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Design, Fabrication & CFD Analysis of Multi-Hole Orifice Plate

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***Abstract*:- Compared to single-hole orifices (SOs), multi-hole orifices (MOs) have smaller orifice sizes and various patterns of orifice distribution. The geometric description of MOs is more complex, increasing the difficulty of MO structural design. Therefore, it is worthwhile to investigate the key factors affecting MO throttle or flow control characteristics and to develop a general MO design method. This work presents a practical geometric design methodology for MOs and applies this procedure in throttle experiments. To describe the MO geometry in detail, the methodology first introduces a comprehensive set of geometric architectures involving orifice arrangement criteria and geometric parameters such as the total orifice number, n; the orifice distribution density and the equivalent diameter ratio. Then, a series of throttle tests in water flow are conducted to investigate the effect of various geometric features on the pressure loss characteristics of MOs. Finally, a simple model to calculate the pressure loss coefficient of MOs is presented. Aiming to find the discharge variations of single hole, 4 hole, 5 hole and 7 hole Orifice by designing and experimenting on them we concluded that 5 hole orifice gave best results as expected.**

Keywords : CFD ,Ansys,Orifice Plate ,Flow meters.

1. INTRODUCTION

Orifice meter:

An orifice meter is a differential pressure flow meter which reduces the flow area using an orifice plate. An orifice is a flat plate with a centrally drilled hole machined to a sharp edge. The orifice plate is inserted between two flanges perpendicularly to the flow, so that the flow passes through the hole with the sharp edge of the orifice pointing to the upstream. The relationship between flow rate and pressure drop can be determined using Bernoulli's equation as:

$$Q=\frac{C_d}{\sqrt{1-\beta^4}}*\in*\frac{\pi}{4}*d_{e*}\sqrt{2*\Delta p*Q_1}$$

there, Q is the volumetric flow rate, A_o is the orifice cross sectional area, p_1 and p_2 are the pressure measured at the upstream and downstream and C_d is the discharge coefficient for the orifice .β is the ratio of orifice diameter to the pipe diameter= where is the diameter of the orifice and is the pipe diameter.

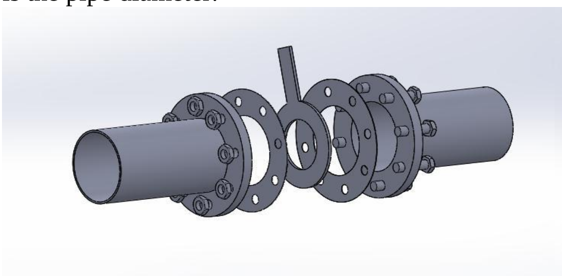

Fig.1Assembly of Orifice Meter

The fluid contracts and then expands as it moves through the orifice and this result in a pressure drop across the orifice, which can be measured. The magnitude of the pressure drop can be related to the volumetric flow rate. An orifice in a pipeline is shown in figure 1 with a manometer for measuring the drop in pressure (differential) as the fluid passes through the orifice. The minimum cross sectional area of the jet is known as the "vena contracta."

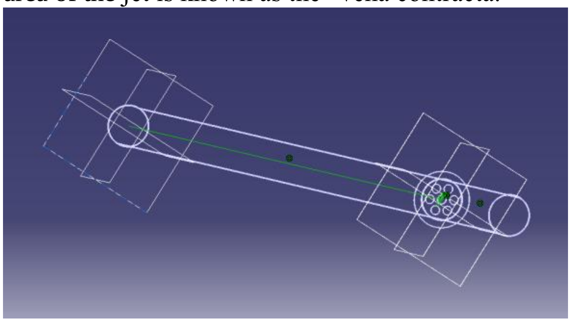

Fig.2 Assembly of 7 Hole Orifice Plate

How does it work?

As the fluid flows through the orifice plate the velocity increases, at the expense of pressure head. The

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pressure drops suddenly as the orifice is passed. It continues to drop until the “vena contracta” is reached and then gradually increases until at approximately 5 to 8 diameters downstream a maximum pressure point is reached that will be lower than the pressure upstream of the orifice. The decrease in pressure as the fluid passes thru the orifice is a result of the increased velocity of the fluid passing through the reduced area of the orifice. When the velocity decreases as the fluid leaves the orifice the pressure increases and tends to return to its original level. All of the pressure loss is not recovered because of friction and turbulence losses in the stream. The pressure drop across the orifice increases when the rate of flow increases. When there is no flow there is no differential. The differential pressure is proportional to the square of the velocity, it therefore follows that if all other factors remain constant, then the differential pressure is proportional to the square of the rate of flow.

Following types of pressure taps can be located for differential pressure measurement:

Corner: pressure taps one each on the upstream and downstream flanges.

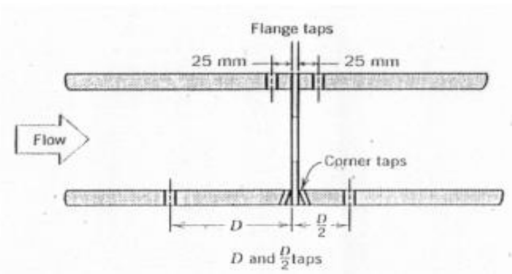

Fig.3 Corner Tapping

Radius taps: One pipe diameter upstream side and one and a half pipe diameter on the downstream side.

Pipe taps: Upstream side- 2.5pipe diameters and downstream side- 8 pipe diameters.

Flange taps: 1” upstream side and 1” downstream side.

2. LITERATURE REVIEW

MalateshBarki et al.[1]presents the effect of orifice holes arrangement or distribution in a plate on the performance of flow characteristics. The analysis is carried out for four diameter ratio. The pressure drop is minimum for multi holes orifice plate compare to single hole. It shows that the nine holes in circular arrangement have better performance compare with square arrangement.

Ramya B N*, Prof. Yogesh Kumar K J, Dr. V Seshadri [2]did the analysis on standard sharp edge orifice meter for different plate thicknesses (3 mm, 5 mm, 10 mm and 15 mm) in a pipe of 50 mm diameter and the effect of pipe diameter on coefficient of discharge has been studied. The value of coefficient of discharge depends on the type of flow, pressure tapping’s, contour of the obstruction and it is a function of Reynolds number.

Tianyi Zhao, Jili Zhang and LiangdongMa[3]Compared to single-hole orifices (SOs), multi-hole orifices (MOs) have smaller orifice sizes and various patterns of orifice distribution.The geometric description of MOs is more complex, increasing the difficulty of MO structural design. Therefore, it is worthwhile to investigate the key factors affecting MO throttle or flow control characteristics and to develop a general MO design method. This work presents a practical geometric design methodology for MOs and applies this procedure in throttle experiments. To describe the MO geometry in detail, the methodology first introduces a comprehensive set of geometric architectures involving orifice arrangement criteria
and geometric parameters such as the total orifice number, n; the orifice distribution density, Dd; and the equivalent diameter ratio, EDR. Then, a series of throttle tests in water flow are conducted to investigate the effect of various geometric features on the pressure loss characteristics of MOs. Finally, a simple model to calculate the pressure loss coefficient of MOs is presented.

Akshay Dandwate1, Sagar Mittal, OshinUmale, PallaviShelar, Rahul Bajaj[4]Flow measurement is measurement of the quantity of the fluid that passes through the pipe, duct or an open channel. Flow may be measured by measuring the velocity of fluid over a known area. Differential pressure measuring devices such as orifice plates and nozzles are extensively applied in several industries to estimate the mass flow rate running through a channel by correlating the measured pressure loss. In this paper, orifice plates with different geometry were designed and compared on the basis of their coefficient of discharge. This was done with the help of simulations done with k-ε and SST model on CFX as a solver. Simulations were carried out on a single hole, perforated (5 holes, 7 holes and 9 holes) and triangular shape orifice plates. β ratio taken was 0.6 for single hole, perforated, triangular orifice plates. By comparing the Cd. of various orifice plates, 7 holes orifice plate was found to be the best plate. This plate was manufactured and again tested experimentally. The result and outcomes are shown in the form of pressure contour, velocity contours and graphs showing comparison of Cd.

ChanghaoJi1,Zhixia He1, Yuhang Chen1.[5]The multi-holes orifice plate are simple hydrodynamic devices which can be used forintensification of liquid-liquid heterogeneous micro-mixture for preparing bio-diesel or emulsified diesel. In this study,a flow visualization experiment system with a transparent hydrodynamic cavitation reactor was setup to investigate the cavitation in the orifice plate and the outlet of the orifice plate. The effect of upstream pressure and cavitation number were investigated. The experimental results show that with the increasing of upstream pressure the caviation occurs in the orifice plate and the outlet of the orifice plate which are correspond with the numerical results.Thenumerical results also show that cavitation cloud shedding are the source of the cavitation of the outlet of the orifice plate.

Abhishek Kala, Dr. S.K Mittal, Prof M.K.Choudhary[6]In case of pipe conduits various flowmeters are used for flow estimation; out of which venturimeterand orifice meter are most commonly used and conventional means. Pipes or conduit carrying sediment laden flow or slurry-water mixture is very common in most

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of the industries, sewage carrying system etc. Suitability of flow meters i.e. venturimeter and flow meter need to be analyzed for sediment laden flow. Due to the presence of slurry or sediments, coefficient of discharge of flow meter will vary. In the present paper, various works that have been carried out till now in the analysis of characteristics of venturimeter and orifice meter with sediment laden flow are described.

3. PROBLEM DESCRIPTION

Design, develop and fabricate an Orifice Meter to reduce the losses and to increase the coefficient of discharge in order to measure the correct flow rate of fluid flowing through the pipe.

3.1 Objectives

1) To understand the problem statement and analyze it.
2) Suggest a feasible solution for the proposed problem.
3) Design the component (orifice meter) accordingly.
4) Do the simulation for the same and find the errors if any.
5) Fabricate the orifice meter according to the best analysis results.

3.2 Scope

- To design an orifice meter for increasing the coefficient of discharge
- Analysis using suitable flow simulation software
- Fabrication of the analyzed component

3.3 Methodology

A product development process is the sequence of steps or activities which an enterprise employs to conceive, design and commercialize a product. Many of these steps and activities are intellectual and organizational rather than physical. Every organization employs a process at least slightly different from that of other organization.
A well-defined development process is useful which is as follows:

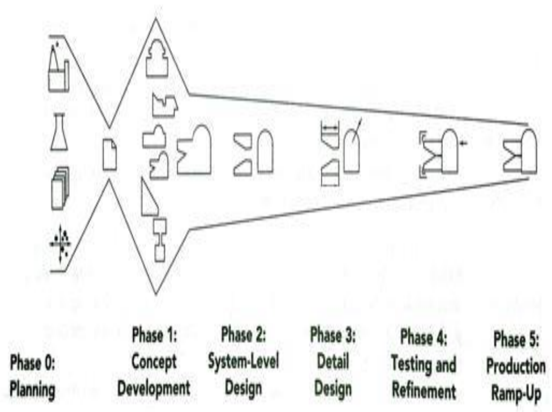

Fig. 4.Generic Development Process

Phase 0: Planning

The planning activity is often referred to as "phase zero" since it precedes the project approval and the launch of the actual product development process. This phase begins with corporate strategy and includes assessment of technology development and market objectives. The output of the planning phase is the project mission statement which specifies the target for the product, business goals, key assumptions and constraints.

Phase 1: Definition & Concept Development

In this phase, the product is defined, the needs of the target are identified product concepts are generated and evaluated. A concept is a description of the form, function and features of a product usually accompanied by a set of specifications.

Phase 2: System Level Design

The system level design includes the decomposition of the product into subsystems and components. This phase includes the analysis and finding the causes for the problems in the product.

Phase 3: Detail Design

The detail design phase includes the complete specification of the geometry, material and tolerances of all of the unique parts in the product and identification of all standard parts to be purchased from the supplier. A process plan is established and tooling is designed for each part to be fabricated within the production system.

Phase 4: Testing & Refinement:

The testing and refinement phase involves the construction and evaluation of the multiple preproduction versions of the product. This phase also includes the analysis carried out using different software whose goal is usually to answer the question about the performance and reliability.

Phase 5: Production Ramp-Up:

In the production ramp-up phase, the product is made using the intended production system. The purpose of ramp-up is to train the work force and to work out the remaining problems in the production processes.

4. PROCEDURE:

1. Procurement of equipments used.
2. Arrangement of Equipments as per required length (l=10d)
3. Attaching the Blower.
4. Switching on the Plug.
5. Taking reading for full closed valve on anemometer, manometer.
6. Now by keeping the valve half open.
7. Reading for quarter open.
8. Analysis on CFD.
9. Results, Calculations.
10. Conclusion.

5. CALCULATIONS:

Key Formulas:

1. $q_m = \frac{C_d}{\sqrt{1-\beta^4}} * \epsilon * \frac{\pi}{4} * d_e \sqrt{2 \Delta p Q_1}$

$$\beta = \frac{d}{D}$$
$$\in = 1$$

2. $\delta = 3.483407 * \frac{GP_f}{Z_f T_k}$

G =Ideal Specific Gravity
P_f = Flowing Pressure
Z_f = Compressibility factor at flowing condition
T_k =Flowing Temperature

3. C_d=0.596+0.026$\beta^2$0.216β^8+0.000521*$(\frac{10^6\beta}{Red})^{0.7}$+(0.018+0.0063A)$\beta^{3.5}$*$(\frac{10^6}{Red})^{0.3}$+(0.043+0.080*$e^{-10L_1}-0.123e^{-7L}$)(1-0.1A)*$\frac{\beta^4}{1-\beta^4}$-0.031($M_2^1-0.8M_2^1$)$\beta^{1.3}$

4. $P_1+\frac{1}{2}*\rho * V_1^2=P_2 + \frac{1}{2}*\rho*V_2^2$

5. Q=$A_1 * V_1$=A_2*V_2

6. Coefficient of Discharge=$\frac{Actual\ Discharge}{Therotical\ Discharge}$

	Sr.No.	Discharge 1.1	Actual Discharge
Single Holed(Larger Dia.)	1 Full open	7.86E-02	0.0733
	2 Half open	8.29E-02	0.08
	3 Quarter open	8.43E-02	0.088
	4 Fully closed	8.49E-02	0.091
4 Holed Plate	1 Full open	6.93E-02	0.07
	2 Half open	7.59E-02	0.081
	3 Quarter open	7.97E-02	0.083
	4 Fully closed	7.63E-02	0.086
5 Holed Plate	1 Full open	7.05E-02	0.071
	2 Half open	7.57E-02	0.078
	3 Quarter open	7.84E-02	0.081
	4 Fully closed	8.09E-02	0.085
7 Holed Plate	1 Full open	6.89E-02	0.075
	2 Half open	7.45E-02	0.083
	3 Quarter open	7.77E-02	0.086
	4 Fully closed	7.95E-02	0.088

Table – Results of Actual Readings and Calculated

6. ANALYSIS OF 5 HOLED ORIFICE PLATES

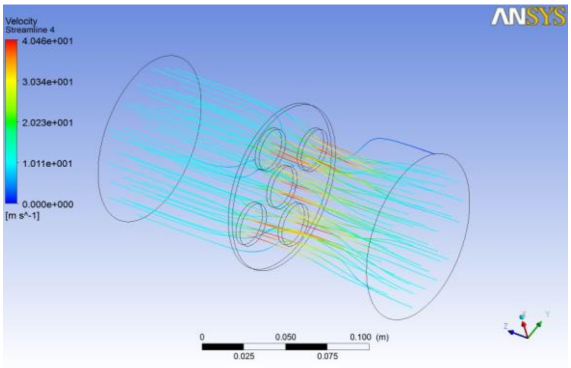

Fig.5 Streamline Flow Of 5 holed Orifice Plate

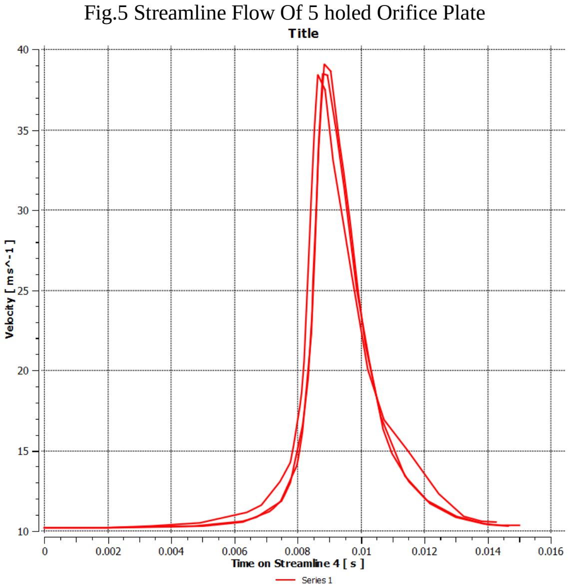

Fig.6 Velocity Chart for 5 holed orifice plate

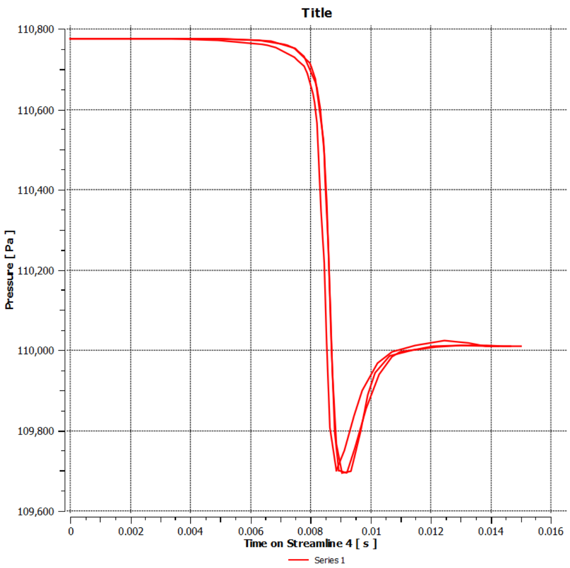

Fig.7Pressure Chart for 5 holed orifice plate

7. FUTURE SCOPE

Orifice meter is widely used in industries these days to measure the flow rate of fluid flowing through the pipe as it is an easy and cheaper method of measuring the

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flow rate. The only problem with the orifice meter industries are facing is while measuring the flow rate of fluid through a pipe of shorter length; the fluid is creating turbulence due to sudden decrease in the cross section area. So the solution we are proposing here in this project will definitely solve this problem and if this concept worked mass scale production of the same can be done in the future.

8. CONCLUSION

In this project we analyzed designed and calculated the variations in readings of single holed,4 holed ,5 holed and 7 holed orifice meters, on doing the same we concluded that we get exactly similar reading for 5 holed orifice meter and that it is most suitable for the following work. We compared the actual and analytical testings.

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