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Finite Element Analysis of different shape slottedorifice Plate

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Abstract

The slotted orifice meter is one such version of the standard design found to be better performing by several researchers. Slotted design was reported to be substantially less sensitive to upstream flow conditions and generating a smaller permanent head loss compared to the standard orifice with the samebeta ratio. Static pressure recovery was also found to be faster than the standard orifice. Thus, in the present work a CFD simulation for comparison and analysing the effect of different design of slots forthe metering characteristics of slotted orifice plate. An attempts has been made to simulate the flow pattern for orifice with the help of Computational Fluid Dynamics (CFD). Different slot shape has been considered for the analysis. The discharge coefficient, pressure drop, turbulent kinetic energy, turbulenteddy dissipation rate and velocity are the prime considered parameters for the comparison.

Keywords: Orifice Plate, Rectangular perforations, Circular perforations, parabolic perforations, pressure drop, velocity distribution etc.

1. Introduction

1.1 Flow Measurement Types and Principles

Normally flow measurements refers to fluid flow measurements. In reality this is not the case, there aremany other types of flow, such as solid flow (in cement industries, food industries), multiphase flow (in oil exploration and chemical plants), and slurry flow (in mineral processing), which are important for many industrial applications. Although many of the technologies used in fluid flow are also applicable to slurry/multiphase flow measurements they are treated separately. So, flow measurementsare first categorized as shown in Fig. 1.1.

Based on Fig. 1.1, the discussions on various types of flow-measuring systems are presented. Under fluid flow measurement, flow measurements of both incompressible and compressible fluids are covered. The necessary fluid mechanics have already been covered in the previous section.

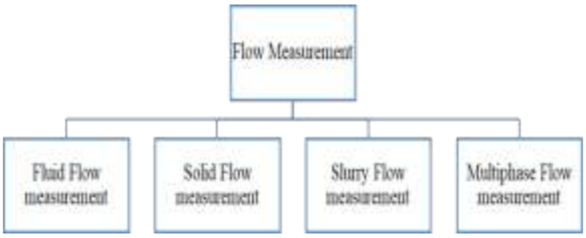

Figure 1.1 Basic flow measurement categories.

Fluid Flow Measurement Types and Principles

Fluid flow metering in a closed pipe can be classified into four classes: inferential, positive displacement, velocity, and mass. However, this is not sacrosanct. When an open-channel flow measurement (frequently encountered in irrigation) is taken into consideration they can be categorized differently, such as differential pressure (head type), positive displacement, velocity, mass, variable area types, and open-channel flow measurement. Some even subcategorize them into mechanical and electrical types.

Orifice Plate

Of the various types of head flow meters, the orifice plate is the most common. This is basically a machined metal plate with a round hole or orifice, through which fluids flow. The integral metal tab, often referred to as the tongue, where details of the plate size, thickness, serial number, etc. are embossed, facilitates orifice installation. Orifice plates cover a wide range of applications of fluid and operating conditions. Orifice plates offer acceptable uncertainties at comparatively lower cost.

The orifice plate is manufactured from sheet metal. It is a flat circular plate with an outer diameter greater than the inner diameter of the process pipe into which it is to be fitted. A circular/segmental holeis drilled into it, this is the orifice.

There are a number of ways in which orifice plates can be classified. They can be classified by functionand/or use. There are mainly four types of orifice plates. These are:

- Measuring orifice plate;
- Integral orifice;
- Senior orifice;
- Restriction orifice.

These divisions are not strictly accurate; other than the restriction orifice (RO), all the other types are deployed for measurement purposes. Senior and integral orifice plates are intentionally kept separate from measuring orifices as they have special purposes and uses, as well as construction differences.

Types of measuring orifice: From a construction point of view orifice plates for measurement can be divided into the following:

Concentric orifice: As the name implies, this has its hole or orifice concentric with the main thin circular plate. Concentric orifice plates represent the majority of plates used in all orifice-based devices. They must have an upstream edge that is very sharp and square. The thickness and material are guidedby the flow conditions and the fluid that it has to handle. There are a number of varieties:

Concentric square edge: These are applied for measurement of flow of clean, low viscosity liquids, gases, and dry steam at Reynolds numbers in the turbulent regime. The bore is sharp-edged on the inletand parallel or chamfered on the outlet, based on the beta ratio and thickness. Depending on the designconditions it can offer upto ±0.5%full-scaledivision (FSD) accuracy.

Concentric conical: Concentric conical entry orifice plates have a bore with a conical inlet section anda parallel outlet section. This type of orifice plate design can maintain accuracy even at low Reynolds numbers and can be used to measure the flow of low-density gases and/or clean liquids at high viscosity.These can offer an accuracy of 2% FSD and are available in various sizes from 25 to 600 mm.

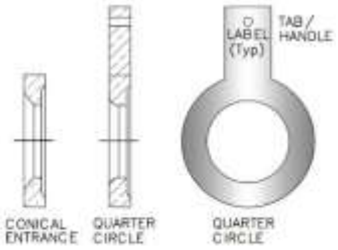

Figure 1.2 Some other orifice types.

2. Literature Review

Haitham Osman et. al. presented as study to find the optimal shape of an orifice plate that reduces the pressure loss. To reach this goal, the adjoint method was used to reshape the sharp-edged orifice plate. Moreover, surrogate-based optimization was employed to determine the optimal parameters of interest that control the flow through orifice meter. The optimal shape of the orifice plate using the adjoint method shows 55 % reduction in the pressure loss coefficient at a Reynolds number Re = 1.84 × 104. Besides, the effect of inserting a downstream ring was investigated.

Muhammad Asim Mehmood et. al. presented the study on the use of multi-holed orifice plate for measuring flow rate is a growing area of research. As compared to standard orifice plate, multi-holed orifice plates (MO) have number of advantages, such as, these plates require minimum straight piping at the upstream without compromising the pressure losses and provide better accuracy in the measurement of flow rates. In this study, a systematic methodology is adopted for investigating the effect of different geometrical parameters on pressure loss coefficient and values of parameters under investigation varied using central composite design. The geometrical parameters chosen for the study are: (a) Number of holes; (b) Multi-hole Diameter ratio and (c) Compactness of holes.

3. Research Methodology

Geometry

Flow predictions were carried out to study the performance of different geometrical orifice flow meters consisting of a 5 mm plate with β = 0.40 in a horizontal pipe (equivalent to an inner diameter of 105.74mm).

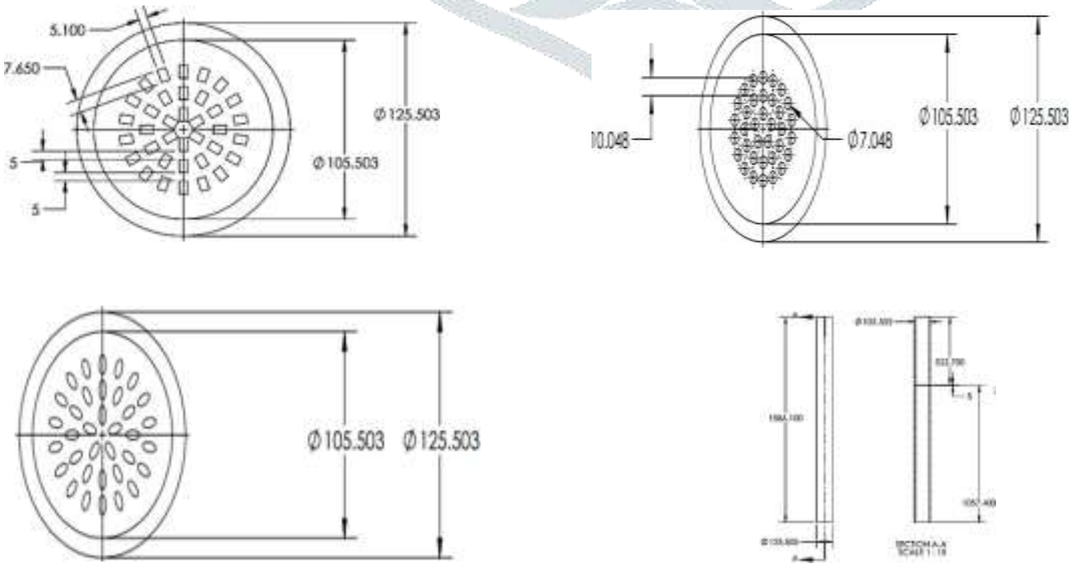

Figure 3.1 Geometry of general structure of the (a) rectangular, (b) circular (c) elliptical orifices (d)Orifice meter used in the flow investigation

Computational Mesh

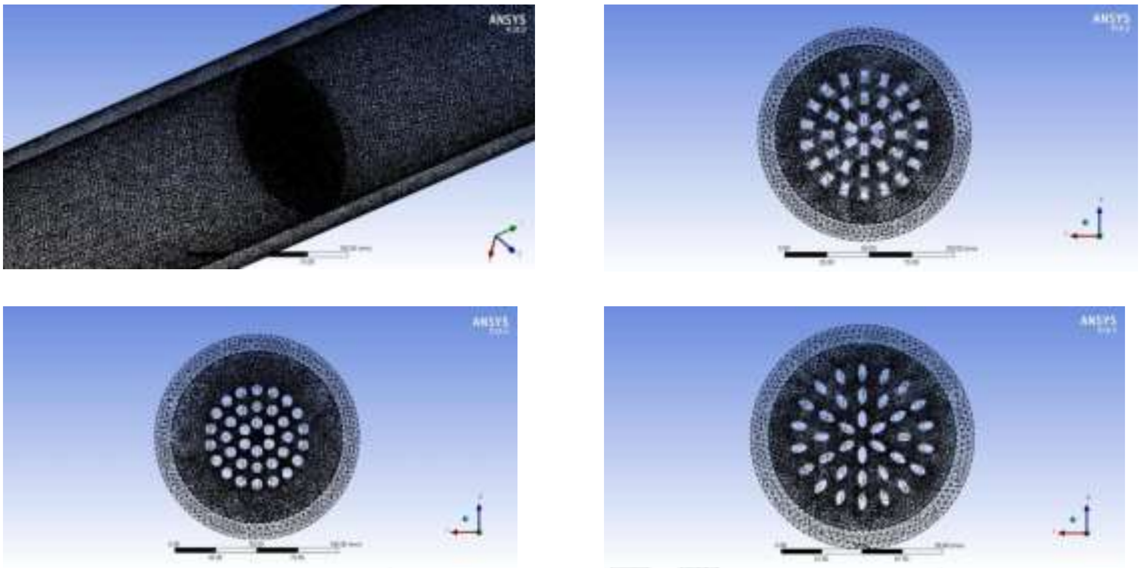

Figure 3.2 Meshing of Orifice Meter (a) Flow Domain (b) Rectangular Cross Section (c) CircularCross Section (d) Elliptical Cross Section

4. Results & Discussion

Results for Parabolic Slots

Figure 4.1-4.5 shows the Eddy Viscosity, Pressure, Turbulence Eddy Dissipation, Turbulence KineticEnergy and Velocity variation for parabolic slot while considering inlet pressure 2 bar.

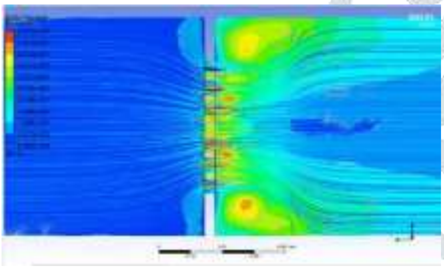

Figure 4.1 Eddy Viscosity variation for parabolic slot while considering inlet pressure 2 bar

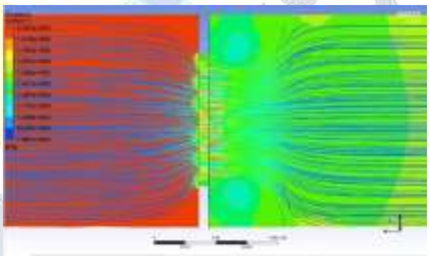

Figure 4.2 Pressure variation for parabolic slot while considering inlet pressure 2 bar

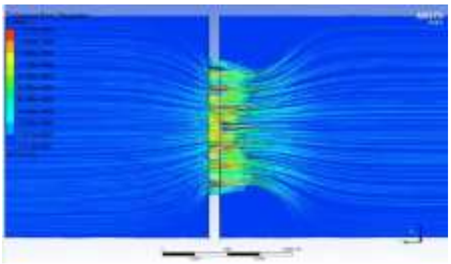

Figure 4.3 Turbulence Eddy Dissipation variation for parabolic slot while considering inlet pressure 2 bar

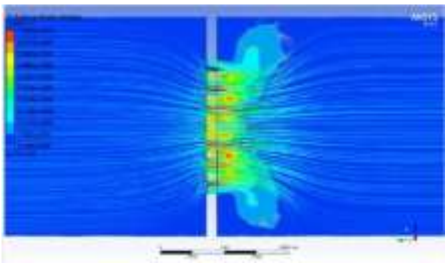

Figure 4.4 Turbulence Kinetic Energy variation for parabolic slot while considering inlet pressure 2 bar

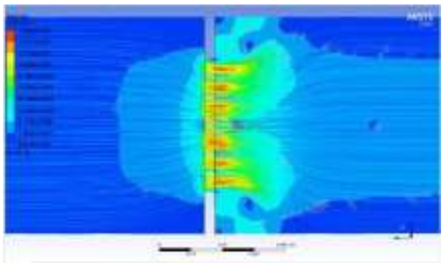

Figure 4.5 Velocity of fluid variation for parabolic slot while considering inlet pressure 2 bar

Results for Rectangular Slots

Figure 4.6-4.7 shows the Eddy Viscosity, Pressure, Turbulence Eddy Dissipation, Turbulence KineticEnergy and Velocity variation for rectangular slot while considering inlet pressure 2 bar.

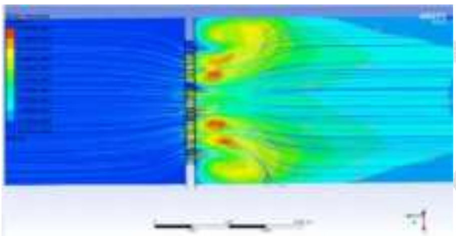

Figure 4.6 Eddy Viscosity variation for rectangular slot while considering inlet pressure 2 bar

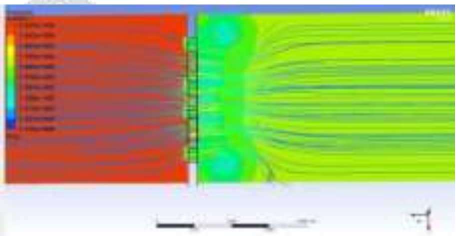

Figure 4.7 Pressure variation for rectangular slot while considering inlet pressure 2 bar

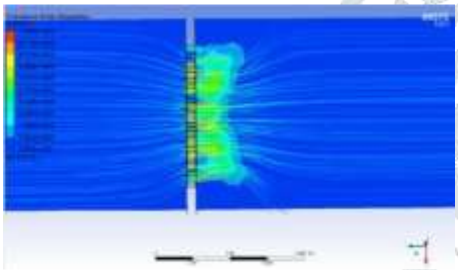

Figure 4.8 Turbulence Eddy Dissipation variation for rectangular slot while considering inlet pressure 2 bar

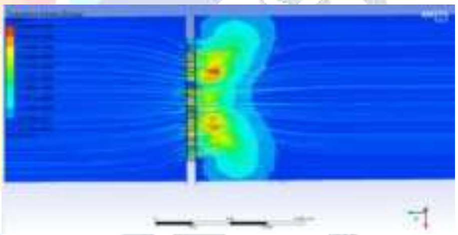

Figure 4.9 Turbulence Kinetic Energy variation for rectangular slot while considering inlet pressure 2 bar

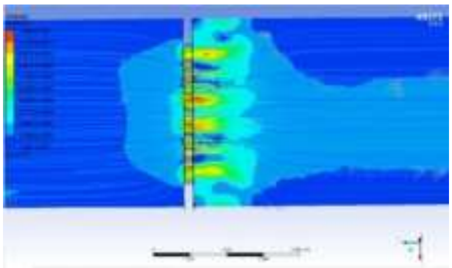

Figure 4.10 Velocity of fluid variation for rectangular slot while considering inlet pressure 2 bar

Results for Circular slots

Figure 4.11-4.15 shows the Eddy Viscosity, Pressure, Turbulence Eddy Dissipation, Turbulence KineticEnergy and Velocity variation for circular slot while considering inlet pressure 2 bar.

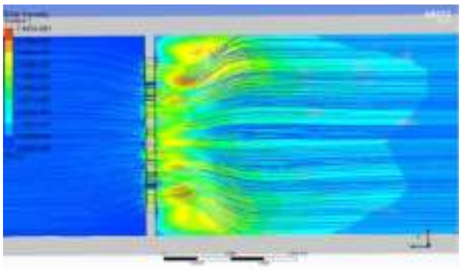

Figure 4.11 Eddy Viscosity variation for rectangular slot while considering inlet pressure 2 bar

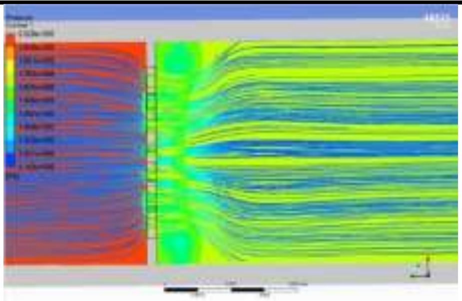

Figure 4.12 Pressure variation for rectangular slot while considering inlet pressure 2 bar

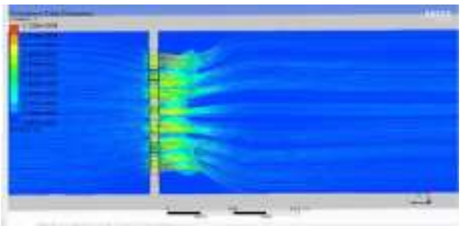

Figure 4.13 Turbulence Eddy Dissipation variation for rectangular slot while considering inlet pressure 2 bar

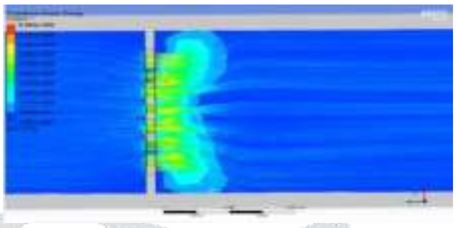

Figure 4.14 Turbulence Kinetic Energy variation for rectangular slot while considering inlet pressure 2 bar

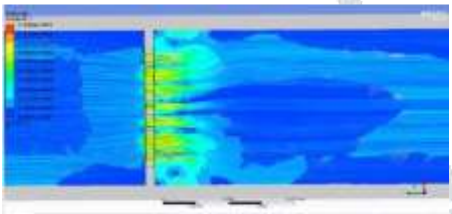

Figure 4.15 Velocity of fluid variation for rectangular slot while considering inlet pressure2 bar

5. Conclusion

An attempt has been made to simulate the flow pattern for orifice with the help of Computational Fluid Dynamics (CFD). Different slot shape has been considered for the analysis. The discharge coefficient, pressure drop, turbulent kinetic energy, turbulent eddy dissipation rate and velocity are the prime considered parameters for the comparison. Following conclusions can be made:

- Discharge coefficient is better for parabolic slot orifice meter compare than the other two.
- Rectangular and circular slotted orifice generates a smaller pressure drop than the parabolic slot orifice under the same β and same gas flow rate conditions.
- The pressure drop caused by the orifice results largely from the abrupt change in the flow passage cross-sectional area causing high level of turbulence and thus creating considerable hydraulic losses.

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