bernoulli's equation.

4.3. Kappa-Epsilon Model

The K-epsilon model is most commonly used to describe the behavior of turbulent flows. It was proposed by A.N Kolmogrov in 1942, then modified by Harlow and Nakayama and produced K-Epsilon model for turbulence.

The Transport Equations for K-Epsilon model are for k,

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial t}(\rho k u_i) = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right] + P_k + P_b - \rho\epsilon - Y_k + S_k$$

(8)

For,

$$\frac{\partial}{\partial t}(\rho \epsilon) + \frac{\partial}{\partial t}(\rho \epsilon u_i) = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial \epsilon}{\partial x_j}\right] + C_{1\epsilon}\frac{\epsilon}{k}(P_k + C_{3\epsilon}P_b) - C_{2\epsilon}\rho\frac{\epsilon^2}{k} + +S_\epsilon$$

(9)

Realizable k-epsilon model and RNG k-epsilon model are some other variants of K-epsilon model. K-epsilon model has solution in some special cases. K-epsilon model is only useful in regions with turbulent, high Reynolds number flows.

5. RESULTS

5.1 Results of Round Type Flow Meter

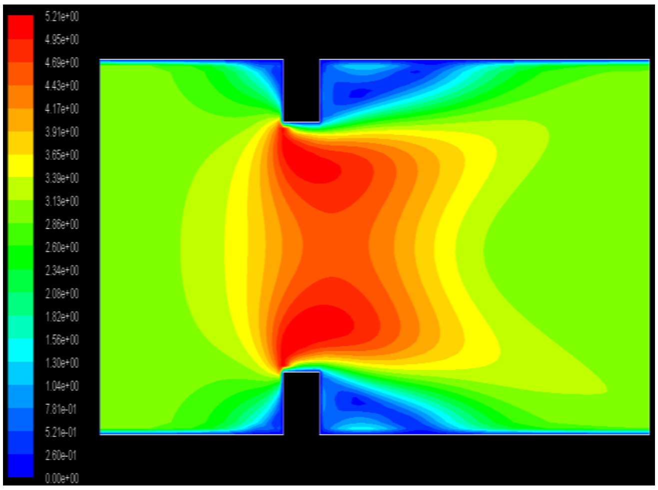

Fig- 5.1.1: velocity contours.

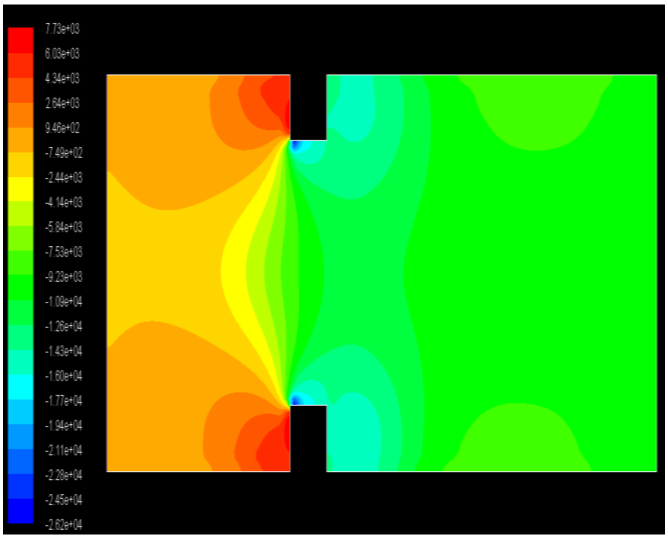

Fig- 5.1.2: pressure contours.

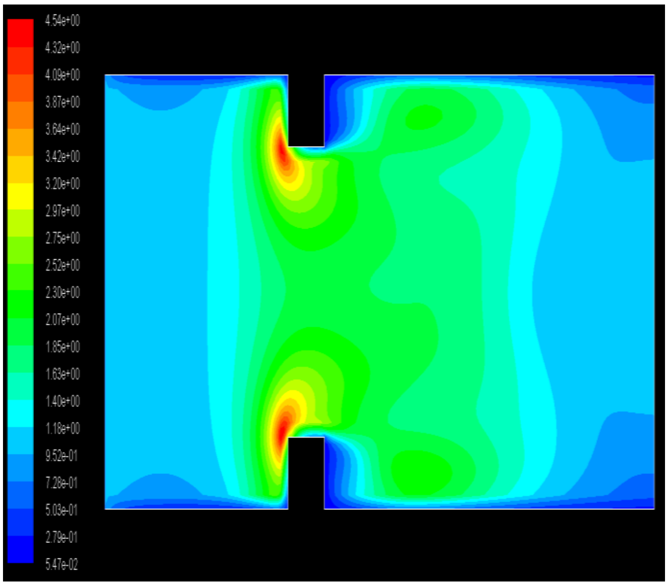

Fig- 5.1.3: turbulent contours.

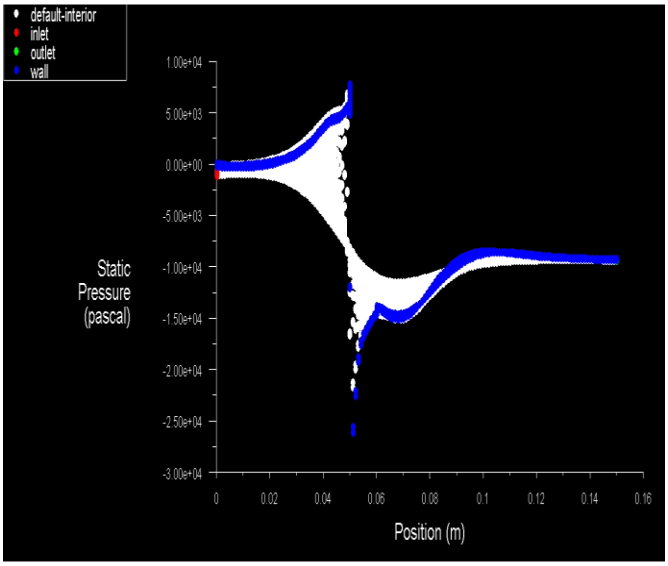

Chart-5.1.1: Pressure-position.

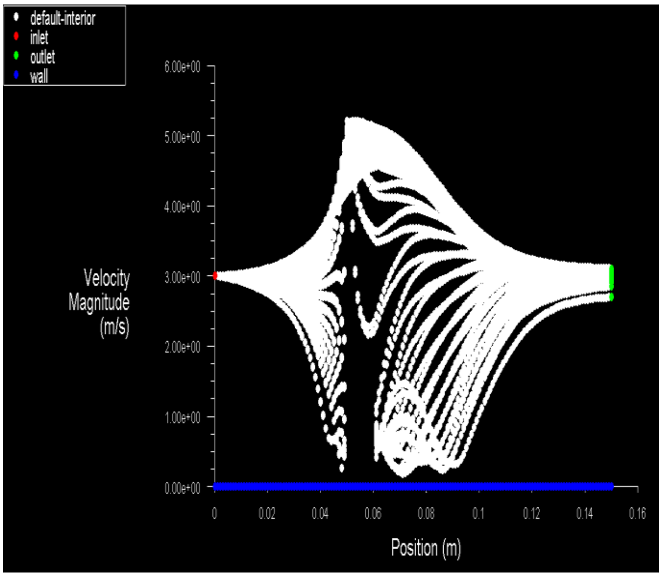

Chart-5.1.2: Velocity-position.

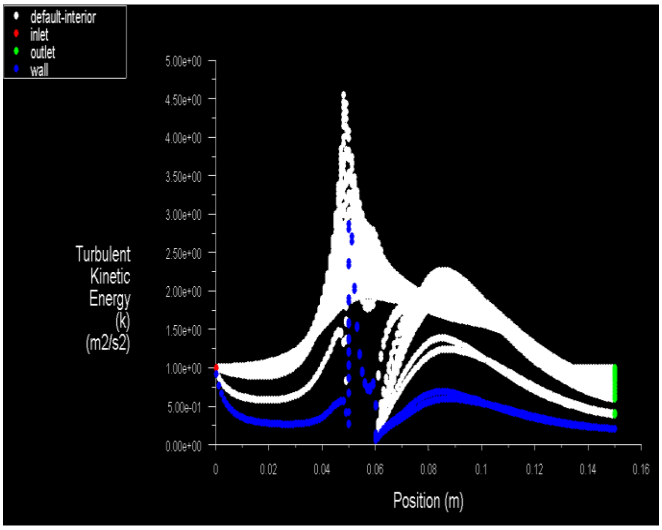

Chart-5.1.3: turbulence-position.

Table-5.1.1: results of flow analysis.

s.no	parameters	Min.	Max.
1	Pressure(Pascal)	-26180.56	7727.657
2	Velocity(m/s)	0	5.208365
3	Turbulent(m^2/s^2)	0.054719	4.5418

Table-5.1.2: results of mass flow rate.

Mass Flow Rate	(kg/s)
Interior	-5569.2096
Inlet	179.67601
Outlet	-179.67601
Wall	0

5.2 Results of Short Tube Type Flow Meter

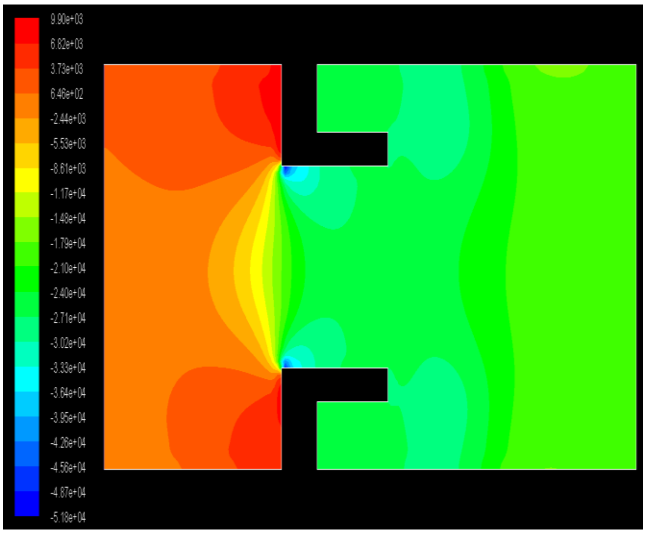

Fig- 5.2.1: Pressure Contours.

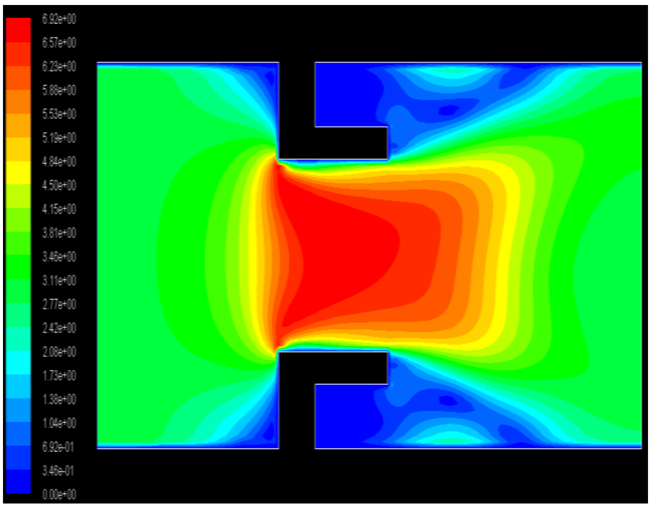

Fig- 5.2.2: Velocity Contours.

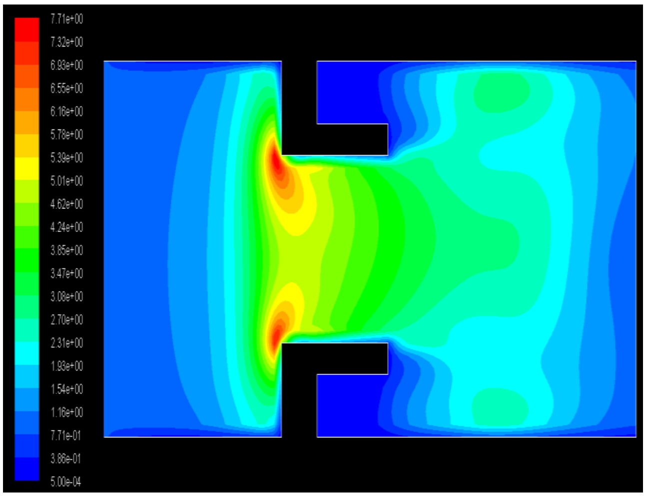

Fig- 5.2.3: Turbulent Contours.

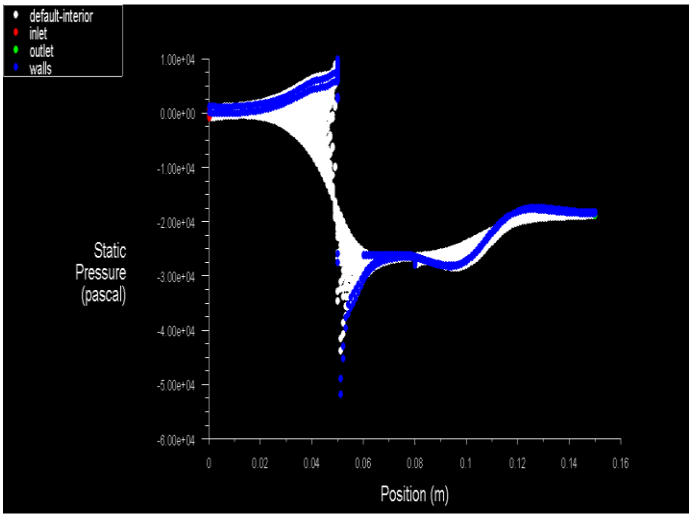

Chart-5.2.1: Pressure-Position.

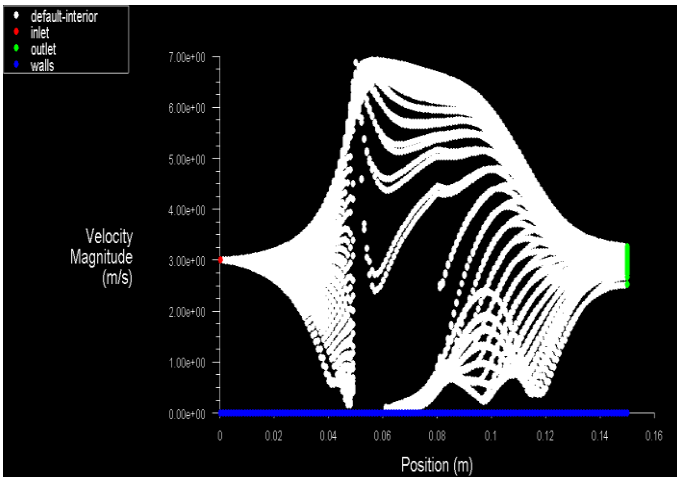

Chart-5.2.2: Velocity-Position.

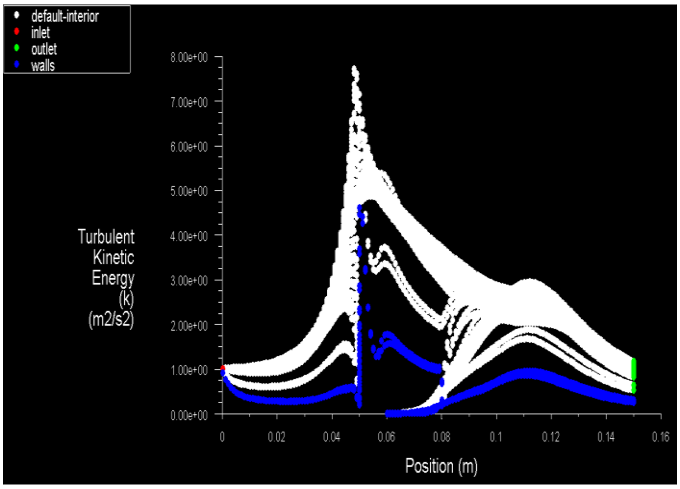

Chart-5.2.3: Turbulence-Position.

Table-5.2.1: results of flow analysis.

s.no	parameters	Min.	Max.
1	Pressure(Pascal)	-51817.77	9904.737
2	Velocity(m/s)	0	6.918732
3	Turbulent(m^2/s^2)	0.00050	7.705388

Table-5.2.2: results of mass flow rate.

Mass Flow Rate	(kg/s)
Interior	1169.6085
Inlet	179.67601
Outlet	-179.67601
Wall	0

5.3 Results of Borda Type Flow Meter:

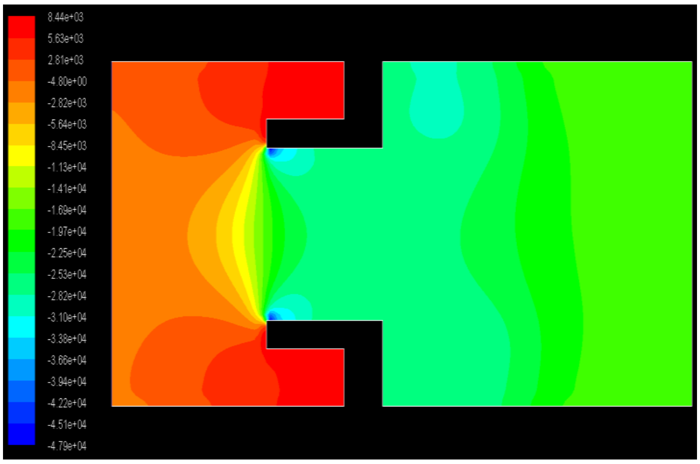

Fig- 5.3.1: Pressure Contours.

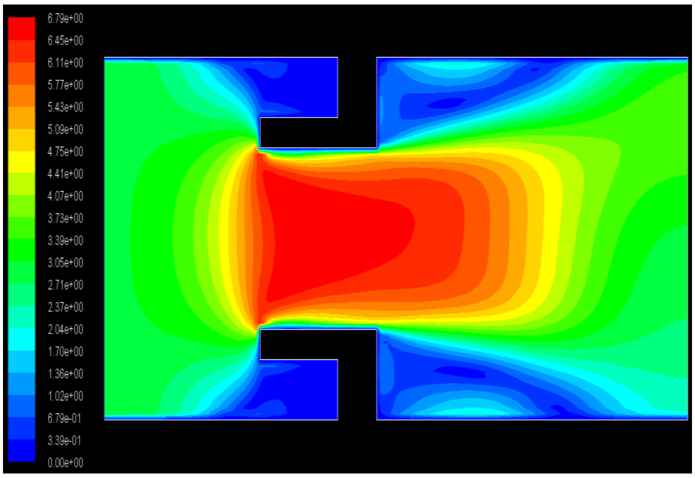

Fig- 5.3.2: Velocity Contours.

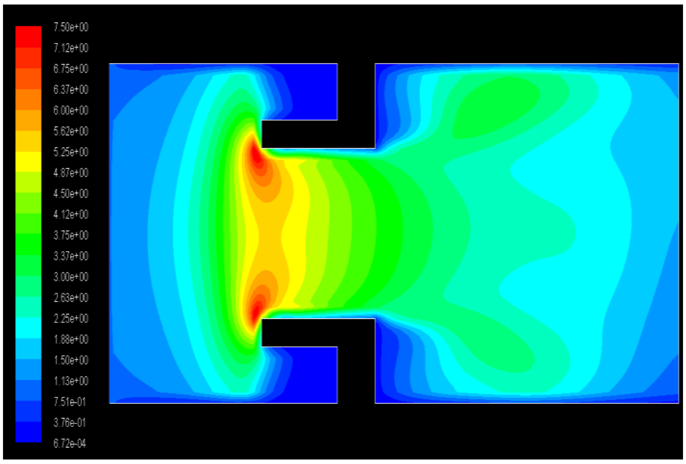

Fig- 5.3.3: Turbulent Contours.

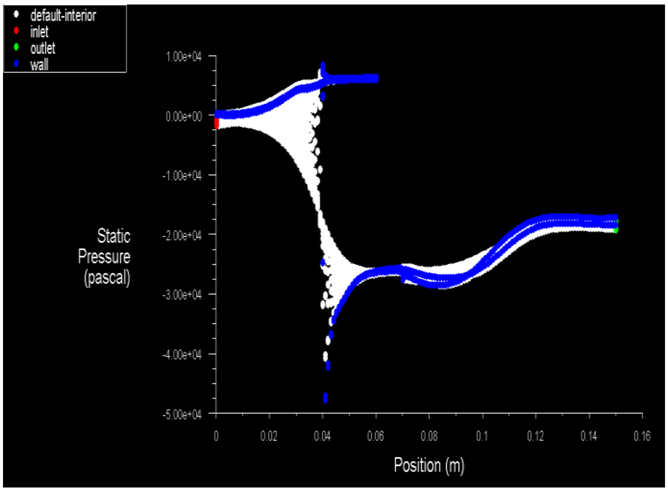

Chart-5.3.1: Pressure-Position.

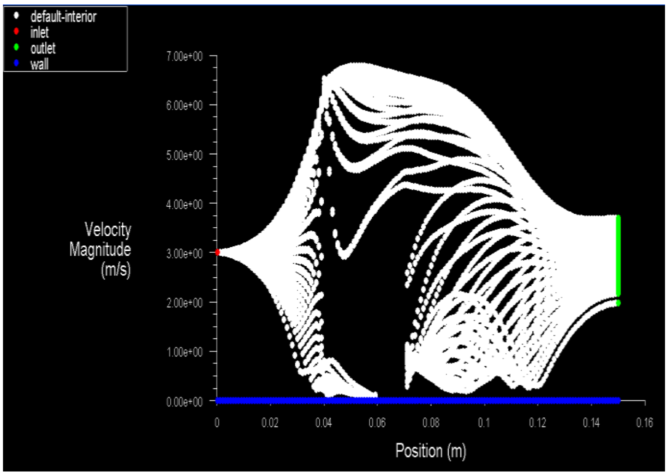

Chart-5.3.2: Velocity-Position.

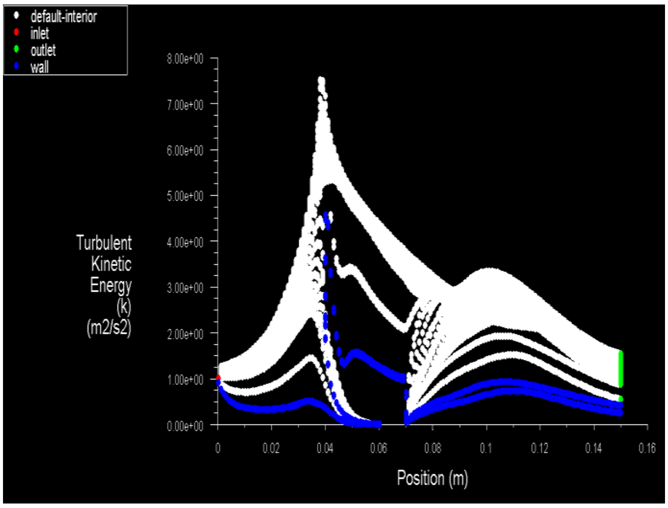

Chart-5.3.3: Turbulence-Position.

Table-5.3.1: results of flow analysis.

s.no	parameters	Min.	Max.
1	Pressure(Pascal)	-47866.36	8441.355
2	Velocity(m/s)	0	6.78514
3	Turbulent(m^2/s^2)	0.0006724	7.499114

Table-5.3.2: results of mass flow rate.

Mass Flow Rate	(kg/s)
Interior	-2036.7402
Inlet	179.67601
Outlet	-179.67601
Wall	0

5.4 Results of Nozzle Type Flow Meter:

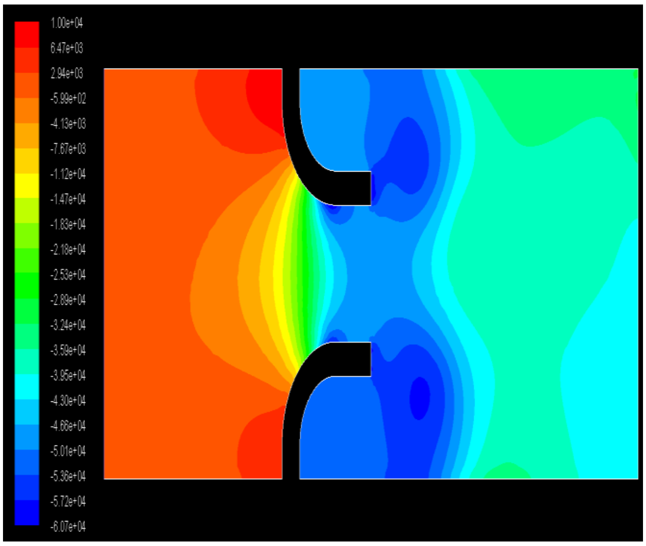

Fig- 5.4.1: Pressure Contours.

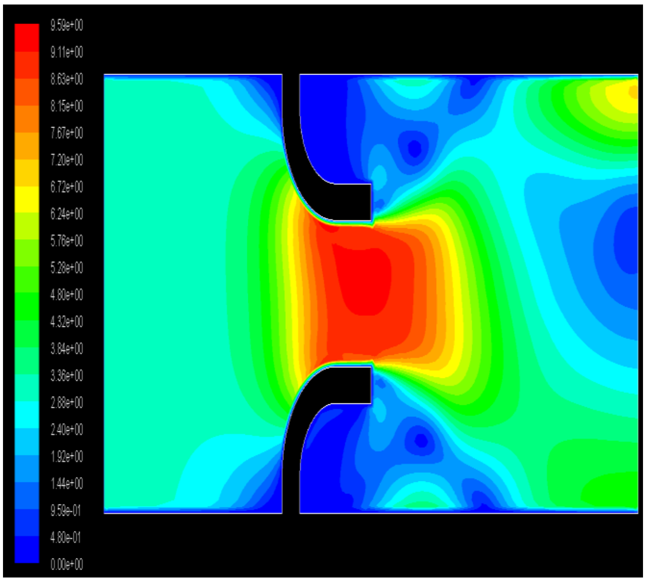

Fig- 5.4.2: Velocity Contours.

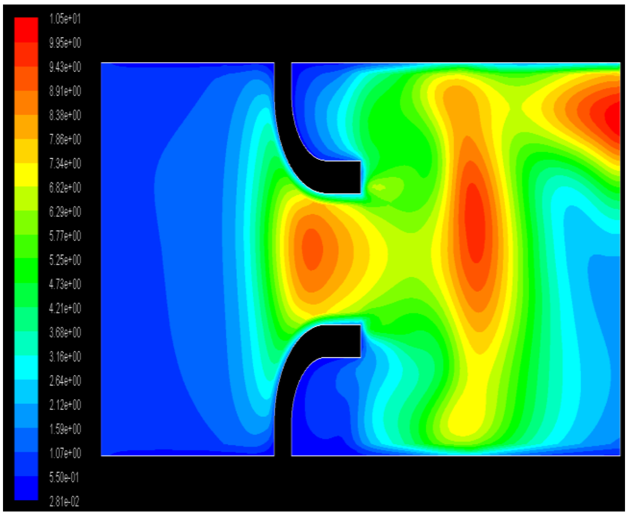

Fig- 5.4.3: Turbulent Contours.

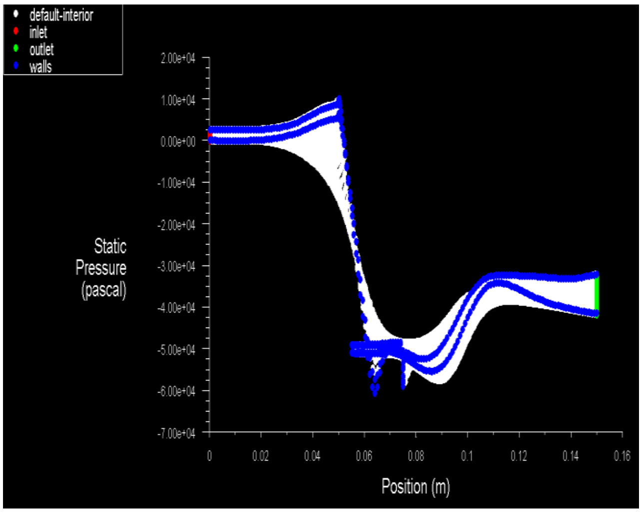

Chart-5.4.1: Pressure-Position.

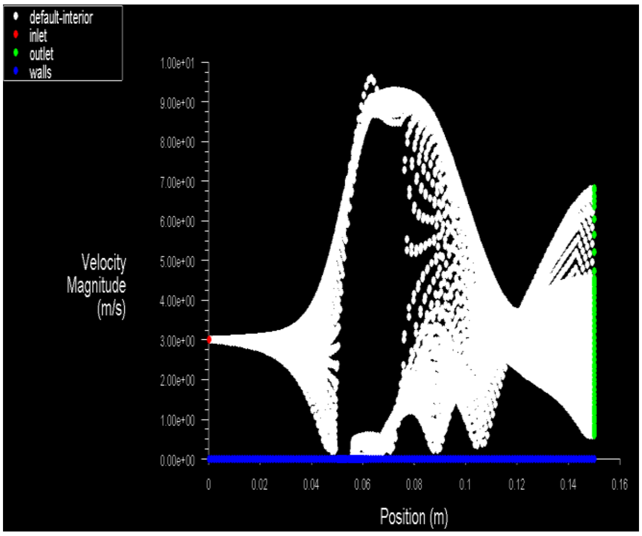

Chart-5.4.2: Velocity-Position.

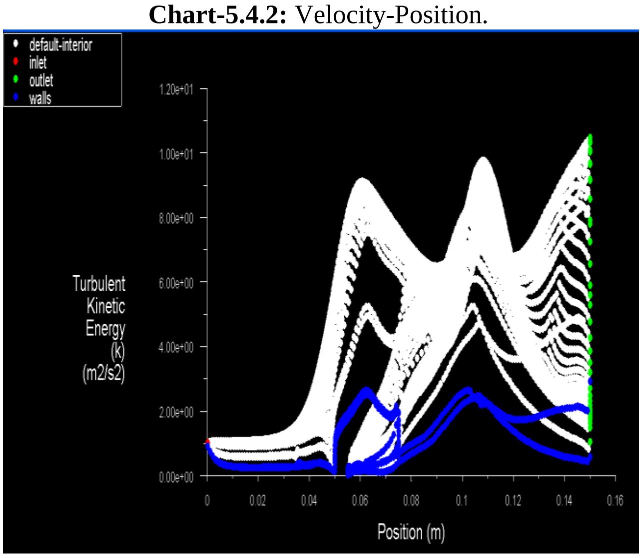

Chart-5.4.3: Turbulence-Position.

Table-5.4.1: results of flow analysis.

s.no	parameters	Min.	Max.
1	Pressure(Pascal)	-60693.42	10006.32
2	Velocity(m/s)	0	9.59358
3	Turbulent(m^2/s^2)	0.028088	10.4724

Table-5.4.2: results of mass flow rate.

Mass Flow Rate	(kg/s)
Interior	1209.1305
Inlet	179.67601
Outlet	-179.67601
Wall	0

6. CONCLUSIONS

The flow pattern through an flow meter has been simulated for four different models, successfully, using CFD technique using fluent 6.3.26 solver. A good agreement between experimental data and CFD predictions flow patterns, pressure profile, velocity profile, turbulence model parameter and mass flow rate. It is also concluded that the CFD technique can be used as an alternative and cost effective tool to wards replacement requirement for estimating mass flow rate.

The design of a flow meter with a provision to track vena contracta using CFD technique has been explained. As per the application, selection of flow meters can be done and the behaviours of the flow pattern are plotted for four different models.

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