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The Design Parameters Analysis for the Manufacturing of an Orifice Plate flow Rig

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Abstract:

An orifice plate flow rig for mass flow rate measurement and control is under investigation and the design of an in-house orifice plate flow rig is being analysed to ascertain the manufacturing equipment, rig dimensions, and fluid flow parameters necessary for the manufacturing of the flow rig capable of measuring a mass flow rate of 5 kg/s. Therefore, the design parameters analysis for the manufacturing of an orifice plate flow Rig is presented. The orifice plate rig is designed and adapted in such a way that the flow intake unit and the orifice unit carried out work simultaneously thereby measuring the flow rate, enhancing Reynolds number analysis and other flow properties. The key principal units of the orifice plate flow rig are the compressor section, laminar flow element, butterfly valve, control valves, rotameter, orifice plates, Venturi, refrigerator dryer, an upstream development length of 14 equivalent diameter pipe length, and 2-inch pipe dimensions designed and incorporated for efficient operation, ease of assembly, and disassembly for efficient maintenance. Bernoulli's principle and Continuity equation were applied in this study. With an orifice upstream pipe designed diameter of 254 mm, upstream pressure of 3 bars gauge with an inlet temperature of 433K, and a mass flow rate of 5 kg/s, the analysis indicates an orifice area of 0.0285 m^2 and a pipe area of 0.0507 m^2 respectively are capable for this flow rig, with a flow density of 3.16 kg/m^3, the flow velocity of 31. 26 m/s, absolute viscosity of fluid of 2.457 x 10^{-5} kg/m s, and Reynolds number of 1019418. Further analyses were carried out, which shows that an increase in the mass flow rate through an orifice plate flow rig will increase the flow velocity, Reynolds number, and differential pressure, but decreases the downstream pressure. Hence, an increase in the Reynolds number decreases the coefficient of discharge and increases differential pressure, thereby, increasing the flow rate. This study is to assist in the calibration of orifice plates for mass flow measurement and control.

KEYWORDS: Diameter, Reynolds, Mass flow, Measurement, Control, Orifice.

1. INTRODUCTION

An orifice plate is a thin plate in which a circular aperture has been machined; used to measure the rate of fluid flow. Orifice plates are the most common method of differential flow measurement. Mass flow measurement and control is very essential in the industrial process because it provides vital information about the flow and may lead to better efficiency of the process, by reducing waste and cost of the operation, hence, it is necessary to calibrate orifice plates with different geometry, therefore the need for a flow test facility for this purpose. An orifice plate produces differential pressures, which depend on fluid characteristics, pipe, and the plate's geometry; these properties have a significant effect on mass flow measurement and mass flow control. This analysis shows the influence of pipe, orifice plate geometry, and the effect of mass flow rate on fluid properties during mass flow measurement and mass flow control process.

Mass flow measurement and control find applications in aerospace, oil, natural gas, chemicals, processing, steam, and the power plant industry. In this study, the sizes of the pipe and orifice dimensions are investigated to ascertain the dimensions capable to measure the required flow rate. A. typical orifice plate is shown in Figure 1.

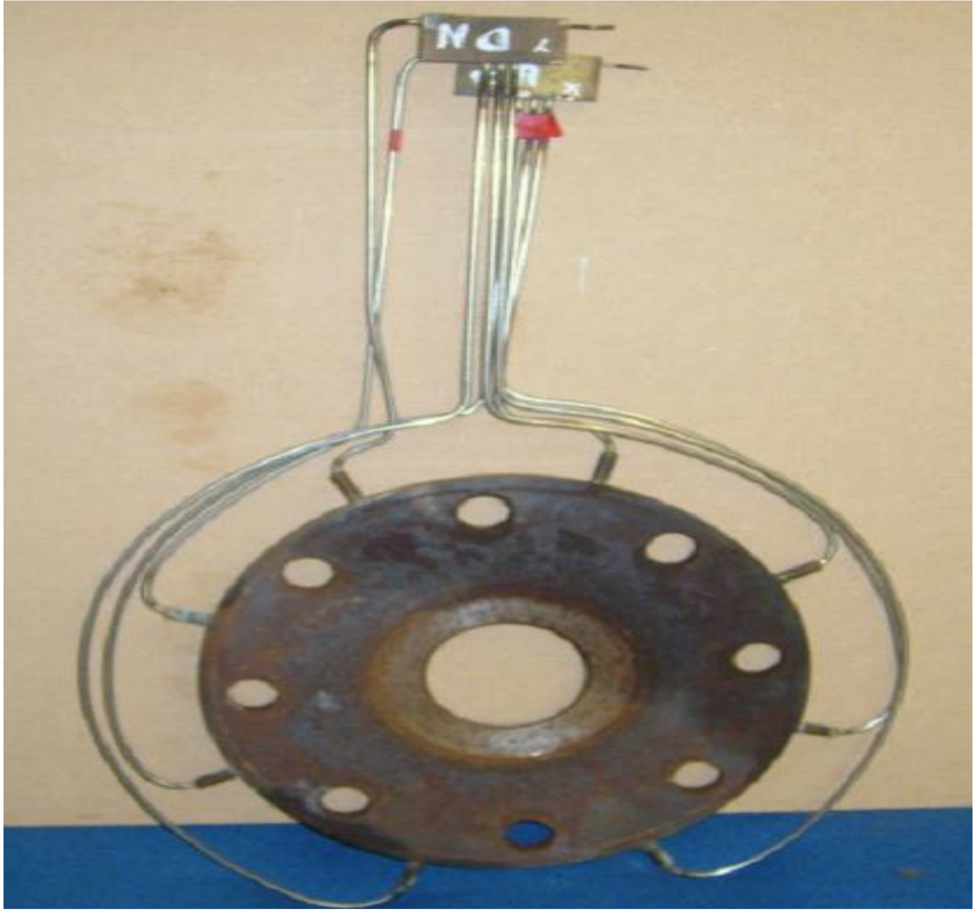

Figure 1: Show an Orifice plate [1]

There are several types of orifice plates in use depending on their shape and position or opening. These include Concentric, Conical, Eccentric, Integral, Quadrant, and

Segmental orifice plates. However, the three most commonly used orifice plates are concentric, eccentric, and segmental orifice plates shown in Figure 2. The aim of this work is to confirm the effectiveness of applying fluid flow principles in the design parameters analysis for the manufacturing of an orifice plate flow Rig for flow measurement and control.

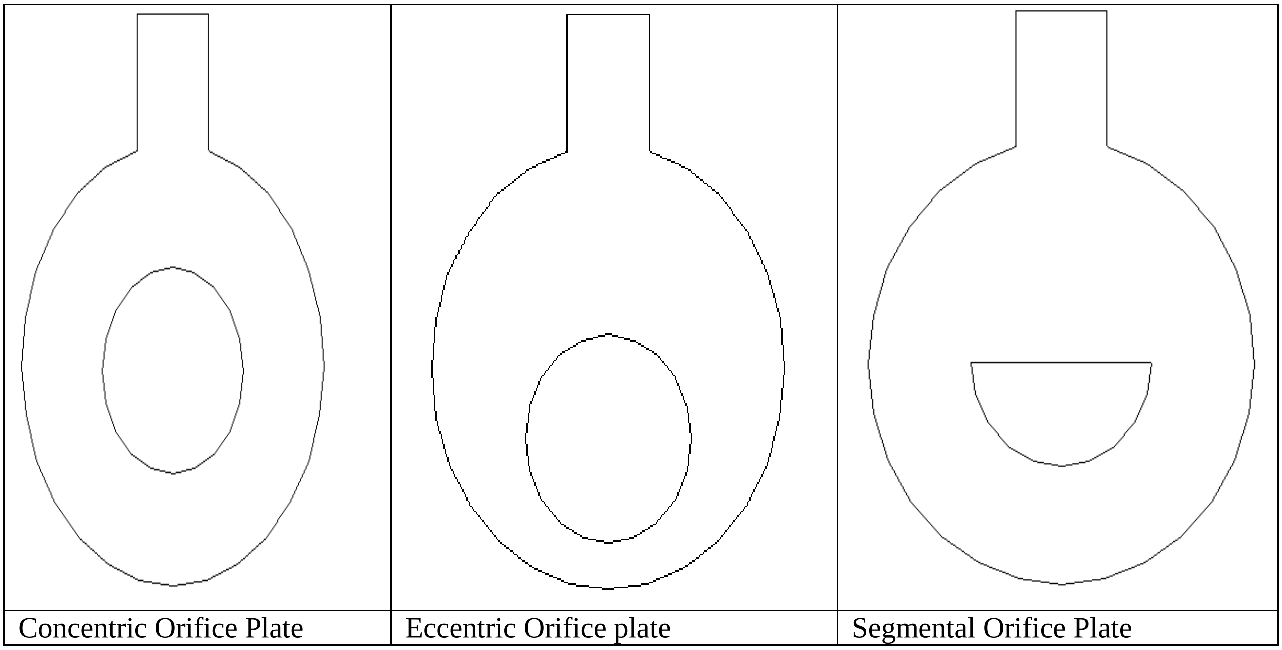
Concentric Orifice Plate
Eccentric Orifice plate
Segmental Orifice Plate

Figure 2: Different types of Orifice Plates [14]

2. LITERATURE REVIEW

This section presents a review of the previous work relating to the orifice plate mechanism which has been extensively discussed by several scholars. The application of orifice plates in research, laboratories, and industries for fluid flow measurement and control analysis and simulation of real-life fluid flow scenarios had been performed by different authors. This has given rise to effective flow measurement and control in devices such as gas turbines in aero engines. The literature review here presents some of the previous work done on mass flow measurement and mass flow control using orifice plates; this includes Sihombing [2] who undertook a visualisation study that shows that a slotted orifice plate can be applied as a flow conditioner for two-phase flow in the pipe in many patterns flow. Casey [3] carried out a characterization of a high-pressure round-edged orifice plate in a test facility and the results show that for the range of pressure differentials tested the orifice plate discharge coefficient is roughly independent of both Reynolds number and cavitation number and that this result, along with the independence of Reynolds number, indicates that for the pressure differential range tested the orifice plate discharge coefficient is only a function of the geometry. Jamaludin [4] uses an orifice plate to compare the effectiveness of the orifice plate steam trap over variable loads. Experiments were conducted and measurement of the rate of steam loss under different condensate loads was investigated. According to the results obtained, a fixed diameter hole was able to pass only a calculated amount of condensate under one set condition. Thus the fixed orifice plate steam trap would not be suitable for a steam system with variable condensate load, but the steam trap orifice would serve better than the conventional orifice steam trap in preserving the steam. Flores [5] uses a slotted orifice plate to evaluate the performance of a single-phase flow meter using air and a two-phase flow meter using water and air. In the study, the brass plates were tested in one water and air facility in a previous study and the stainless steel plates were tested using two-phase data from air and water and also from steam and water. It was concluded the differential pressure effects using water and steam as a mixture were better since there is a change in fluid quality as the fluid drops in pressure across an orifice plate. Hollingshead [6] conduct the relationship between the Reynolds number (Re) and discharge coefficients (C) was investigated through differential pressure flow meters. The study was directed toward very small Reynolds numbers commonly associated with pipeline transportation of viscous fluids. Heavy oil and water were used separately as the two flowing fluids to obtain a wide range of Reynolds numbers with high precision. The study indicates that the various discharge coefficients decrease rapidly as the Reynolds number approaches 1 for each of the flow meters; however, the Reynolds number range in which the discharge coefficients were constant varied with meter design. Wali [7] carried out an experiment to understand the behaviour of multi-phase flow through orifices in horizontal pipes. Several different geometries were used in the pipe to compare flow mechanisms at different flow rates. Superficial velocities for water ranged from 0.35 to 0.75 m/s and from 0.04 m/s to 0.1 m/s for air. Pressure drop across the orifice was measured, and a video system was used in order to obtain images of flow under selected conditions. The recorded pressure drop signals give insights into the flow behaviour, and results indicated that at higher pressure drops, a significant amount of air flows through an orifice. Nitter [8] Performed Computational Fluid Dynamics CFD) simulations to obtain the discharge coefficients for different orifice characteristics and investigate the flow behavior through the orifices and came to the conclusion that the flow is accelerated from a distance before the orifice plate and this is more prominent with increasing Reynolds number. Other fluid flow measurements and control were undertaken by Ekong *et al* (9) in a gas turbine high-pressure compressor for clearance control using a heat transfer approach which indicated that increasing the thermal response of the high-pressure compressor (HPC) drum of a gas turbine engine assembly will reduce the drum time constant, thereby reducing the reslam characteristics of the drum causing a reduction in the cold build clearance (CBC), and hence the reduction in cruise clearance. And various concepts to control tip clearance in aero-engine high-pressure compressors such as lumped parameter method investigated by Ekong (10) show that the lumped parameter method is a very good method for tip clearance control in HP compressor, as it will give a quick approximation of the clearance during engine transient. Ekong *et al* (11) use thermodynamic principles to show that as the compression pressure increases, there is a corresponding increase in the efficiency of the single-acting reciprocating compressor, while the performance analysis of a single-acting reciprocating mechanism was studied by Ekong and Ekanem (12) heir results show that an increase in the pump speed increases the pump's discharge, the work done by the pump, and the power required to drive the pump and Ekong *et al* (13) in their indicate that an increase in the pump speed of a reciprocating will increase the discharge through the pump. Ekong (14) in his work on the effect of the design parameters on mass flow measurement and control using an orifice plate, concluded that an increase in the upstream pressure result in an increase in the differential pressure, hence, an increase in the mass flow rate and Ekong (15) performed the parametric effect on the discharge of Venturimeter flow rig showing that as the head increases, the discharge through the Venturimeter increases and according to Ekong [16], by increasing the value of the pressure head, there was a corresponding increase in discharge, hence confirming the effectiveness of the Bernoulli's principles and continuity equation in the analysis of flow discharge through Venturimeter.

3. MATERIALS AND METHODS

In the test facility, pipes of varying cross-sectional areas were analysed. But the constant flow rate in the varying cross-sectional area of the duct gives rise to the fact that the fluid velocity and pressure must be compensated accordingly on the basis of conservation of mass and energy. In this study, the designed capacity of the mass flow rate to be measured is 5 kg/s using orifice plates, hence, the determination of the sizes of pipes and orifice, and other equipment to be used. The following principles and more are employed in the analysis of this research, this include Bernoulli's principle, continuity equation, discharge coefficient the Reynolds number, Sutherland's law, and mass flow rate equation are employed for effective analysis in the design of an orifice plate test facility successfully measuring and controlling the mass flow rate of the fluid. During the conception, accurate selection of materials, equipment, and installation of the equipment is essential to a successful flow measurement and control to enhance better performance of the system, with precaution for a good assembly and disassembly. Certain factors were taken into consideration such as mechanical strength, size of the components, aesthetics, availability, and cost with the help of creativity techniques such as forty inventive principles, lateral thinking, and brainstorming which are presented in Ekong *et al* [17] the application of Creativity Tools to Gas Turbine Engine Compressor Clearance, Ekong [18] the application of Creative techniques in Effective Management of a Power Generation Plant, Ekong [19] the application of Ideal Final Result in the design of a Pneumatic Foot Pump for rural areas, Ekong [20] the application of 40 inventive principles in tip clearance control concepts in Gas Turbine H.P compressor, Ekong [21] the Improvement of Government Parastatals using Creativity tools, Ekong [22] the application of Ideal Final Results in the Establishment and Management of a Cold storage facility for rural areas and Ekong *et al* [23] the development of concepts for the control of tip clearance in Gas turbine HP compressors using TRIZ. The designed orifice plate flow measurement test facility incorporates a laminar flow element, a butterfly valve, control valves, a Rotameter, orifice plates, Venturi, compressors, a refrigerator dryer, an upstream development length of 14 equivalent diameter pipe length, 2-inch pipe dimensions and other accessories as shown in Figure 3.

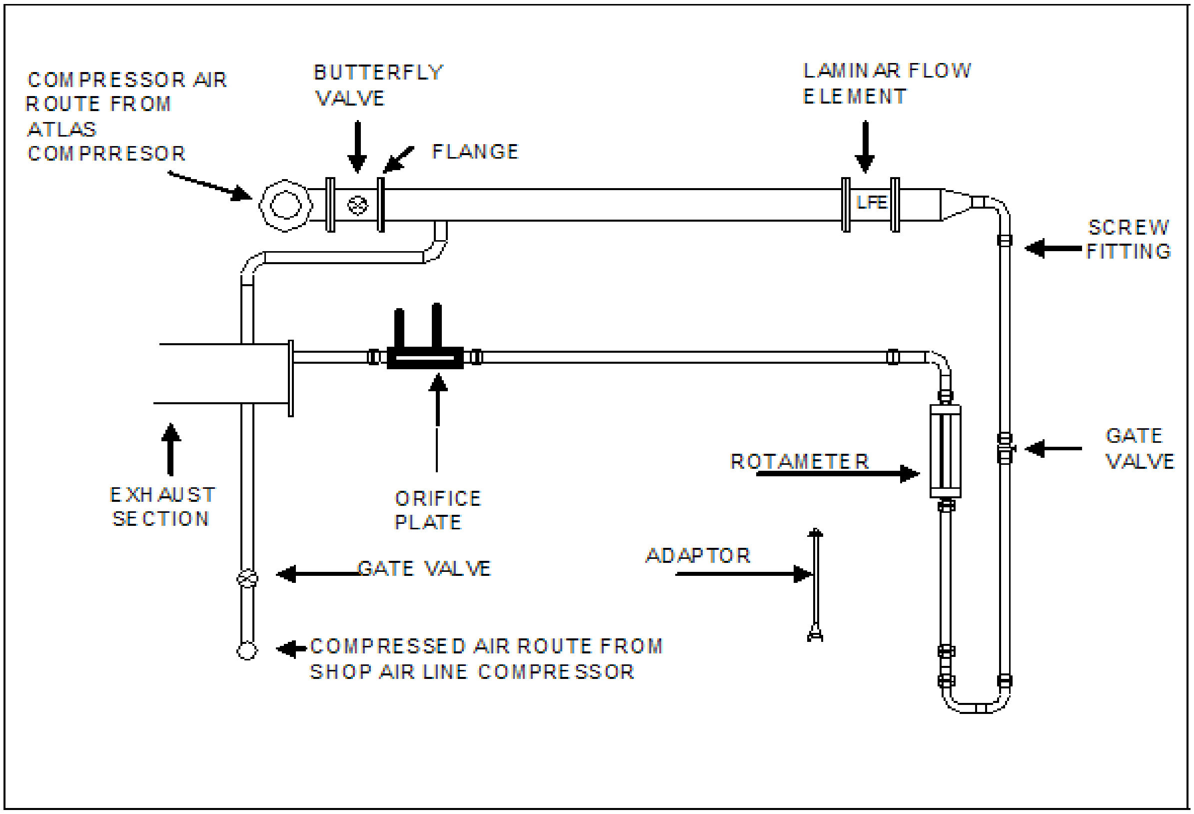

Figure 3: An Orifice Plate Flow Rig Assembly Drawing [14]

3.1 Parameters Use for the Analysis

The various parameters used in the analysis include; differential pressure, pressure ratio, Reynolds number, expansibility factor, upstream and down pressure, coefficient of discharge, diameter ratio, density, temperature, absolute viscosity, and Sutherland's law, which is used to compute the absolute viscosity. All parameters retain their usual nomenclature, concept, and meaning and their analyses are based on ISO 5167 and BS 1042 standards.

Differential pressure, ΔP, is the difference between the static pressure measured at the wall pressure tapping namely the upstream and downstream pressures.

$$\Delta P = P_1 - P_2 \qquad (1)$$

Pressure ratio, PR, is the ratio of the absolute static pressure at the downstream pressure tapping to the absolute static pressure at the upstream pressure. It is dimensionless, and is given as,

$$\tau = \frac{P_2}{P_1} \qquad (2)$$

An orifice operates on Bernoulli's principle which state that for an ideal fluid, an increase in velocity will cause a decrease in pressure. Bernoulli's principle of equation 1 shows the principle of conservation of energy for a steady flow.

$$\frac{v^2\rho}{2} + \rho g h + p = constant \quad (3)$$

where P = static pressure
ρ = density
h= height of the tube
v = fluid velocity
g = acceleration due to gravity

When Bernoulli's principle is applied to orifice plates, the energy quantities due to gravity (ρgh) is ignored and it is assumed that the system is horizontal as such the potential energy is the same.

The Continuity equation is given as Equation 3,

$$\dot{m} = \rho A V \qquad (4)$$

$$\dot{m} = \rho Q \qquad (5)$$

where:

$\dot{m}$= mass flow rate

ρ = density

V = velocity

A = area

Q = volume flow rate

Bernoulli's equation is given as Equation 6,

$$\frac{\upsilon^2 \rho}{2} + \rho g h + p = constant \qquad (6)$$

Discharge coefficient, C, for an incompressible fluid, relates the actual flow rate to the theoretical flow rate of a device and is given as,

Discharge coefficient (C_d):

$$C_d = \frac{q_m \sqrt{1-\beta^4}}{\frac{\pi}{4} d^2 \sqrt{2 \Delta P \rho_1}} \qquad (8)$$

where q_m= mass flow rate in (kg/s)

β = diameter ratio

d = Diameter of orifice in (m)

ΔP = Differential pressure in (Pa)

ρ_1 = Density of the fluid in (kg/m^3)

A = Area of the orifice (πd²/4) in (m)

ε = Expansibility factor

The expansibility factor, ε, is a coefficient used to take care of the compressibility of the fluid. It is given as,

$$\varepsilon = \frac{q_m \sqrt{1-\beta^4}}{\frac{\pi}{4} d^2 C \sqrt{2 \Delta P \rho_1}} \qquad (9)$$

The mass rate of flow can be determined using the mass flow rate equation,

$$q_m = \frac{C}{\sqrt{1-\beta^4}} \varepsilon_1 \frac{\pi}{4} d^2 \sqrt{2 \Delta P \rho_1} \qquad (10)$$

where ρ_1 refers to the upstream conditions.

The diameter ratio, β, is an important parameter in the design of an orifice plate flow measurement test facility. It is the ratio of the orifice diameter to the internal diameter of the measuring pipe. and is given as, $\beta = \frac{d}{D}$ (11)

Orifice area, $A = \frac{\pi d^2}{4}$ m^2 (12)

Pipe area, $A = \frac{\pi D^2}{4}$ m^2 (13)

Density, $\rho = \frac{P}{RT}$ kg/m^3 (14)

Flow velocity, $u = \frac{q_m}{\rho A} \ m/s$ (15)

Absolute viscosity, μ, is the measure of the ability of fluid to resist deformation under shear stress. Viscosity increases as temperature increases. Sutherland's law is used to compute the absolute viscosity. Sutherland's law expresses the relation between the dynamic viscosity and the absolute temperature of an ideal gas.

Absolute viscosity, is given by Sutherland law $\mu = \frac{C_1 T^{3/2}}{T+S}$ (16)

where $C_1 = 1.458 x 10^{-6} kg/ms\sqrt{K}$

$T = 273.15$K

$S = 110.4$K

Reynolds number is the expression of the ratio between the fluid inertia and fluid viscous force. It is dimensionless and is given as, $Re_D = \frac{\rho u D}{\mu}$ (17)

However, according to ISO 5167 standard, the Reynolds number is described in terms of the upstream condition of the fluid and the upstream diameter of the pipe making the equation take subscripts of 1.

The Reynolds number,

$$R_{eD} = \frac{\rho_1 u_1 D_1}{\mu_1} \qquad (18)$$

The discharge coefficient, C is given by the Stolz equation:

$$C = 0.5959 + 0.0312\ \beta^{2.1} - 0.1840\ \beta^{8} + 0.0029\ \beta^{2.5} \left(\frac{10^6}{\mathrm{Re}_D}\right)^{0.75} + 0.039\ L_1\ \beta^4 \left(1-\beta^4\right)^{-1} - 0.0337\ L_2\ \beta^3$$

3.2 Principle of Operation of an Orifice Plates

The orifice plates measure the mass flow rate when the increase in velocity of fluid passing through a narrow orifice induced a pressure drop. As the fluid passes through the orifice, the fluid converges, and the velocity of the fluid increases to a maximum value. At this point, the pressure is at a minimum value. As the fluid diverges to fill the entire pipe area, the velocity decreases back to the original value, and the pressures on both sides are measured resulting in a differential pressure, which is proportional to the flow rate. When the fluid gets in touch with the orifice plate, the fluid is made to converge and cross the orifice. However, the point of maximum convergence actually occurs a short distance downstream of the orifice, at a point called Vena contracta shown in Figure 4, which is the point in a fluid stream where the diameter of the stream is the least. The Vena contracta occurs short distance on the downstream side of the Orifice and at a point where the jet is horizontal. When a fluid passes through an orifice constriction, it will experience a pressure drop across the orifice. This change in pressure is called differential pressure and is used to measure the flow rate of the fluid.

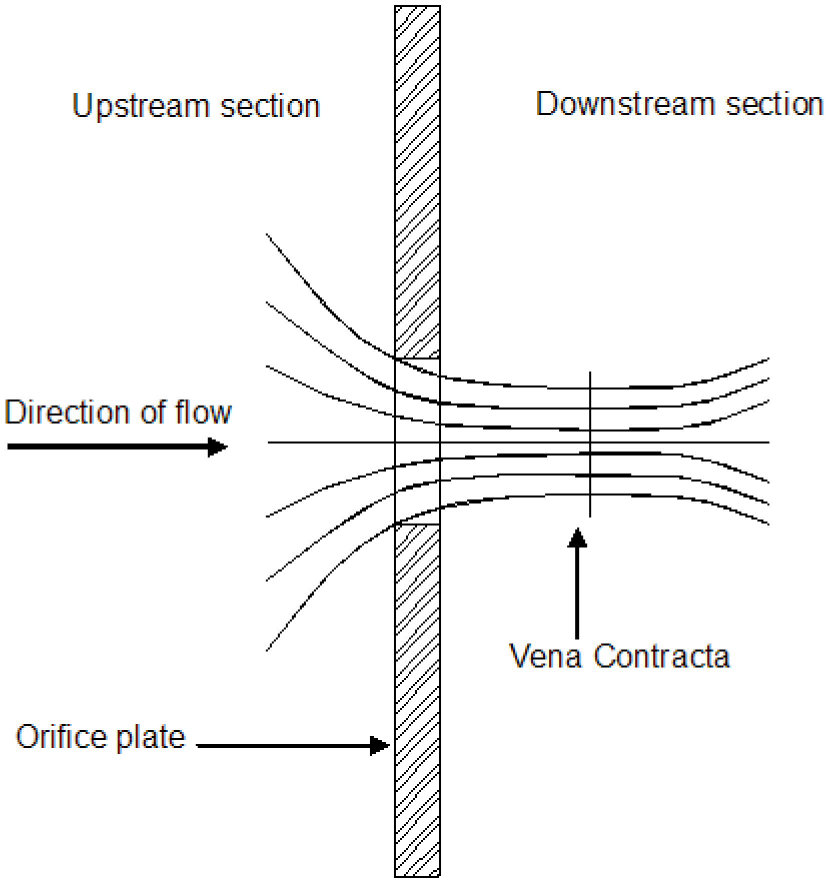

Figure 4: An orifice plate with a vena contracta

The coefficient of contraction C_c is given as the ratio between the area of the jet at the Vena contracta to the area of the orifice.

$$C_c = \frac{area\ of\ Vena\ contracta}{area\ of\ orifice} \qquad (19)$$

A typical value of the coefficient of contraction may be taken as 0.64. Further away from the vena contracta, the fluid expands and the velocity and pressure change again. When the differences in fluid pressure between the normal pipe section and the vena contracta are measured, the volumetric and mass flow rates can be obtained. The mass flow rate equation incorporates the coefficient of discharge C_d which is a function of Reynolds number to take care of the effect of frictional losses, viscosity, and turbulence. An orifice plate works satisfactorily when supplied with a fully developed flow profile. It is not expensive and easy to assemble. Analysis involving orifice plates requires accurate measurement of this pressure difference which is made possible by the measurement of fluid properties which includes upstream and downstream pressures, upstream temperature, and other parameters like the pipe diameter, orifice diameter, and computing the following: beta ratio, orifice area, density, Reynolds number, absolute viscosity, discharge coefficient, pressure ratio flow velocity, and mass flow rate.

4. RESULTS AND DISCUSSION

This section presents the results and discussion of this work. The influence of designed parameters on the mass flow measurement and control using an orifice plate is presented. The pipe area, orifice area, flow density, flow velocity, absolute viscosity, Reynolds number, and discharge coefficient are determined to ascertain the functionality of the orifice flow rig with the application of relevant fluid flow concepts.

4.1 Design Analysis of the Orifice Plate Rig

An orifice plate with D and D/2 tappings has been installed in a pipe and is required to measure a mass flow of 5kg/s of air at 443K and 3 bars gauge. Dimensions require a suitable orifice plate to fit in a 10-inch pipeline and give an indication of the expected pressures. A minimum pressure loss across the orifice plate is desirable whilst still giving reasonable sensitivity.

Given upstream pipe diameter, D = 254 mm = 0.254 m

From Equation 11, $\beta = d/D = 0.75$

Hence, $d = \beta \text{ x } D = 0.75 \text{ x } 0.254 = 0.1905$ m

From Equation 12, Orifice area, $A_1 = \dfrac{\pi d^2}{4} = \dfrac{3.142 x 0.1905^2}{4} = 0.028506\ \text{m}^2$

From Equation 12, Area, $A_2 = \dfrac{\pi D^2}{4} = \dfrac{3.142 x 0.254}{4} = 0.050677\ \text{m}^2$

Given that mass flow (q_m) = 5 kg/s

Upstream temperature, T_1 = 443 K

Upstream pressure P_1 = 300000 Pa (g)

∴ Upstream pressure P_1 (a) = 401325 Pa (a)

Where P_1 (a) = absolute pressure

Pa (g) = gauge

Specific gas constant of air, R = 287 J/kgK

$$Density,\ \rho = \frac{P}{RT} = \frac{401325}{287\ x\ 443} = 3.16\ kg/m^3$$

$$Flow\ velocity,\ u = \frac{q_m}{\rho A} = \frac{5}{3.156535\ x\ 0.050677} = 31.26\ m/s$$

Absolute viscosity, is given by Sutherland law, $\mu = \dfrac{C_1 T^{3/2}}{T + S}$

where C_1= 1.458 x10^{-6} kg/m s $\sqrt{K}$

S = 110.4 K

$$\therefore \qquad \mu = \frac{1.458 x 10^{-6} x 443^{3/2}}{443 + 110.4} = 2.46 x 10^{-5}$$

kg/m s

Reynolds number, $\text{Re}_D = \dfrac{\rho u D}{\mu}$

$$Re_D = \frac{3.16\ x\ 31.26\ x\ 0.254}{2.46\ x\ 10^{-5}} = 1019418$$

Discharge coefficient, C is given by Stolz equation:

$$C = 0.5959 + 0.0312\ \beta^{2.1} - 0.1840\ \beta^8 + 0.0029\ \beta^{2.5} \left(\frac{10^6}{\text{Re}_D}\right)^{0.75} + 0.039\ L_1\ \beta^4 \left(1 - \beta^4\right)^{-1} - 0.0337\ L_2\ \beta^3$$

Considering the tappings for D and D/2 tappings, where L_1 = 1 and L_2 = 0.47

$$\therefore C = 0.5959 + 0.0312\ x\ (0.75)^{2.1} - 0.1840\ x\ (0.75)^8 + 0.0029\ x\ (0.75)^{2.5} \left(\frac{10^6}{1019418}\right)^{0.75} + 0.039\ x\ 1\ x\ (0.75)^{\ 4}\ x\ (1 - 0.75)^{-1} - 0.0337\ x\ 0.47\ x\ (0.75)^3 = 0.61357$$

Expansibility factor, ε;

Let ε = 0.963

The differential pressure is given from the flow rate equation:

$$q_m = \frac{C}{\sqrt{1 - \beta^4}} \varepsilon_1 \frac{\pi}{4} d^2 \sqrt{2 \Delta P \rho_1}$$

$$\therefore \ \Delta P = \left(\frac{4.q_m \sqrt{1 - \beta^4}}{C.\varepsilon.\pi.d^2}\right)^2 \div 2.\rho$$

$$\Delta P = \left(\frac{4\ x\ 5\sqrt{1 - 0.75^2}}{0.61357\ x\ 0.963\ x\ 3.142\ x\ 0.1905^2}\right)^2 \div 2\ x\ 3.16 = 9542.10\ Pa$$

Downstream pressure P2 = P1 - ΔP = 401325 – 9542.10 = 391782. 90 Pa

4.2 Effect of Mass Flow Rate on Flow Properties in an Orifice Flow Rig

In this analysis, the mass flow rate of 5 kg/s was gradually increased, for four consecutive times to ascertain the effect on flow velocity, Reynolds number, differential and downstream. The data were computed which is presented in Table 1. The analyses indicate that an increase in the mass flow rate through an orifice plate flow rig will increase the flow velocity, Reynolds number, differential, and a decrease in the downstream pressure. This can be confirmed in the literature and the results are presented graphically in Figures 5, 6, 7, and 8 respectively.

Table 1: The mass flow rate relationship with flow properties

SN	Mass flow	Flow velocity	Reynolds number	Differential pressure	Downstream pressure
1	5	31.27	1019418	9542.11	391782.90
2	10	62.51	2038835	38238.75	363086.25
3	15	93.77	3058253	86098.16	315226.84
4	20	125.03	4077670	153122.63	248202.375
5	25	156.30	5097088	239313.38	162011.62

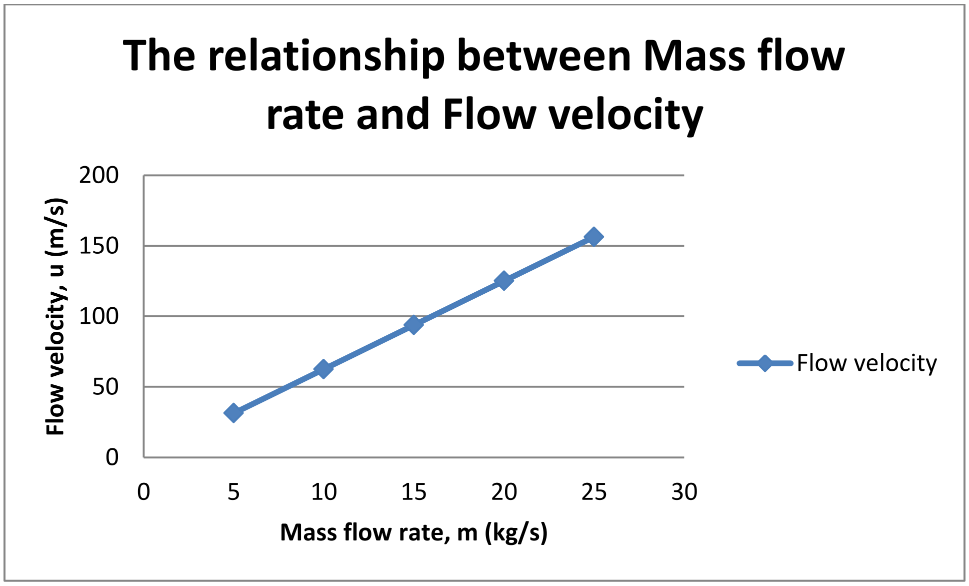

Figure 5: The relationship between the Mass flow rate and the Flow velocity

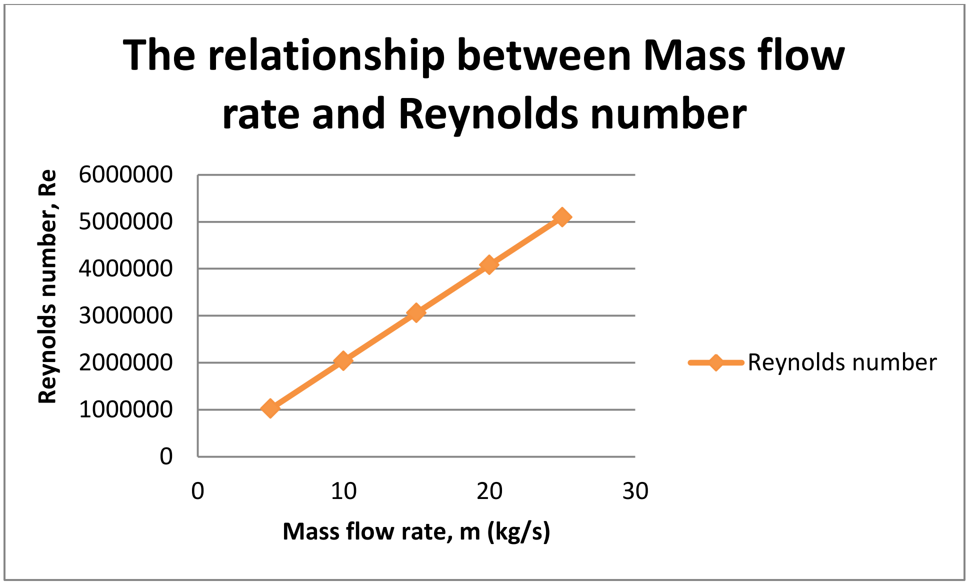

Figure 6: The relationship between the Mass flow rate and the Reynolds number

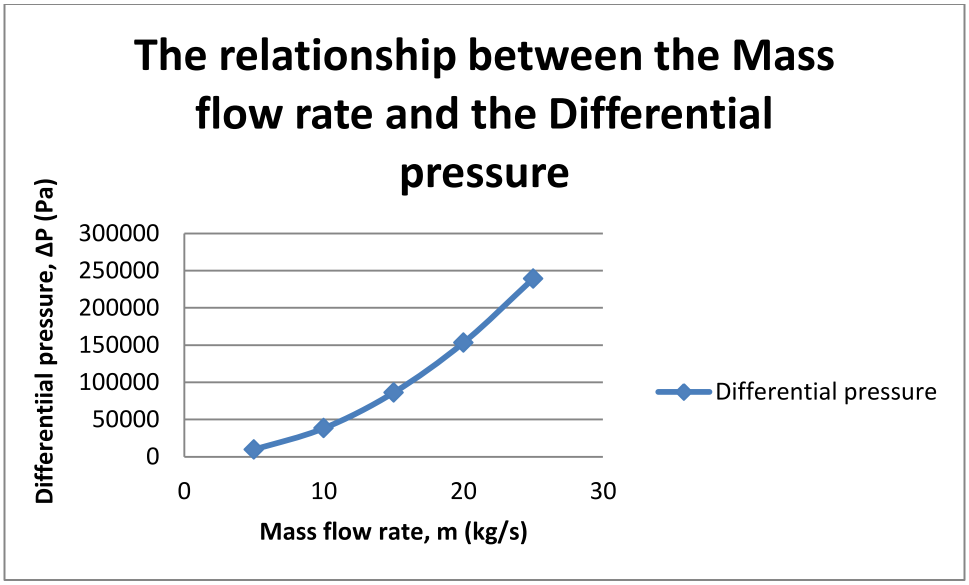

Figure 7: The relationship between the Mass flow rate and the Differential pressure

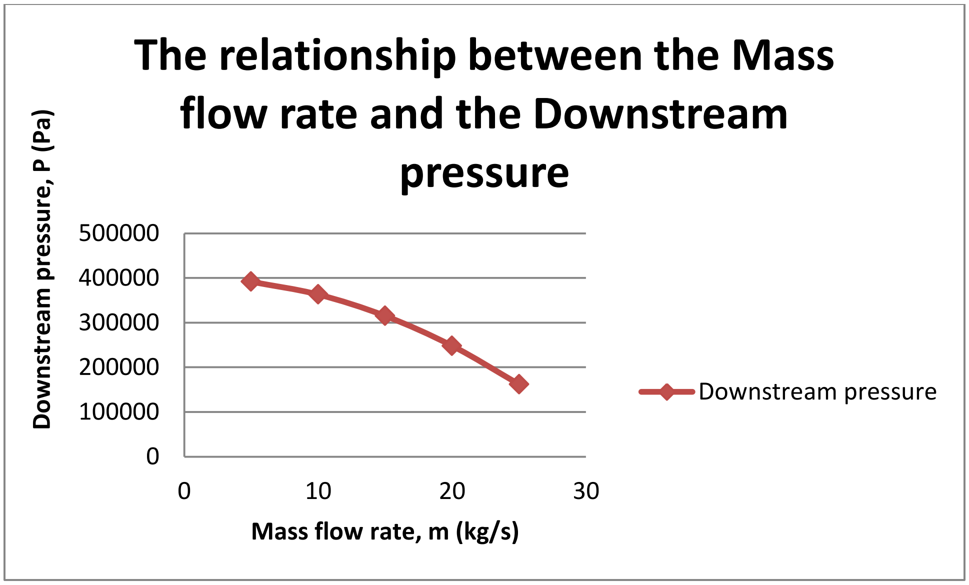

Figure 8: The relationship between the Mass flow rate and the Downstream pressure

Table 2 shows the relationship between the Reynolds number and the coefficient of discharge, which indicate that an increase in the Reynolds number, decreases the coefficient of discharge and is presented graphically in Figure 9.

Table 2: The relationship between the Reynolds number and the coefficient of discharge

Reynolds number	Discharge Coefficient
1019418	0.613570162
2038835	0.613005658
3058253	0.612788555
4077670	0.612670002
5097088	0.612594135

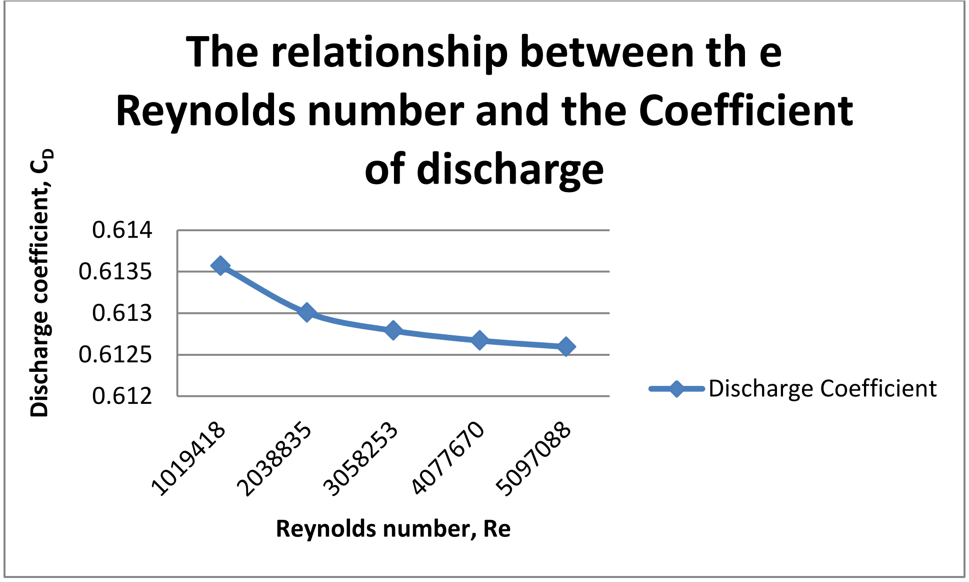

Figure 5: The relationship between the Reynolds number and the Coefficient of discharge

4.3 Discussion of Result

In the analysis, the effect of mass flow rate on fluid density, flow velocity, Reynolds number, and pressures in orifice plate analysis agrees with the results in the literature and that an increase in the Reynolds number decreases the coefficient of discharge and increases differential pressure, hence, an increase the flow rate. Proper design and manufacturing of this orifice plate flow rig can be ensured by accurate sizing of orifice plates, pipe dimensions, and instrumentation to ascertain the effectiveness of the rig. The orifice plate flow rig characteristics used in this study are feasible for the measurement and control of fluid in pipelines and in the aerodynamic study of the importance of an orifice in an aero engine.

5. CONCLUSION

In this work, the design parameters analysis for the manufacturing of an Orifice plate flow rig was investigated. This study focused mainly on the dimensions of the flow rig and the performance of the orifice plate for mass flow measurement and control in a horizontal orientation using compressed air as the working fluid. Fluid flow principles such as Bernoulli's principle and Continuity equation were applied in this study for the analysis of the effect of mass flow rate on fluid density, flow velocity, absolute viscosity, and Reynolds number in orifice plate and the results agree with the results in the literature. With an orifice upstream pipe designed diameter of 254 mm, upstream pressure of 3 bars gauge with an inlet temperature of 433K, and a mass flow rate of 5 kg/s, the analysis indicates an orifice area of 0.0285 m2 and a pipe area of 0.0507 m2 respectively are capable for this flow rig, with a flow density of 3.16 kg/m3, the flow velocity of 31. 26 m/s, absolute viscosity of fluid of 2.457 x 10-5 kg/m s, and Reynolds number of 1019418. Further analyses were carried out, which shows that an increase in the mass flow rate through an orifice plate flow rig will increase the flow velocity, Reynolds number, and differential pressure, but decreases the downstream pressure. Hence, an increase in the Reynolds number decreases the coefficient of discharge and increases differential pressure, thereby, increasing the flow rate. The analysis shows the influence of orifice plate geometry, pipe configuration, and fluid properties on mass flow measurement and mass flow control. This study will enable the selection of orifice type and dimension, validation of pipe networks, choice of apparatus, and instrumentation arrangement for a dedicated fluid flow test rig in a fluid machinery laboratory for use in flow measurement and control in pipelines and gas turbine engine internal flow systems. This in-house designed concept can be employed for flow measurement and control analysis for industrial purposes, such as in pipelines in oil and gas industries and in aero engines in the aviation industry.

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