ANALYSIS AND EVALUATION OF COEFFICIENT OF DISCHARGE ON ORIFICE PLATE AND FLOW NOZZLE

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Abstract - *An orifice plate is a tool used for measuring flow charge. Either a volumetric or mass float fee can be decided. The Flow Nozzle is a flow tube consisting of a smooth convergent phase leading to a cylindrical throat region. It is used for measuring the float quotes of the liquid discharged into the ecosystem. The differential strain gadgets which include orifice plates and drift nozzles are substantially used in numerous industries with a purpose to estimate the mass float rate strolling thru a conduit by way of correlating the measured stress loss, speed loss and the mass waft fee. The present work is directed toward to the observe of coefficient of discharge of an orifice plate and float Nozzle. Catia is used for designing the orifice plate and glide nozzle and Ansys is used for analysis of the orifice plate and go with the flow nozzle. Computational Fluid Dynamics (CFD) is used to are expecting the go with the flow capabilities in the orifice plate and drift Nozzle. Outcomes of the CFD simulations in phrases of profiles of pace, strain and coefficient of discharge are discussed in detail. As the diameter of orifice and glide nozzle will increase, the coefficient of discharge also will increase. Flow nozzle has excessive coefficient of discharge than orifice plate. Furthermore, the values of theoretical coefficient of discharge have less deviation from the analytical coefficient of discharge.*

Key Words: *Computational Fluid Dynamics (CFD), Orifice plate, Flow Nozzle, Velocity, Pressure, Coefficient of discharge*

1.INTRODUCTION

1.1 Orifice Plate

Orifice plates are primary flow elements, which is used for measuring the flow rate, either a volumetric or mass flow rate may be determined. An orifice plate is a type of differential pressure device with a hole in it, which is usually placed in a pipe. When a fluid (whether liquid or gaseous) passes through the orifice, its pressure develops somewhat upstream of the orifice however as the liquid is constrained to converge and passed through the hole of orifice, the velocity increases and the fluid pressure decreases. A somewhat downstream of the orifice the flow reaches its point of maximum convergence, where the velocity reaches its maximum and the pressure reaches its minimum.

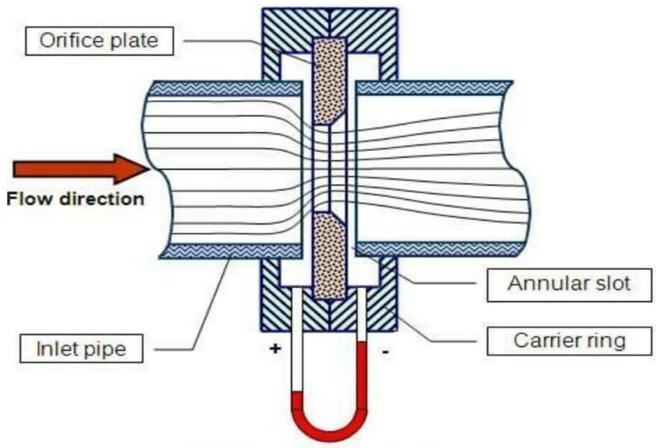


Fig.1: Orifice plate[4]

Beyond that, when the flow extends the velocity falls, and the pressure rises. By measuring the difference in fluid pressure across upstream and downstream of the plate, the flow rate can be obtained from Bernoulli's principle which states that there is a connection between the pressure and the velocity of the fluid. When the velocity rises, the pressure falls and vice versa. The orifice plate is commonly used in clean liquids, gas and steam service. It is available for all pipe sizes, and it is very cost effective for measuring fluid flows in larger pipes. [5]

1.2 Flow Nozzle

Flow Nozzle has a smooth elliptical inlet main to a throat section with a sharp outlet. Restriction in the fluid flow causes a pressure drop, which relates to the flow rate by applying Bernoulli's equation.

The flow nozzles are a flow tube consisting of a easy convergent section main to a cylindrical throat place. Throat is smallest section of the nozzle. Pressure taps are placed on the upstream side of the nozzle plate and at the downstream side of the nozzle outlet.

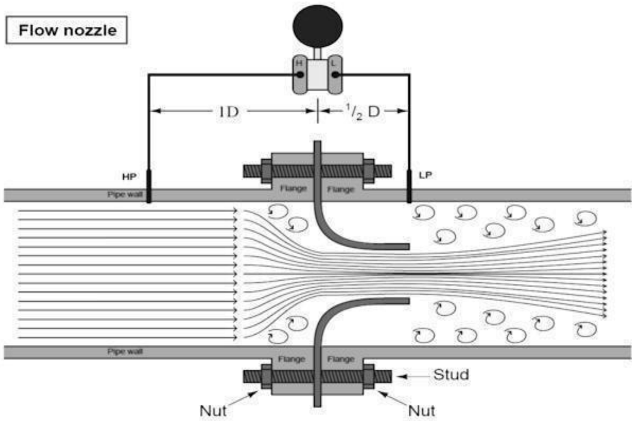


Fig. : Flow nozzle[6]

They may be in the form of an annular ring, i.e., equally spaced holes related collectively which open in to the pipeline, or in the form of single holes drilled into the pipeline. [7]

1.3 Modelling

It is the process of converting 2 -dimensional/cartoon diagram into three- dimensional model the usage of software program's which convert a diagram right into a mathematical model and venture on show like a model. The purpose of which is to make a selected part or function world less complicated to apprehend, outline, quantity, visualize with the aid of referencing it to current and typically typically accepted know-how.

1.4 Analysis

Trouble capturing a designed component about their endurance restriction via making use of strain (each structural and thermal) at the particle within the evaluation software to find if the designed item can overcome sensible problems. It is a system of breaking a complex topic or substance into smaller parts so that it will gain a better know-how of it.

1.5 Computational Fluid Dynamics (CFD)

Computational Fluid Dynamics (CDF) is the analysis of fluid flows using numerical solution methods and data structure to analyze and solve problems that involved in fluid flows. Computers are used to perform the calculations required to simulate the free-stream flow of the fluid and the interaction of the fluid (liquids and gases) with surfaces defined by boundary conditions CFD is carried out to a huge variety of research and engineering problems in many fields of take a look at. In engineering fields where CFD analyses are frequently used for example aerodynamics and hydrodynamics, where quantities such as lift and drag or field properties as pressures and velocities are obtained.[8]

2. LITERATURE SURVEY

Saeid Mokhatab et.al. This paper says that orifice plate is the most commonly used flow sensor, but it creates a rather large non recoverable pressure due to the turbulence around the plate, leading to high energy consumption. An orifice plate has an opening hole that is smaller than the diameter of the pipe. The ordinary orifice plate has a concentric, sharp-edged opening. Because of the smaller area, the fluid speed increases to cause a corresponding lower in pressure. The flow rate may be calculated from the measured pressure drop throughout the orifice plate. [1]

Sangani et.al Made the attempt to compare the pressure drop across the sharp edged orifice between the experimental values with the theoretical and numerical values. The experiments are conducted in the orifice meter setup and for different flow rates of water and the corresponding pressure drop is calculated based on the orifice meter geometry and inlet pace, theoretical pressure drop is calculated for exclusive go with the flow rates. The similar problem is associated using ANSYS CFX 15.0 for corresponding flow rates using k-ω model. 16 Results are compared with experimental and theoretical values, and it is found that the agreement is reasonably good. [2]

Mohammad azim aijaz et.al Discussed their work "Finite Element Analysis (FEA) ofpressure drops in orifice meter". The objective of the task became to examine the theoretical pressure drop and experimental pressure drop. They demonstrated the experimental pressure drop by way of comparing it with the FEA pressure drop acquired through the CFD code simulations. They calculated theoretically pressure drop for 4 different flow velocities and conducted experiments to find out experimental pressure drop for the same flow velocities. Then they modeled the concentric orifice plate to analyze the FEA pressure drop and compared it with experimental pressure drop. [3]

3.PROBLEM STATEMENT

In past decades, the coefficient of discharge of orifice plate and flow nozzle is calculated by theoretical equations to determine the losses associated with a certain piece of the equipment, while determining the losses theoretically or mathematically way, we have faced many problems regarding pressure loss, velocity, accuracy and time consumption in practical/ real applications. All these problems can be solved by using CFD, which is used to analyze complex problems involving fluid-fluid, fluid-solid or fluid-gas interaction. The performance of characteristics of various types of integral orifice plate and flow nozzle for diverse working conditions are analyzed using commercially available CFD software.

4. MODELLING OF ORIFICE PLATE AND FLOW NOZZLE

4.1 Modelling of Orifice Plate in Catia V5

- To create orifice plate, go to CATIA and open it. Now start and select mechanical design, part design then we will enter into part design module.in part design select sketcher and select suitable plane.

- Select circle and specify the diameter. Then click on exist in workbench. Then we will return to part design module.

- In part module, select the pad command and specify the length. Then go to sketch module and select circle with required diameter. Click on exist in workbench.

- Now select the pocket command, specify depth and click on ok. Now in sketcher module , select the pad command and specify the length , thickness then click on ok. Now we will obtain orifice plate.

4.2 Modelling of Flow Nozzle in Catia V5

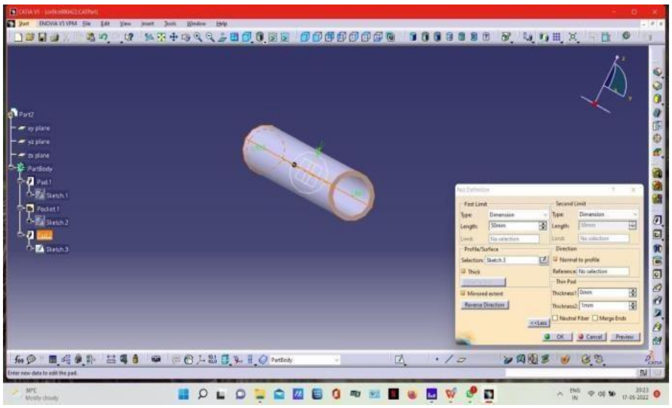
- To create Flow Nozzle, go to CATIA and open it. Now start and select mechanical design, part design then we will enter into part design module.in part design select sketcher and select suitable plane.

- Select circle and specify the diameter. Then click on exist in workbench. Then we will return to part design module.

- In part module, select the pad command and specify the length. Then go to sketch module and select circle with required diameter. Click on exist in workbench.

- And select the pocket command, specify the depth and click on ok. Now select the chamfer and specify the length, angle, and give propagation and then click on ok.

- In sketch module, select the pad command and specify length, thickness, then click on ok. Now we will obtain the final flow nozzle.



Fig, 3: Orifice plate β = 0.2

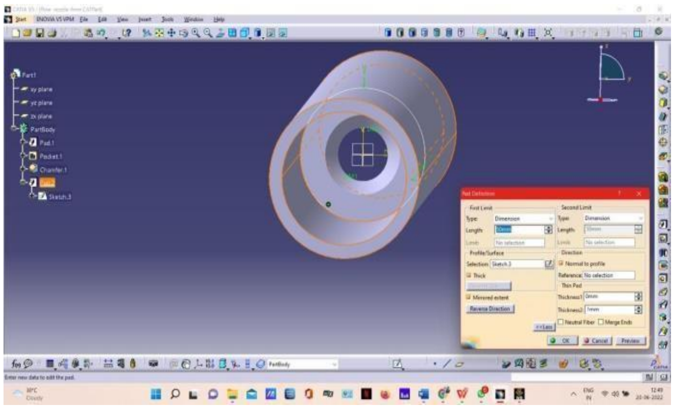


Fig. 5: Flow Nozzle β = 0.2

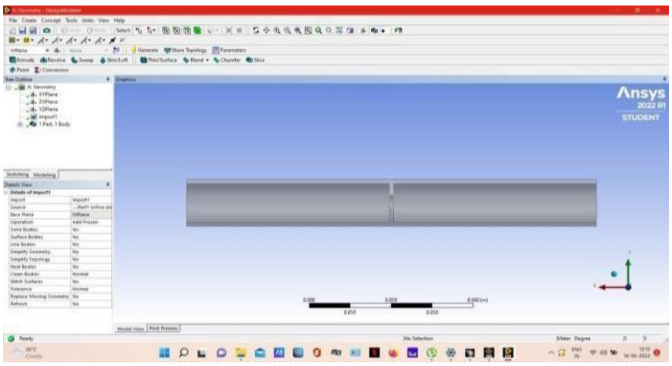


Fig. 4: Orifice plate β = 0.4

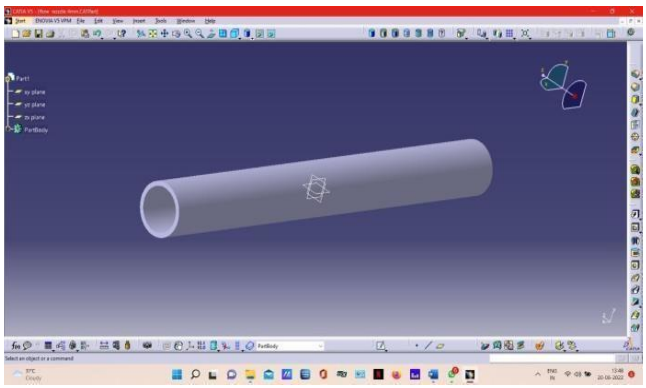


Fig. 6: Flow Nozzle β = 0.4

5. ANALYSIS OF ORIFICE PLATE AND FLOW NOZZLE

ANSYS develops and markets engineering simulation software program to be used throughout the product existence cycle. Ansys Mechanical finite element analysis software is used to simulate laptop models of systems, electronics, or system components for evaluation the energy, durability, elasticity, temperature distribution, electromagnetism, fluid glide, and different attributes.

In ANSYS, the fundamentals of FEA concepts, modelling and the analysing of engineering trouble the usage of ANSYS workbench. Computational Fluid Dynamics (CDF) is the evaluation of fluid flows the usage of numerical answer methods and information structure to investigate and clear up troubles that involved in fluid flows. The orifice plate and flow nozzle is subjected to Ansys fluent and the resulted pace, stress are studied and calculated coefficient of discharge for special diameters. The cloth selected for reading is Aluminum and fluid used is air.

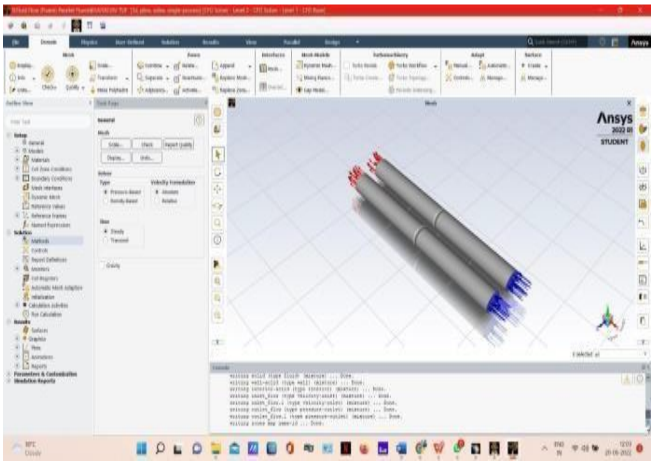


Fig. 7: Model setup

6. RESULTS AND DISCUSSION

After the analysis is finished the next important step is to understand the evaluated results. In this project, we had evaluated velocity, pressure, coefficient dfscharge so far.

6.1 Orifice plate

6.1.1 Velocity

Select velocity under the solution node in the tree outline, the velocity of model is displayed in the graphics screen. Also, the corresponding legend is displayed in the graphics screen.

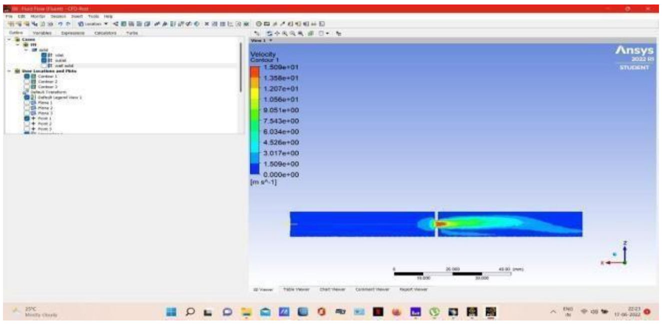


Fig. 8: velocity contour β = 0.2

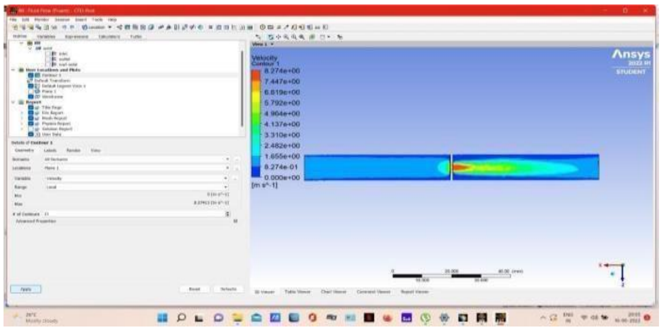


Fig. 9: velocity contour β = 0.4

The legends have colors arranged in a band from pinnacle to bottom. Depending upon the type of analysis and parameters evaluated, each color will suggest a extraordinary value. From the abovefigures 8 and nine it's miles observed that, the minimal velocity is located at place wherein waft processes the orifice and the maximum velocity comes out as jet the plate hollow and reaches the downstream. The point at which pace is the maximum is called vena settlement. The blue shade within the version represents the bottom cost of the speed, while the pink color denotes the maximum fee of the speed.

6.1.2 Pressure

Select pressure under the solution node in the tree outline, the pressure of model is displayed in the graphics screen. Also, the corresponding legend is displayed in the graphics screen.

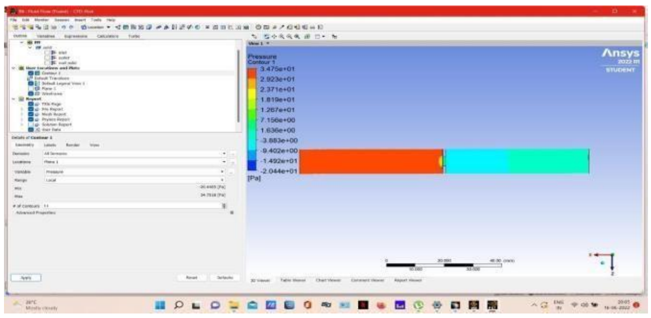


Fig. 10: Pressure contour β = 0.2

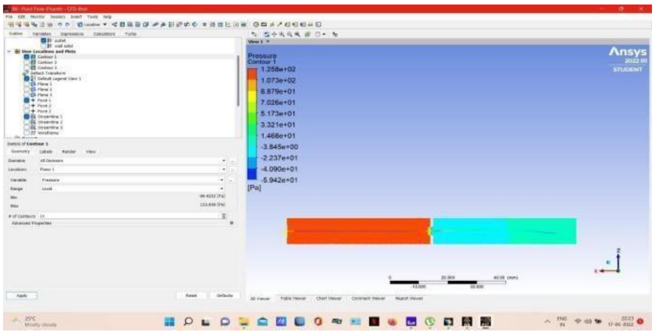


Fig. 11: Pressure contour β = 0.4

From the above figures 10, 11 it is observed that, the maximum pressure is observed at the flow approaches the orifice and minimum pressure comes out from the plate hole and its reaches the downstream. The red colour in the model represents the maximum value of the pressure, whereas the blue colour denotes the minimum value of pressure.

Formulas;

Diameter of orifice d = 2 mm Diameter of pipe D = 10 mm

Beta ratio β = d/D

- P1V1 = P2V2, A1V1 = A2V2

- $$QTH=\frac{A_2}{\sqrt{1-\beta^4}}\sqrt{\frac{2g+(p_1-p_2)}{\rho g}}$$
- $$Cd=\frac{Q}{\frac{A_0A_1\sqrt{2gh}}{\sqrt{A_1^2-A_0^2}}}$$

Variables		Beta = 0.2	Beta = 0.4
Theoretical outlet values	Pressure	101333.69pa	101327.171pa
	Velocity	25.009m/s	6.249m/s
Analytical outlet values	Pressure	101262.5pa	101304.56pa
	Velocity	15.0853m/s	8.27m/s
Theoretical Coefficient of discharge (C_d)		0.627	0.678
Analytical Coefficient of discharge (C_d)		0.601	0.634

Table-1: Calculations of Orifice plate

The above table -1, summarizes the results for coefficient of discharge of each orifice size. It is evident from the above table that increasing the orifice diameter will increase the coefficient of discharge. Furthermore, the values of theoretical coefficient of discharge have less deviation from the Analytical values of coefficient of discharge.

6.2 Flow Nozzle

6.2.1 Velocity

Select velocity under the solution node in the tree outline, the velocity of model is displayed in the graphics screen. Also, the corresponding legend is displayed in the graphics screen.

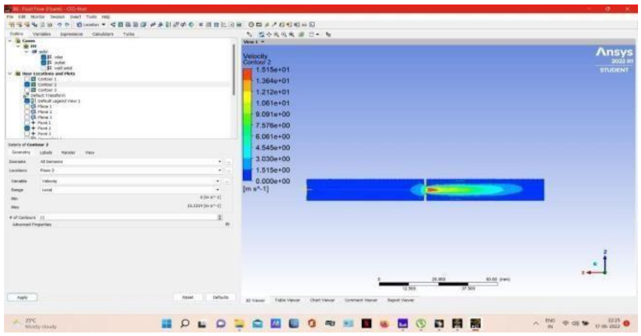


Fig. 12: Velocity contour β = 0.2

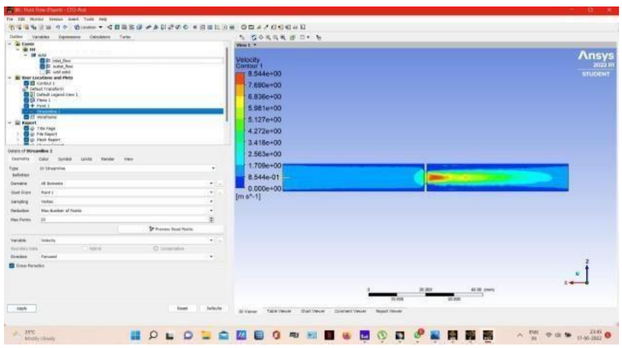


Fig. 13: Velocity contour β = 0.4

The legends have colours arranged in a band from top to bottom. Depending upon the type of analysis and parameters evaluated, each colour will indicate a different value. From the above figures 12 ,13 it is observed that, the minimum velocity is observed at the region where flow approaches the nozzle, and the maximum velocity comes out as jet from the nozzle and reaches the outlet. The blue colour in the model represents the lowest value of the velocity, whereas the red colour denotes the maximum value of the velocity.

6.2.2 Pressure

Select pressure under the solution node in the tree outline, the pressure of model is displayed in the graphics screen. Also, the corresponding legend is displayed in the graphics screen.

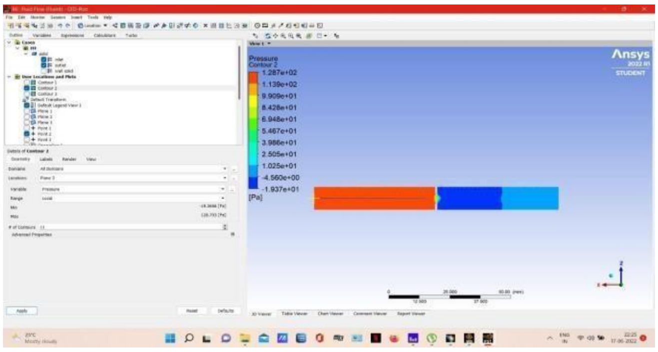


Fig. 14: Pressure contour β = 0.2

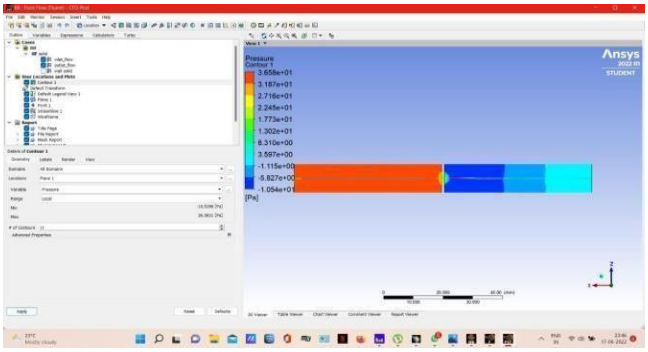


Fig. 15: Pressure contour β = 0.4

From the above figures 14 ,15 it is observed that, the maximum pressure is observed at the flow approaches the flow nozzle and minimum pressure comes out from the nozzle and its reaches the outlet. The red colour in the model represents the maximum value of the pressure, whereas the blue colour denotes the minimum value of pressure.

Formulas;

Diameter of Flow nozzle d = 2 mm Diameter of pipe D = 10 mm

Beta ratio β = d/D

- P1V1 = P2V2, A1V1 = A2V2
- QTH = 28.9 * $d^2 * \sqrt{P}$
- $Cd = \frac{Q}{\frac{\pi}{4}D^2\sqrt{\frac{2(P_1-P_2)}{\rho(1-\beta^4)}}}$

Variables		Beta = 0.2	Beta = 0.4
Theoretical outlet values	Pressure	101329.34pa	1013260.11pa
	Velocity	25.009m/s	6.24m/s
Analytical outlet values	Pressure	101453.703pa	101314.46pa
	Velocity	15.1514m/s	8.5446m/s
Theoretical Coefficient of discharge (C_d)		0.89	0.91
Analytical Coefficient of discharge (C_d)		0.76	0.81

Table-2: Calculations of Flow Nozzle

From the above table-2 summarizes the results for coefficient of discharge of each nozzle size. It is evident from the above table that increasing the nozzle diameter will increase the coefficient of discharge. Furthermore, the values of theoretical coefficient of discharge have less deviation from the Analytical values of coefficient of discharge. As compared to the orifice plate the flow nozzle as high coefficient of discharge.

7. CONCLUSION

The conclusion of the work is that by analysis and studying the velocity, pressure, and coefficient of discharge of orifice plate and flow nozzle of different diameters. It is observed that the velocity is maximum at downstream than the upstream of the Orifice plate and Flow nozzle, the point at which velocity is maximum is known as vena contracta. Pressure is maximum at the inlet and minimum at the outlet of the orifice plate and flow nozzle. When the diameter of the Orifice and Flow nozzle increases, the velocity, pressure decreases and the coefficient of discharge increases. It is observed that the values of theoretical coefficient of discharge have less deviation from the values of analytical coefficient of discharge. The coefficient of discharge of flow nozzle is higher than the orifice plate by theoretically and analytically.

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