A review on "Study of flow through altered slotted orifice meters at different pressure of fluid"

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***Abstract*- Many engineering applications involving piping systems utilize flow passage restrictions such as control valves and orifices to achieve control of flow rates and pressures. Accurate determination of flow characteristics through these restrictions especially orifices is important for industrial operations such as control measures in HVAC, quality control in food processing industry, metering of high viscous liquids and calibrating tools in metrology of liquid and gas flows.**

This paper gives a review on the numerical analysis of different slotted orifice plate used for flow measurement of liquids.

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

I.INTRODUCTION

1.1 General

The transport of water to major centers allowed civilizations to flourish, the measurement and control of fluid flow has been a critical aspect of the development of industrial processes. Not only is metering flow important to maintaining stable and safe operating conditions, it is the prime means to account for the raw materials consumed and the finished products manufactured. While pressure and temperature are critical operating parameters for plant safety, the measurement of flow rate has a direct impact on process economics. For basic chemicals (as opposed to specialty chemicals or pharmaceuticals) like ethylene, propylene, methanol, sulfuric acid, etc. profit margins are relatively low and volumes are large, so high precision instruments are required to ensure the economic viability of the process.

Flow meters are instruments that measure the quantity of movement of a fluid in a duct, pipe, or open space. The fluid can be water, a liquid solution, a chemical product or slurry, gas or vapor, and even solid—powders, for example. In everyday life, we use flow meters to pump gasoline into automobile fuel tanks, methane gas is metered to houses and metering water to houses is becoming more common. With respect to anatomy, the heart's pumping action ensures blood circulation and lung health is assessed by measuring the volume of air the lungs can hold. Trees are amazing for their ability to transport water in xylem and phloem for vertical distances exceeding 100 m! Despite the importance of transporting water and its contribution to the rise of many great civilizations, most of the ancient technology used to build and maintain aqueducts, water distribution, and sewage systems was lost. Rome declined from a city of 1.6 million habitants at its zenith in 100 AD to less than 30 000 during the dark ages up until the Renaissance partly because of the destroyed aqueducts that remained in disrepair.

1.2 Flow Measurement Laws

Modern fluid dynamics was pioneered by the Swiss physicist Bernoulli who published the book entitled "Hydrodynamica" in 1738. Bernoulli's work is based on the principle of the conservation of energy, which holds that mechanical energy along a streamline is constant. He demonstrated that increasing the potential energy of a flowing fluid (by raising the elevation of a pipe, for example) reduces the pressure of the fluid in the pipe (above that which would be expected based on wall friction); decreasing the cross-section of the pipe increases the velocity head and decreases the pressure head.

Considering the flow restriction of a pipe in Figure 1.1. The fluid accelerates from left to right as it passes through the restriction. Based on continuity-conservation of mass-the mass flow rate, m, crossing point 1 equals that atpoint 2:

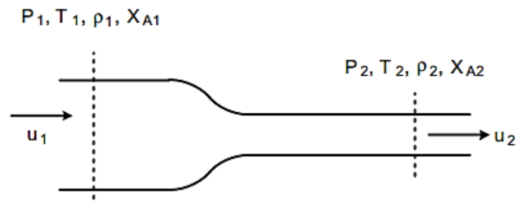

Figure 1.1 Fluid Flow through a Constriction

Conservation of mass states that the mass rate is constant. In other words, the amount of fluid moving through a meter is neither added to nor taken from as it progresses from point 1 to point 2. This is also called the Law of Continuity. It can be written in mathematical form as follows:

$$m_1 = m_2$$

$$m_1 = m_2 = m = \rho A_1 u_1 = \rho A_1 u_1$$

Where ρ is the fluid density (kg m^{-3}), A is the cross-sectional area (m^2), and u is the velocity (ms^{-1}).

For an incompressible fluid, the fluid accelerates in proportion to the ratio of the cross-sectional areas. Bernoulli derived an equation based on an energy balance around a fluid flowing in a pipe and is expressed in a simplified form as

$$\frac{\Delta P}{\rho} + \frac{1}{2}\Delta u^2 + g\Delta Z = h_f$$

Where h_f is the head loss due to friction.

1.3 Flow Meter Selection

Just as with the measurement of temperature and pressure, many technologies have been invented to quantify the flow rate of gases and liquids. Crabtree (2009) identified 33 distinct technologies and divided them into eight categories. In industry, obstruction flow meters, Coriolis meters, and vortex shedders are more standard. Selecting a flow meter for a given application depends on several criteria including:

- Process conditions.
- Required precision.
- Robustness.
- Size.
- Response time.

Few instruments can be used for open channel flow or pipes that are semifilled with the exception of weirs and flumes

II LITERATURE REVIEW

Orifice Plate is a thin plate in which a circular concentric aperture (bore) has been machined. The orifice plate is described as a "thin plate" and "with a sharp edge," because the thickness of the plate material is small compared with the internal diameter of the measuring aperture (bore), and because the upstream edge of the measuring aperture is sharp and square.

The orifice plate flow meter, the most common of the differential pressure (DP) flow meter family, is also one of the most common industrial flow meters. It is apparently simple to construct, being made of a metal plate with an orifice that is inserted between flanges with pressure tappings formed in the wall of the pipe. It has a great weight of experience to confirm its operation. However, it is far more difficult to construct than appears at first sight, and the flow through the instrument is complex.

Some researchers have been carried out their work for different design consideration of orifice plate meter some of them are as:

2.1 Previous Research

[1]. Abdulrazaq A. Araoye, Hasan M. Badr, Wael H. Ahmed, "Investigation of flow through multi-stage restricting orifices" Annals of Nuclear Energy 104 (2017) 75–90

In this study, the characteristics of flow through a serial arrangement of two similar bevel-edged orifice plates fitted in a horizontal pipe of 25.4 mm internal diameter has been investigated. Computational fluid dynamics calculations were performed using the realizable k-eeddy viscosity model to predict the flow features. The effects of various parameters such as pipe flow velocity in the range 14 m/s, orifice spacing of 1D and 2D, and orifice plate diameter ratios of 0.5, 0.63 and 0.77 on axial velocity and pressure distributions were obtained. The flow is always turbulent with Reynolds number ranging from Re= 2.54×10^4 to 1.02×10^5. *Feng Shan, Zhichun Liu, Wei Liu, Yoshiyuki Tsuji, "Effects of the orifice to pipe diameter ratio on orifice flows", Chemical Engineering Science 152 (2016) 497–506*

This study presents the effects of the orifice to pipe diameter ratio (defined as the βratio) on the flow field behind a thin circular square-edged orifice plate. We adopted a planar particle image velocimetry (PIV) system using two side-by-side cameras to measure velocity fields of a large area covering the reattachment region. The core, recirculation, and axisymmetric shear-layer regions are first suitably defined, and the characteristic length and velocity scales in different regions are then determined.

[2]. D Zahariea, "Numerical analysis of eccentric orifice plate using ANSYS Fluent software", International Engineering Research and Innovation Symposium (IRIS) 2013

In this paper the eccentric orifice plate is qualitative analysed as compared with the classical concentric orifice plate from the point of view of sedimentation tendency of solid particles in the fluid whose flow rate is measured. For this purpose, the numerical streamlines pattern will be compared for both orifice plates. The numerical analysis has been performed using ANSYS Fluent software. The methodology of CFD analysis ispresented: creating the 3D solid model, fluid domain extraction, meshing, boundary condition, turbulence model, solving algorithm, convergence criterion, results and validation. Analysing the numerical streamlines, for the concentric orifice plate can be clearly observed two circumferential regions of separated flows, upstream and downstream of the orifice plate. The bottompart of these regions are the place where the solid particles could sediment. On the other hand, for the eccentric orifice plate, the streamlines pattern suggest that no sedimentation will occur because at the bottom area of the pipe there are no separated flows.

[3]. Shaaban, S., "Optimization of Orifice Meter's Energy Consumption", Chemical Engineering Research and Design (2013), http://dx.doi.org/10.1016/j.cherd.2013.08.022

Orifice meters are commonly used in many industrial facilities and pipelines. However, they increase the annual energy consumption and cost due to their high pressure loss. The present research introduces a new design that reduces this high pressure loss by inserting a ring downstream the standard orifice meter. Maximum reduction of pressure loss is achieved by optimizing the downstream ring geometry. Numerical optimization is implemented using CFD simulation together with a genetic algorithm. *Manish S. Shah, Jyeshtharaj B. Joshi, Avtar S. Kalsi, C.S.R. Prasad, Daya S. Shukla "Analysis of flow through an orifice meter: CFD simulation", Chemical Engineering Science 71 (2012) 300–309*

Orifice meters are the most common instruments used for fluid flow measurement because of its ruggedness, simple mechanical construction and other known advantages. Orifice coefficients are empirical because of difficulty in accurately predicting the effects of geometrical complicacy and flow separation from the wall on the flow. In the present paper, Computational Fluid Dynamics (CFD) simulation has been used to predict the orifice flow with better accuracy. CFD simulations have been performed using OpenFOAM-1.6 solver and validated with the published experimental data of Nail (1991) and Morrison et al. (1993). CFD simulations have been validated with pressure drop and energy balance of our experimental data of water as fluid. The outcomes of the CFD simulations in terms of profiles of velocity, pressure, etc. are discussed in detail. A new scheme has been proposed to track vena-contracta with the help of CFD and with a suitable provision in the hardware of orifice meter. The new scheme maintains the existing advantages of orifice meters and provides better accuracy and sensitivity.

[4]. Perumal Kumar, Michael Wong Ming Bing, "A CFD study of low pressure wet gas metering using slotted orifice meters", Flow Measurement and Instrumentation 22 (2011) 33–42

Wet gas metering is becoming an increasingly important problem to many industries, in particular the oil and gas industry. Extensive studies have been done in the past on Venturi and standard orifice differential pressure (DP) flow meters to tackle wet gas flow problems. However in recent years, the slotted orifice flow meter has been developed in the attempt to improve the performance of the standard orifice meter.

The commercial CFD code, FLUENT 6.3 was used to model the wet gas flow. Simulation results revealed that the shape of the perforation has no effect on the differential pressure, However, a marginally better pressure recovery was observed with rectangular perforations of l/w = 3.0. The relatively higher over-reading values obtained in this work are consistent with the results of Geng et al. (2006) [1] that for a slotted orifice, a low β ratio is more sensitive to the liquid presence in the stream and hence is preferable for wet gas metering. Mass flow prediction by wet gas correlations showed that the homogeneous model, Steven's and De Leeuw's correlations had the best performance, with a calculated mean error of 4%–5%.

[5]. Gerald L. Morrison, Dwayne Terracina, Carl Brewer, K.R. Hall, "Response of a slotted orifice flow meter to an air/water mixture", Flow Measurement and Instrumentation 12 (2001) 175–180

The ability of a flow meter to respond predictably to the presence of liquid and gas is important to the natural gas industry and to users of steam. In both cases, the gas can become saturated and some liquids can condense in the line. The response of orifice flow meters to the presence of liquids is erratic and produces considerable uncertainty. Turbine flow meters can sustain severe damage when subjected to two phase flow. The slotted orifice flow meter has been developed to address the problem of upstream flow conditioning. This device has been shown to be insensitive to the upstream velocity profile. To further evaluate the flow meter for use by the natural gas industry, the effects of adding liquid to a gas flow upon the meter performance has been investigated by subjecting a slotted orifice flow meter with an equivalent ratio of 0.50 to a two phase flow consisting of air and water.

III.CONCLUSION

On the basis of previous research study it is concluded that 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 effects of various parameters such as pipe flow velocity, orifice spacing and orifice plate diameter ratios on axial velocity and pressure distributions can also be find out for future work.

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