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Investigating the inaccuracies in Orifice Metering based Natural Gas measurement

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Abstract: Natural gas measurement is essential in various industries, and one commonly employed method is through the use of orifice meters. These meters determine the volumetric flow of natural gas by assessing the differential pressure between the upstream and downstream sections of a partially impeded pipe, orifice. Orifice meters offer several advantages, including simple to install, cost-effectiveness, mechanical stability, and a wide operational range in terms of temperature, pressure, and size. There are several parameters involved in measurement of accurate gas flow like gravity, pressure, temperature, and composition. In addition to this, installation of plate, proper dia for certain flow measurements, beveling of orifice dia and bending of plate over the period of time play significant role to over/under cast the flow measurement. The objective of this research is to comprehensively investigate the factors affecting the accuracy of orifice metering for natural gas measurement through numerical simulations. This study entails the development of a 3D Computational Fluid Dynamics (CFD) model for orifice metering and focuses on three primary research objectives. First, a detailed examination of the impact of variations in orifice plate characteristics (such as plate thickness, bevel-edge angle, orientation, and plate bending) on measurement inaccuracies will be conducted using CFD simulations. By addressing these objectives, this research aims to provide valuable insights into the factors affecting orifice metering accuracy, contributing to a better understanding of the operational limitations and potential areas for improvement in natural gas measurement using orifice meters.

Keywords: *Orifice Metering, Natural Gas Measurement, Computation Fluid Dynamics (CFD), Ansys Fluent, Simulation*.

1. Introduction

The natural gas industry relies significantly on the accurate measurement of gas flowrates, a task predominantly carried out by orifice meters. The precision of these meters is pivotal for economic transactions within the industry, affecting billing accuracy and operational efficiency [1]. This research investigates into the nuanced aspects influencing the accuracy of orifice meters in measuring natural gas flowrates. Understanding and mitigating inaccuracies is crucial to prevent financial losses for suppliers and consumers [2]. Inaccuracies in orifice meter readings within the natural gas industry present a multifaceted challenge with significant economic consequences. Financial losses for both suppliers and consumers may result from billing discrepancies due to miscalculations in the actual volume of gas being transported or sold [3]. This research seeks to address the imperative need to identify and understand the various factors contributing to inaccuracies in orifice meter measurements, laying the foundation for their optimization.

The investigation employs numerical simulations to explore critical parameters, including orifice plate characteristics, installation methods, and the impact of condensate formation [4]. By systematically analyzing these factors, this study aims to provide valuable insights for optimizing orifice meter accuracy and, consequently, enhancing the reliability of flow measurements in the natural gas sector [2].

The findings contribute to the broader goal of refining measurement techniques, addressing economic challenges, and fostering trust within the natural gas industry.

Orifice meters for gas measurement are considered to be accurate to ± 1 to $\pm 2\%$, accuracies better than $\pm 1\%$ can be achieved by individual calibration. However, it tends to have relative low accuracy when measuring at low flow conditions. The turndown for this design typically is less than 5:1, which is a relatively low range compared to other meters. Apart from it, the accuracy is highly affected with design and operating conditions. It also has high-pressure loss (15–55%) which can impact operating cost. Orifice meter is also flow-profile sensitive and usually requires a long meter tube or flow conditioner, and it is not capable of self-cleaning thus can be easily damaged or clogged by high flow rates [5]. Hence, the formation of condensate on the plate, or physical damage to the plate could lead a serious wrong measurement issue. Hence in this project different scenarios will be studied for understanding the impact on orifice measurement accuracy with the help of numerical simulations.

2. Related Work

The literature review encapsulates a comprehensive overview of previous studies and research works pertaining to orifice meters and their role in the natural gas industry. Previous research emphasizes the critical importance of accurate flow measurements in various contexts, including billing accuracy, operational efficiency, and regulatory compliance. The review spans various parameters, encompassing orifice plate characteristics, flow conditions, and metering techniques, providing a holistic understanding of existing knowledge in the field.

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In [6] Nasiruddin and Singh investigated the impact of innovative design modifications on orifice meter performance using CFD. Their study revealed a 22% improvement in discharge coefficient for a newly designed orifice meter compared to a reference meter, showcasing the significance of surface topology changes.

In [7] Puspitasari and Husni addressed flow measurement inaccuracies in Orifice Flow Meters (OFM). Through numerical simulations, they proposed a correction factor model to enhance measurement accuracy, considering factors like Pearson correlation and Kolmogorov-Smirnov data normalization.

In [8] Schena highlighted the crucial role of flowmeters in minimizing ventilator-induced lung injury. They provided an overview of various flowmeter types used in mechanical ventilators, emphasizing the importance of meeting strict criteria for dynamic and static characteristics.

In [9] Kumar and Bing conducted numerical studies on slotted orifices, revealing that perforation shape has minimal impact on differential pressure. Their findings indicated that a low β ratio is preferable for wet gas metering, aligning with similar observations in the field.

In [10] Steven and Hall addressed the wet gas response of horizontally installed orifice plate meters, developing a wet gas flow correlation. Their work corrected liquid-induced gas flow rate errors, achieving ±2% accuracy at a 95% confidence level.

In [11] Roul and Dash investigated two-phase flow pressure drops through thin and thick orifices using CFD. Their simulations, validated against experimental data, considered various orifice geometries and provided insights into pressure losses in air-water flows.

In [12] Shah et al. utilized Computational Fluid Dynamics (CFD) to enhance orifice flow predictions, proposing a new scheme for tracking vena-contracta. Their approach maintained existing orifice meter advantages while improving accuracy and sensitivity.

In [2] Ettouney and El-Rifai analyzed the impact of temperature and gas composition fluctuations on isentropic exponent and viscosity in natural gas metering. Their study emphasized the importance of considering these factors for accurate flow calculations.

In [13] Manshoor et al. addressed the sensitivity of orifice plate flow meters to upstream flow conditions and proposed a fractal flow conditioner. Experimental results demonstrated the combination's insensitivity to initial flow conditions.

In [14] Dezfouli et al. developed a method for determining gas leakage rates from household gas pipes using numerical simulations. Their approach, validated experimentally, showed measurement errors within ±10%, providing a reliable means for leakage rate estimation.

In [15] Đurđević et al. compared Single-Hole Orifice (SHO) and Multi-Hole Orifice (MHO) flow meters using CFD. Results favored MHO flow meters, showing lower singular pressure loss coefficients and quicker pressure recovery, supported by experimental verification.

In [16] Xu et al. focused on understanding and improving mass flow rate measurement uncertainty in orifice flow meters, comparing computational models and commercial codes. Their study aimed to quantify and analyze measurement errors encountered at low flow rates and start-up.

In [17] Dong et al. introduced an improved carbide orifice flow meter (ICOF) and compared it with a traditional orifice flow meter. The ICOF demonstrated improved accuracy and stability, making it a promising choice for engineering applications.

In [18] Singh and Tharakan investigated multi-hole orifice flow meters, using both numerical simulations and experiments. Their findings revealed significantly lower pressure loss in multi-hole meters compared to single-hole meters of identical flow area.

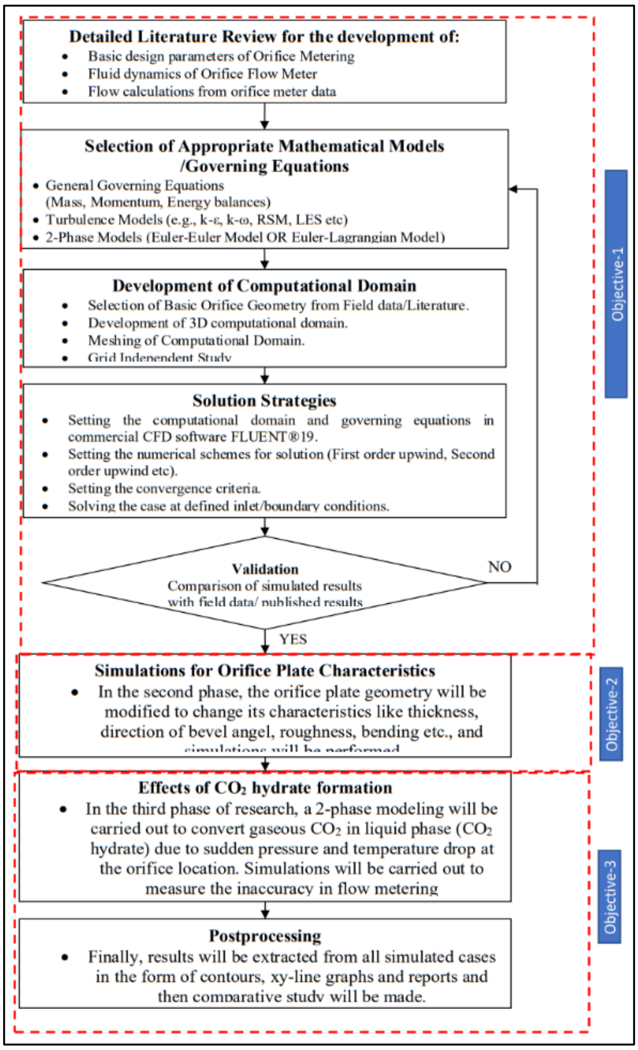
In [12] Shah et al. utilized Computational Fluid Dynamics (CFD) for accurate orifice flow predictions, proposing a new scheme to track vena-contracta. Their approach maintained existing orifice meter advantages while enhancing accuracy and sensitivity.

3. Methodology

The research methodology adopts a numerical simulation approach to systematically assess the impact of key parameters on orifice meter accuracy using ***Ansys Fluent 19.1*** software. Numerical simulation has been carried out for plate thickness, bevel angle, plate bending, reverse installation, and condensate formation are chosen as the focal points for investigation. Numerical models are developed to simulate flow conditions, allowing for the controlled variation of these parameters and subsequent analysis of their effects on orifice meter performance .[,ix] The methodology is designed to provide a robust and comprehensive understanding of how each parameter, individually and collectively, influences the accuracy of orifice meters in measuring natural gas flowrates.

3.1 Development of Computational Domain

A 10-inch orifice meter (242.87 mm nominal diameter of pipe) was simulated in current study. The orifice bore was of size 145.72 mm size. The 3D geometry was created using ***Ansys Design Modeler 19.1*** application. The orifice meter



used for the computations was of flanged taps in which the upside and downside pressure taps for measuring pressure difference across the orifice plate are being installed on the flanges of orifice meter.

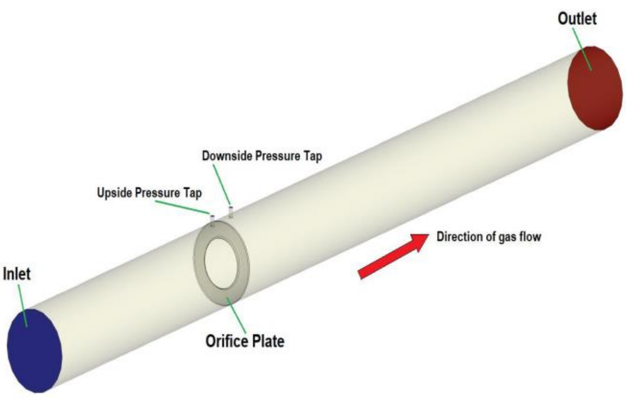


Fig. 3.1. Isometric view of created 3D orifice plate of 10" diameter

Figure 1. shows a different view of orifice meter along with the close-up view of orifice plate whereas Figure 2. shows the meshed geometry or computational domain used for computations.

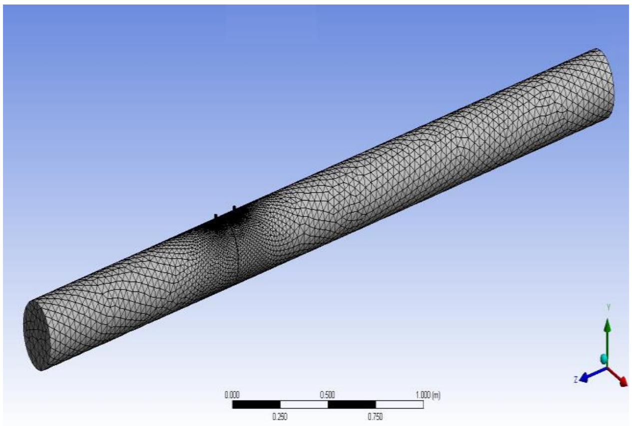


Fig .3.2. Mesh view of developed 10" diameter orifice meter and orifice plate

Total length of the upside spool of orifice meter was set at 1215 mm whereas the downside spool of orifice meter was set at 2430 mm.

The orifice meter has no flow conditioning veins rather than the flow conditioning was done with the assumption of laminar flow condition at flow entry point. A total of 12 different geometries were created with varying plate thickness, varying bevel-edge angle, and orientation of orifice plate installation with respect to bevel-edge angle. The details of all geometries along with simulated cases has been shown later on in this chapter.

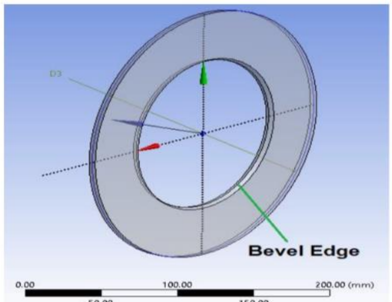


Fig3.3. Close-up view of orifice plate showing the bevel edge

Fig 3.4. Front view of created 3D orifice plate

3.2 Selection of Appropriate governing equations

The computational fluid dynamics (CFD) modeling of an orifice meter involves the application of fundamental governing equations to simulate fluid flow through the device. The primary equations employed in this context are the Navier-Stokes equations, which describe the conservation of mass and momentum in a fluid. These equations, when supplemented with the continuity equation, represent the foundation for understanding the complex flow patterns and pressure differentials associated with orifice meters. In addition, the energy equation may be incorporated to account for changes in fluid temperature. The application of these governing equations allows CFD simulations to predict the velocity profiles, pressure distributions, and overall performance of orifice meters under various operating conditions. Accurate modeling of these equations is crucial for optimizing the design and performance of orifice meters in applications such as fluid measurement and control in industrial processes.

Table No. 01. Few pre-selected governing equations for the CFD analysis

Regarding the phase change for the formation of condensate, the Volume of Fluid (VOF) model is a widely used approach in Fluent, a computational fluid dynamics (CFD) software, for simulating multi-phase flows. In the context of VOF, the governing equations include the mass and momentum conservation equations for each phase, coupled with a volume fraction equation that tracks the distribution of each phase within the computational domain. The volume fraction represents the fraction of a cell occupied by a specific phase, allowing the model to capture the interface between different phases. The VOF model is particularly effective for simulating scenarios where distinct phases, such as air and water, coexist and interact. It is especially valuable in applications like free surface flows, sloshing tanks, and liquid-gas interfaces. The accurate prediction of phase interactions and interface dynamics provided by the VOF model in Fluent contributes to a better understanding of complex multi-phase phenomena in various engineering and scientific domains. All the concerned governing equations are tabulated in Table-01.

3.3 NUMERICAL SETUP OF MODEL

CFD software ANSYS FLUENT® 19.1 was used for numerical computations. Finite-volume method has been utilized by ANSYS FLUENT. Steady-state simulation was carried out with pressure-based solver that utilized an implicit pressure-correction scheme by decoupling the equations for energy and momentum. For coupling the velocity and pressure, SIMPLE algorithm was followed.

Convective terms were spatially discredited by second-order-upwind scheme. The constant values for properties like heat capacity (Cp) and viscosity (μ) were used. Convergence of the solution was achieved when the mass, turbulent kinetic energy and momentum residuals were satisfied at 10-3. Personal computer Core-i7 with processing speeds of 1.3 GHz and 1.50 GHz along with 16 GB RAM was used for computation.

Quantity	Equation	No.
Mass	$\nabla.(\rho\vec{v}) = S_m$	(3.1)
Momentum	$\nabla.(\rho\vec{v}\vec{v}) = -\nabla p + \nabla.(\bar{\bar{\tau}}) + \rho + \vec{F}$	(3.2)
k-ε Turbulence Model	$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_i}(\rho k u_i) = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right] + G_k - G_b - \rho\varepsilon - Y_M + S_k$	(3.3)
	$\frac{\partial}{\partial t}(\rho\varepsilon) + \frac{\partial}{\partial x_i}(\rho\varepsilon u_i) = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}\right] + C_{1\varepsilon}\frac{\varepsilon}{k}(G_k + C_{3\varepsilon}G_b) - C_{2\varepsilon}\rho\frac{\varepsilon^2}{k} + S_\varepsilon$	(3.4)
Energy Equation (only in Phase Change cases)	$\frac{\partial}{\partial x_i}(\rho c_p u_i T) = \frac{\partial}{\partial x_i}\left(\lambda\frac{\partial T}{\partial x_i} - \rho c_p \overline{u_i' T'}\right) + \mu\Phi + S_h$	(3.5)
Volume of Fluid Model (Only for phase change case)	$\frac{1}{\rho_q}\left[\frac{\partial}{\partial t}\left(\alpha_q\rho_q\right) + \nabla\cdot\left(\alpha_q\rho_q\vec{v}_q\right) = S_{\alpha_q} + \sum_{p=1}^{n}\left(\dot{m}_{pq} - \dot{m}_{qp}\right)\right]$	(3.6)

3.4 BOUNDARY AND INLET CONDITIONS

In present research numerical simulations were performed with varying geometrical and operating parameters. Four geometrical parameters were selected for current study i.e., plate thickness, bevel edge angle, bending of plate and orientation whereas inlet volumetric flowrate was varied as operating parameter. A total of 15 different geometries were developed with changed design parameters as discussed above. Table-2 describes all the varying design parameters.

Sr. No.	Case Name	Orifice used	Condensate
1	5mm_30_0_F	Orifice 1	NO
2	7.5mm_30_0_F	Orifice 2	NO
3	10mm_30_0_F	Orifice 3	NO
4	5mm_45_0_F	Orifice 4	NO
5	7.5mm_45_0_F	Orifice 5	NO
6	10mm_45_0_F	Orifice 6	NO
7	5mm_60_0_F	Orifice 7	NO
8	7.5mm_60_0_F	Orifice 8	NO
9	10mm_60_0_F	Orifice 9	NO
10	5mm_45_10_F	Orifice 10	NO
11	5mm_45_20_F	Orifice 11	NO
12	10mm_45_30_F	Orifice 12	NO
13	5mm_45_0_B	Orifice 13	NO
14	7.5mm_45_0_B	Orifice 14	NO
15	10mm_45_0_B	Orifice 15	NO
16	5mm_45_0_F_C	Orifice 4	YES
17	7.5mm_45_0_F_C	Orifice 5	YES
18	10mm_45_0_F_C	Orifice 6	YES

Table No.2: Design parameters for Orifice Plate

The orifice plates were used in numerical simulations where volumetric flow of natural gas was varied from 20,000 Nm3/h (0.71 MMSCFD) to 245,000 Nm3/h (8.65 MMSCFD). A total of 18 simulations were conducted as described in Table-3.

Geometry No.	Plate Thickness	Bevel Edge Angle	Bending of Plate	Orientation of plate
Orifice 1	5 mm	30	0 Degree	Forward
Orifice 2	7.5 mm	30	0 Degree	Forward
Orifice 3	10 mm	30	0 Degree	Forward
Orifice 4	5 mm	45	0 Degree	Forward
Orifice 5	7.5 mm	45	0 Degree	Forward
Orifice 6	10 mm	45	0 Degree	Forward
Orifice 7	5 mm	60	0 Degree	Forward
Orifice 8	7.5 mm	60	0 Degree	Forward
Orifice 9	10 mm	60	0 Degree	Forward
Orifice 10	5 mm	45	2.5 Degree	Forward
Orifice 11	5 mm	45	5 Degree	Forward
Orifice 12	5 mm	45	7.5 Degree	Forward
Orifice 13	5 mm	45	0 Degree	Backward
Orifice 14	7.5 mm	45	0 Degree	Backward
Orifice 15	10 mm	45	0 Degree	Backward

Table No. 3: Various simulated cases

3.5 FLOW CALCULATIONS FROM ORIFICE METER

The orifice meter is commonly used to measure the flow rate of fluids, including gases like natural gas. The flow rate through an orifice can be determined using the following formulas.

3.5.1 Flowrate (Q)

The basic formula for calculating the flow rate (Q) through an orifice is given by:

$$Q = C_d . A . \sqrt{\frac{2.\Delta P}{\rho}} \tag{3.7}$$

where

- Q is the flow rate,
- C_d is the discharge coefficient (accounts for variations in orifice design and fluid properties),
- A is the cross-sectional area of the orifice,
- ΔP is the pressure drop across the orifice,
- ρ is the density of the fluid.

3.6.2 Orifice Area (A)

The orifice area can be calculated using the orifice diameter (d) with the formula:

$$A = \frac{\pi . d^2}{4} \tag{3.8}$$

4. Results and Discussion

In natural gas measurement through orifice measurement, several key factors significantly impact the accuracy and reliability of the process. The criticality of plate thickness cannot be overstated, as it directly influences the pressure drop across the orifice plate and, consequently, the accuracy of flow measurement. Optimal plate thickness ensures that the pressure differential is within the desired range. Additionally, the plate bevel angle plays a crucial role in minimizing disturbances to the gas flow, preventing turbulence, and ensuring precise measurement. The direction of flow is another pivotal factor, affecting the orifice plate's performance and measurement accuracy. Bending the orifice plate demands careful consideration, as it can introduce errors in the readings if not properly addressed. Furthermore, condensate formation poses a challenge, impacting the density and viscosity of the gas, which can distort measurements. Attending to these factors with meticulous attention is paramount for obtaining accurate natural gas measurements through orifice measurement, thereby facilitating efficient and reliable gas flow management.

In present research, all the above-mentioned critical parameters were investigated through numerical simulations with the help of CFD software ANSYS FLUENT. The results regarding all simulated cases are discussed in subsequent paragraphs.

4.1 EFFECT OF BEVEL ANGLE AND PLATE THICKNESS

The bevel angle of an orifice plate is critical in minimizing flow disturbance. An improper bevel angle can lead to turbulence and eddies in the gas flow, causing inaccuracies in measurement by affecting the pressure drop across the orifice. A carefully chosen bevel angle ensures a stable and well-defined pressure differential across the orifice plate. This stability is crucial for maintaining a consistent signal that accurately represents the flow rate of natural gas. In present research 3 orifice bevel edge angles (30°, 45° and 60°) and 3 plate thickness (5 mm, 7.5 mm and 10 mm) were taken. A fixed flowrate was injected in the orifice meter and then the flow was measured from the pressure differential achieved across the orifice plate from the upside and downside pressure taps.

Fig. 4.1 shows the results in terms of flow measurements for orifice plates with different plate thickness at 30° bevel angle. In the figure, the black line shows the original volumetric flow whereas the rest of lines show the flow calculated with respective conditions. Similarly, Fig. 4.2 and Fig. 4.3 shows the flow measurements at 45° and 60° bevel angles. From the figure it has been observed that at 30° bevel angle (Fig. 4.1) the estimated flow is decreasing with increasing the real volumetric flowrate of natural gas. The decrease in estimated flowrate of natural gas is going higher side if the thickness of plate is increased from 5 mm to 10 mm. Contrary with the results of 30° bevel angle, the trend of 60° bevel angle plate is different. The trend of error on the positive side with 60 °bevel angle (Fig. 4.3). The bevel angel of 45° is showing very less error compared to both other angles.

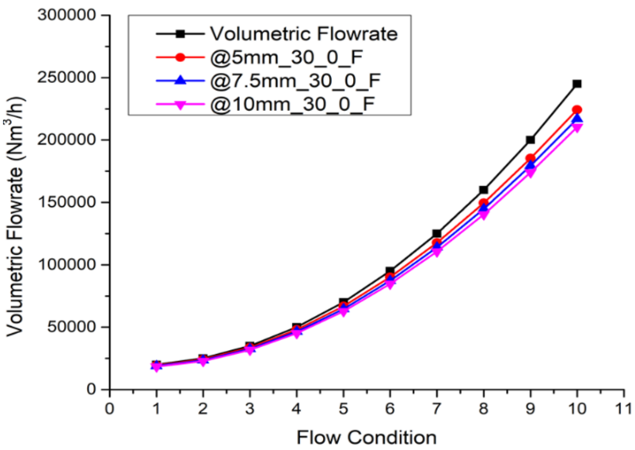


Fig. 4.1: Effect of orifice flow measurements at different plate thicknesses with 30° Bevel Angle

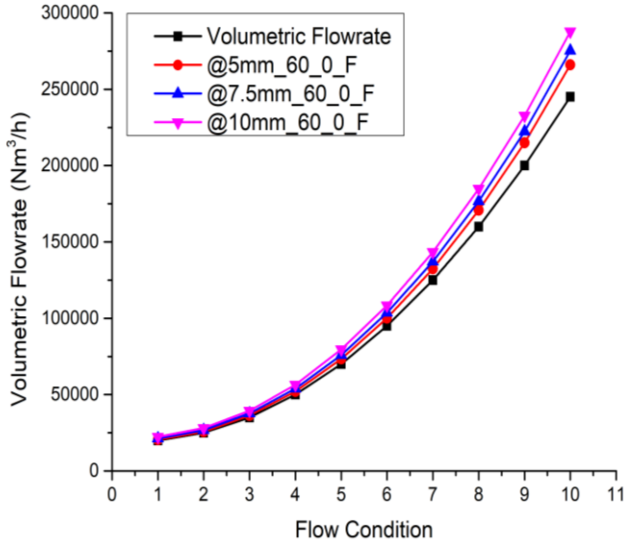


Fig. 4.2: Effect of orifice flow measurements at different plate thicknesses with 45° Bevel Angle

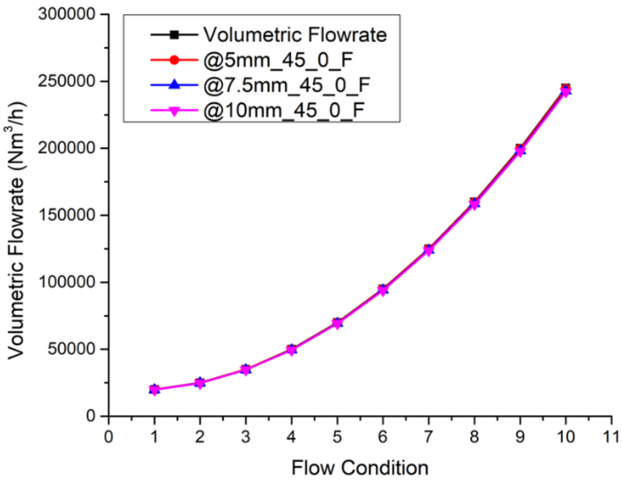


Fig. 4.3: Effect of orifice flow measurements at different plate thicknesses with 60° Bevel Angle

The error between the true (real) flow and estimated flow from all the cases is calculated and plotted in Fig. 4.4. From the figure, it has been observed that the minimum error of –0.188 % was estimated with 5mm thickness and 45° bevel angle. With this angle, the maximum error was –1.148 % with 10 mm thickness of plate, which comes even under insignificant level. The minimum and maximum errors by 60° bevel angle plate were observed up to +5.246 % and +14.096 % with 5 mm and 10 mm thickness of plate respectively. Similarly, the minimum and maximum errors by 30° bevel angle plate were observed up to +5.096 % and +10.796 % with 5 mm and 10 mm thickness of plate respectively. From the discussion, it has concluded that 5 mm thick plate with 45° bevel angel gave good results in terms of flow measurements.

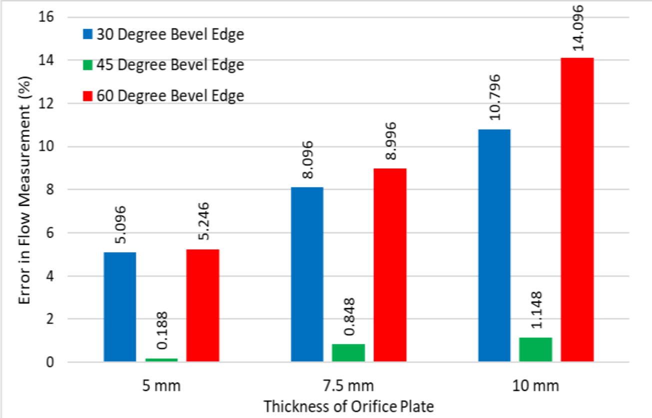


Fig. 4.4: Error in flow measurements due to different plate thicknesses and bevel angles

4.2 EFFECT OF BENDING OF PLATE

The bending of an orifice plate in a flow measurement system can have significant consequences on the accuracy and reliability of the measurements. Orifice plates are designed to create a well-defined restriction in the flow path, and any bending or deformation can alter the flow profile, leading to inaccuracies in pressure differentials and flow rates. Bending can introduce irregularities in the fluid stream, causing turbulence and eddies that disrupt the intended flow pattern. This disturbance can result in inaccurate pressure readings across the orifice, ultimately affecting the calculated flow rate. Proper installation and maintenance, including measures to prevent or correct plate bending, are crucial to ensuring the precision of orifice meter measurements in applications such as natural gas flow monitoring.

The inaccuracies in flow measurement from orifice meter was estimated by having a bending of orifice plate at 10°, 20° and 30° bending in the direction of flow. For the sake of understanding the criticality of bending impact, the rest of the parameters were kept constant. The 5 mm plate thickness was taken with 45° bevel edge angle which was fixed in this study.

The results are shown in Fig. 4.5. It has been observed that bending has high impact on the flow measurement. The flow measurement was observed with negative error (less flow measured). The higher the bending angle, the higher the error in flow measurement observed. The error for all the cases of bending effects is shown in Fig. 4.6. From the figure, it has been observed that with no bending (0°) there is a minute error i.e., –0.188 % but only of 10° bend, the error goes up to –13.796 % and goes increasing. The maximum error was observed –28.706 % at 30° bending angle.

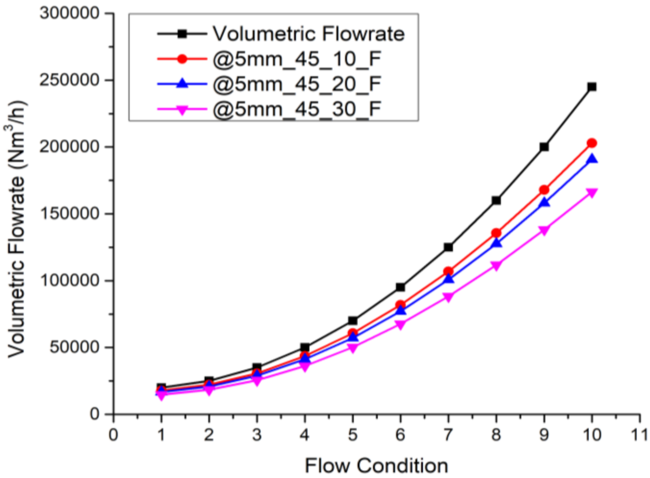


Fig. 4.5: Effect bending of orifice plate at fixed bevel angle (45°) and Plate Thickness (5 mm)

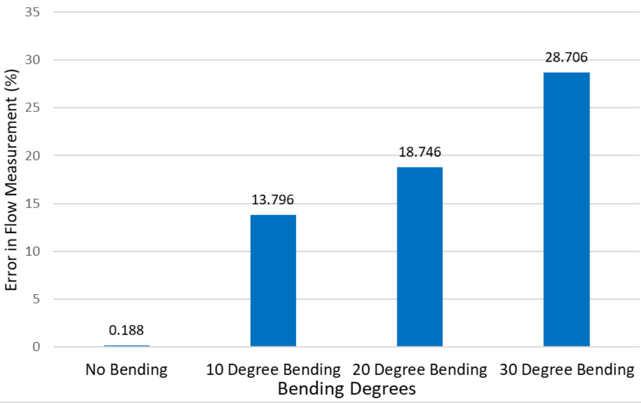


Fig. 4.6: Error in flow measurements due to different plate bending angles

4.3 EFFECT OF INSTALLATION OF REVERSE DIRECTION OF ORIFICE PLATE

Installing an orifice plate in the reverse direction, where the smaller diameter faces the downstream flow, can lead to significant inaccuracies in flow measurement. Orifice plates are designed to create a pressure drop across the plate, enabling the calculation of flow rates based on this pressure difference. When installed in reverse, the flow profile is disrupted, resulting in inaccurate pressure differentials. This misalignment can cause underestimation of flow rates, leading to erroneous readings and potentially compromising the efficiency of the entire measurement system. Additionally, reversed installation may disturb the fluid dynamics and increase the likelihood of cavitation, erosion, and other flow-related issues, thereby compromising the accuracy and reliability of the flow measurement process. It is crucial to adhere to proper installation guidelines to ensure the integrity and precision of orifice plate-based flow measurements.

To check the inaccuracies offered by installation of reverse direction of orifice plate, simulations with 5 mm thick plate having 45° bevel angle were carried out with reverse direction of bevel angle (bevel angle at the flow inlet side). Fig. 4.7 shows the estimated flow with all three cases along with the actual flow (black line). A negative error in the flow measurement was observed. Further it was also noticed as per other cases that the error is directly proportional to the flowrate, at higher flowrate there would be higher the error in the estimated flowrate. It was also noticed that the higher the plate thickness, the higher the error in flow measurement with their reverse installation. The highest error in flow measurement was recorded 23.756% with reverse installation of orifice plate of 10 mm thickness.

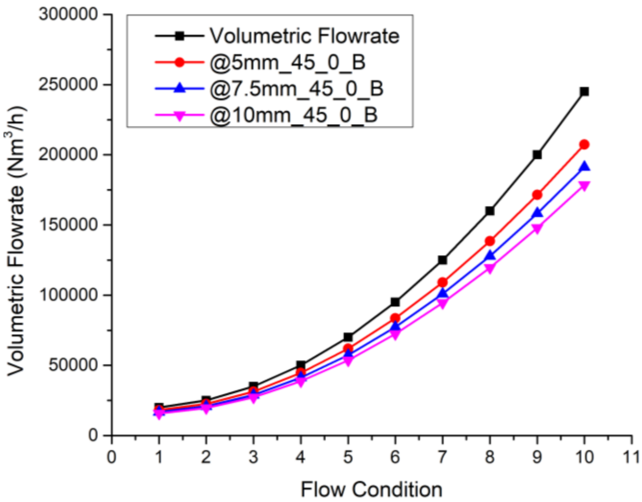


Fig. 4.7: Effect of orifice flow measurements at backward direction of bevel edge with fixed bevel angle (45°)

4.4 EFFECT OF CONDENSATE

Condensate formation in an orifice meter is particularly pertinent when dealing with natural gas, as it often contains hydrocarbons that can undergo phase changes under certain conditions. The Hydrocarbon Dew Point (HCDP) of natural gas is the temperature at which hydrocarbons begin to condense into a liquid phase. Sudden pressure and temperature drops, such as those occurring across an orifice plate, can induce condensation in the natural gas stream. The condensate formed may include heavier hydrocarbons and liquids, leading to alterations in the gas composition and potential plugging of the orifice meter. This can introduce errors in flow measurement due to changes in the gas properties. Proper consideration of the HCDP, along with appropriate measures like heat tracing or insulation to maintain temperature and prevent sudden drops, is essential to ensure accurate flow measurements in natural gas systems.

The inaccuracies of orifice metering were investigated due to condensation of higher hydrocarbons and CO_2 by taking the 5, 7.5 and 10 mm thickness plates with 45° bevel angle. The condensate formation was achieved with 2-phase modeling in Ansys FLUENT with Euler-Euler framework methodology. The results in terms of estimated flowrates for low to high flowrate is shown in Fig. 4.8. As per previous observations, a negative error in flow measurement was observed with lowest error with 5 mm plate and highest error with 10 mm plate.

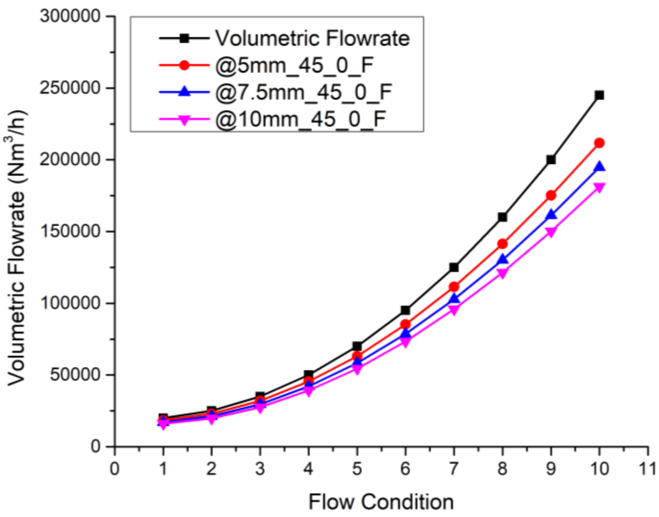


Fig.4.8: Effect of orifice flow measurements due to condensate formation with fixed bevel angle (45°)

The errors in percentages were compiled for cases of reverse direction installation of orifice plate and condensate formation in orifice meter in Fig. 4.9. From the figure it was observed that the reverse direction installation of orifice plate gives more error than condensate formation with each thickness of orifice plate. The smallest error by reverse direction case was observed 11.996% whereas the maximum error was observed 23.759%. However, the smallest error for condensate formation case was observed 10.196% whereas the maximum error was observed 22.646%.

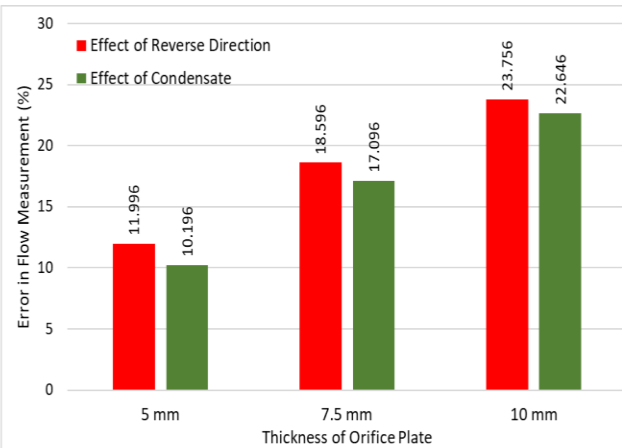


Fig. 4.9: Error in flow measurements due Condensate formation

5. Conclusion

In conclusion, the research provides a comprehensive and in-depth exploration of the factors influencing orifice meter accuracy in measuring natural gas flowrates. The findings underscore the economic significance of precise flow measurements, emphasizing their impact on billing accuracy, resource allocation, and regulatory compliance within the natural gas industry. The optimal conditions for orifice meter accuracy are identified, with a 45° bevel angle and a 5 mm plate thickness demonstrating superior performance. The research contributes valuable insights into the nuanced challenges associated with plate bending, reverse installation, and condensate formation. The negative errors induced by plate bending highlight the importance of maintaining plate integrity, while the highest error recorded with reverse plate installation underscores the criticality of correct plate orientation. Condensate formation introduces variability in flow measurements, emphasizing the challenges posed by sudden pressure and temperature drops. Overall, the research recommends a holistic approach to address the key parameters influencing orifice meter accuracy. Attention to plate thickness uniformity, precise bevel angles, and prevention of plate bending is deemed vital for maintaining intended flow characteristics and enhancing the accuracy of orifice meters. By addressing these parameters comprehensively, orifice meters can offer dependable and accurate flow measurements, thereby bolstering the efficiency and effectiveness of industrial processes within the natural gas sector.

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