© April 2019 | IJIRT | Volume 5 Issue 11 | ISSN: 2349-6002

Investigation of flow through different slotted orifice meters at different pressure of fluid

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Abstract- **This work carried out the numerical analysis of three different slotted orifice plate used for flow measurement of liquids using ANSYS Fluent software. In this study, the characteristics of flow considering pressure and velocity distributions through three different slotted orifice plates fitted in a horizontal pipe of 105.74 mm internal diameter has been investigated. Computational fluid dynamics calculations were performed using the realizable k-ε eddy viscosity model to predict the flow features.**

Index Terms- **Orifice Plate, Rectangular perforations, Circular perforations, parabolic perforations, pressure drop, velocity distribution.**

I.INTRODUCTION

Fluid flow is not only a critical aspect of the process industry: it had a tremendous importance in the development of ancient civilizations. The Sumerians in 4000 BC were the first to use canals for irrigation. Babylon is known to have had toilets and Sargon II's (700 BC) palace had drains connected to a 1 m high and 5 m long sewer that ran along the outer wall of the city. Sargon II's son, Sennacherib, was the first to build an aqueduct (65 km long), which was constructed for the Assyrian capital city Nineveh. In the Persian Achaemenian Empire, qanats were invented that tapped ground water and relied on gravity as the driving force for transport: underground tunnels were dug to the level of the ground water at one point and sloped downwards toward the exit.

Nebuchadnezzar is credited for erecting the Hanging Gardens of Babylon: Water was fed to the gardens through the use of a noria—a water wheel, which could be considered one of the first automatic pumps. Norias were been designed to deliver water for irrigation at rates of up to 2500 l/h. The largest water wheel was 20 m tall and was built in Hama, Syria. Prior to water

II-Literature Review

[1]. H.J. Lee, H. Choi, D.-C. Park, Hydraulic characteristics of high temperature hydrocarbon liquid jets with various orifice geometries, ActaAstronautica (2018)

An experimental study was conducted to investigate the effects of orifice geometry on the hydraulic characteristics of high-temperature aviation fuel jets. Pressurized heated liquid hydrocarbon fuel, simulating fuel used as coolant in the active cooling system of a hypersonic flight vehicle, was injected through a set of plain orifice nozzles of different lengths and diameters. The fuel was heated to close to 573 K (300 °C) using an induction heater at an upstream pressure of up to 1.0 MPa, and discharged to atmospheric downstream pressure conditions. The orifice diameter (D) varies from 0.7 to 1.5 mm and the length (L) from 1.4 to 4.3 mm, which results in length-to-diameter ratios (L/D) from 1.1 to 6.1, and the inlet of the orifice is nominally sharp-edged. Hydraulic characterization in terms of fuel injection temperature (Tinj) was carried out by introducing the discharge coefficient (Cd), and the macroscopic internal flow characteristics were correlated to Reynolds number (Re) and cavitation numbers (K and Ca). The fundamental behaviors of high-temperature liquid fuel jets at the specified operating ranges represented by Cd with respect to Tinjfor a given set of injectors revealed that, as Tinj increases above the boiling point, the Cd of the injector with a longer orifice decreases faster than that of a shorter injector of the same orifice diameter, and for injectors of a given orifice length, Cd decreases with Tinj in a similar way irrespective of orifice diameter. Plots of Re vs. T inj, Cdvs. Re, and Cdvs. K and Ca clearly show the dependence of the cavitation characteristics on the orifice geometry under high temperature injection conditions. In order to quantify the degree of cavitation for various orifice geometries, the Cdvs. Ca curve for each injector configuration has been fitted linearly; the mass flow choking effect in high temperature fuel injection represented by the magnitude of the slope from the linear fit becomes stronger as the orifice is longer and/or wider in diameter. This suggests that longer and wider orifices are more susceptible to choked cavitation. It was also found that the geometric effect is maintained for various ΔP, even though the magnitude of the slope increases with ΔP, and the sensitivity of the magnitude to increasing ΔP becomes stronger for longer orifices.

[2]. V.K. Singh and T. John Tharakan,"Numerical simulations for multi-hole orifice flow meter", Flow Measurement and Instrumentation 2018

The measurement of flow rate is important in many industrial applications including rocket propellant stages. The orifice flow meter has the advantages of compact size and weight. However, the conventional single-hole orifice flow meter suffers from higher pressure drop due to lower discharge coefficient (Cd). This can be overcome by the use of multi-hole orifice flow meter. Flow characteristics of multi-hole orifice flow meters are determined both numerically and experimentally over a wide range of Reynolds numbers. Computational fluid dynamics (CFD) is used to simulate the flow in the single and multi-hole orifice flow meters. Experiments are carried out to validate the CFD predictions. The discharge coefficients for the different orifice configurations are determined from the CFD simulations. It is observed that the pressure loss in the multi-hole orifice flow meter is significantly lower than that of single-hole orifice flow meter of identical flow area due to the early reattachment of flow in the case of the multi-hole orifice meter. The influence of different geometrical and flow parameters on discharge coefficient is also determined.

III-Research Methodology

3.1 Research Objective and Motivation for the Work

The race to develop an accurate, low cost two phase flow meter has been on for many years. The ability to accurately and cheaply measure steam quality for use in process heat, oil well injection, and other applications will have a significant economic impact upon operating costs of various industries and the longevity of the oil wells. The same economic impact is present for the ability to measure other two phase flows such as oil and gas. It is also desirable to know the response of a single phase gas meter to the introduction of some liquids. This situation frequently occurs in pipelines where condensate or water contamination occurs.

Figure 3.1 Slotted Orifice Plate

The slotted orifice flow meter is essentially a standard orifice flow meter in which the orifice plate has been replaced by a slotted orifice plate. Figure 3.1 is a photograph of the slotted orifice plate used by Gerald L. Morrison et al. 2001.

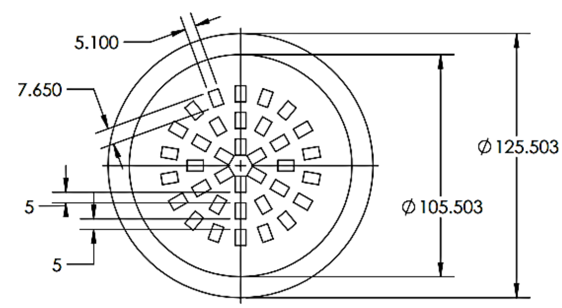
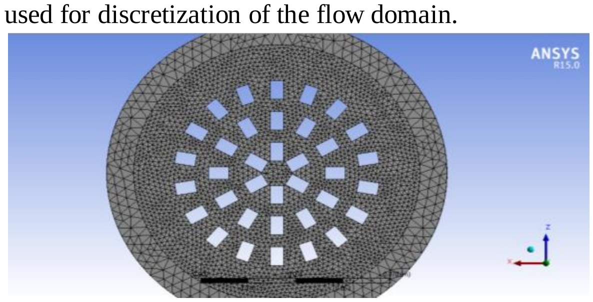


Figure 3.2 Geometry of general structure of the (a) rectangular, (b) circular (c) elliptical orifices (d) Orifice meter used in the flow investigation

3.2 Computational Mesh

Grid generation plays an important role in CFD simulation as it governs the stability and accuracy of the flow predictions. CFD hexahedral grids were used for discretization of the flow domain.



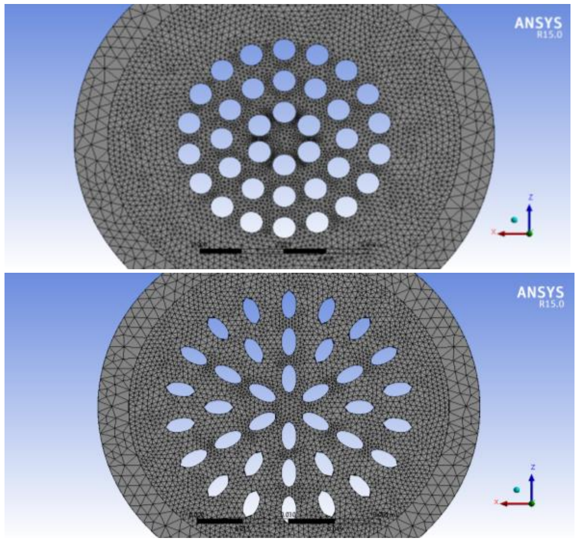


Figure 3.3 Meshing of Orifice Meter (a) Flow Domain (b) Rectangular Cross Section (c) Circular Cross Section (d) Elliptical Cross Section

3.3 Governing equations

Water is assumed to be Newtonian, compressible and non-reactive with constant physical properties (except density and specific heat capacity). Steady state simulations were carried out by solving the species transport model along with the mass, momentum and energy conservation equations, which are expressed as:

Mass conservation:

$$\frac{\partial \rho}{\partial t} + \nabla.(\rho\vec{u}) = 0$$

Momentum Conservation

$$\frac{\partial (\rho\vec{u})}{\partial t} + \nabla.(\rho\overline{uu}) = -\nabla p + \nabla.\tau$$

Where ρ is the density, u is the velocity, p is the pressure, τ is the viscous stress tensor.

IV-RESULT ANALYSIS

4.1 General

The transition from laminar to turbulent flow depends on the geometry, surface roughness, flow velocity, surface temperature, and type of fluid, among other things. The flow regime depends mainly on the ratio of inertial forces to viscous forces in the fluid i.e. called Reynolds number.

4.2 Results for Slotted Orifice meter

There are three types of slots have been considered for the study i.e. Rectangular, circular and parabolic slots. The results considered the two basic variables i.e. pressure changes and velocity changes. The following results are obtained.

4.2.1 Rectangular Slots

Figure 4.1 show the pressure distribution at various distances from inlet for rectangular slotted orifice meter at 3.5 bar and 2 m/s inlet pressure at various distances.

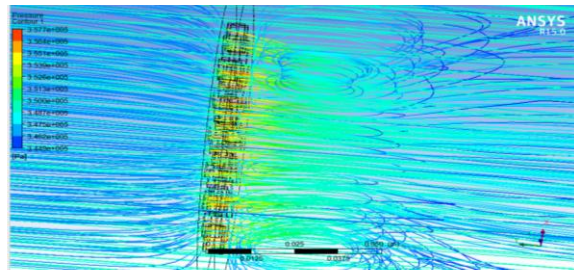


Figure 4.1 pressure distribution at inlet for rectangular slotted orifice meter at 3.5 bar and 2 m/s inlet pressure and velocity respectively

4.2.2 Circular Slots

Figure 4.2 show the pressure distribution at various distances from inlet for circular slotted orifice meter at 3.5 bar and 2 m/s inlet pressure at various distances.

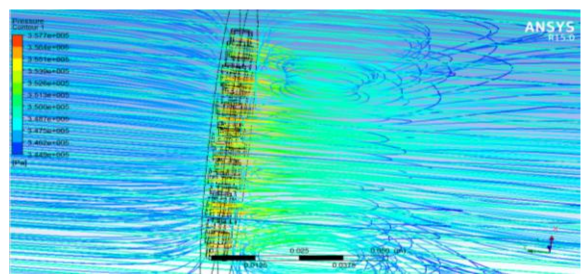


Figure 4.25 pressure distribution at inlet for circular slotted orifice meter at 3.5 bar and 2 m/s inlet pressure and velocity respectively

4.2.3 Parabolic Slots

Figure 4.3 the pressure from inlet for parabolic slotted orifice meter at 3.5 bar and 2 m/s inlet pressure.

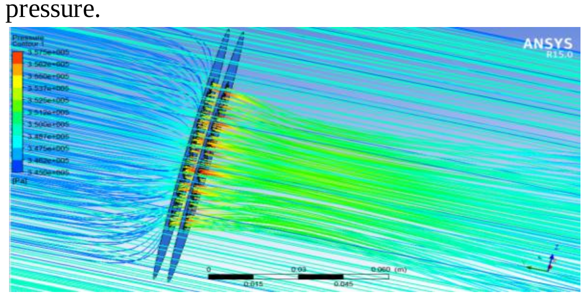


Figure 4.3 pressure distribution at inlet for parabolic

slotted orifice meter at 3.5 bar and 2 m/s inlet pressure and velocity respectively

V-CONCLUSION

The flow field characteristics in different slotted orifice system have been numerically investigated by considering the effects of orifice geometry, orifice spacing on velocity and pressure distribution along the horizontal length of the orifice meter. The inlet flow pressure considered are 2.5 bar.

- The numerical results indicate that pressure drop and static pressure recovery is better with the parabolic slotted orifice compare then the other two i.e. circular and rectangular slotted orifices.
- It is also found that the parabolic slotted orifice is more sensitive compared to the circular and rectangular slotted orifices.

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