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ANALYSIS OF PASSIVE CONTROL OF HIGH SPEED JETS

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ABSTRACT

In an effort to increase mixing in jet flows, a passive control method, using vortex generators in the form of mechanical tabs or small protrusions at the exit of a nozzle had been investigated experimentally in the present paper. The experimental results revealed the great changes of vortex and turbulent structures in the near field of jet flow due to the mechanical tabs intrusion. Compared with a nature jet flow (a circular jet flow without mechanical tabs intrusion), the tabbed jet flow was found to have shorter laminar length, smaller size of the span wise Kelvin-Helmholtz vortices, earlier appearance of small scale turbulent structures. Due to the engulf of the stream wise vortices, an inward indentation of ambient flow into core jet flow and the outward ejection of core jet flow into the ambient flow was found in the cross planes of the tabbed jet. As the stream wise distance increasing, the cross section form of the tabbed jet flow was found to change from "round" to "oval" gradually.

Key words: Nozzle jet,incompressible medium

1.1 INTRODUCTION TO JET

Jet is a free shear flow driven by momentum introduced at the exit of, usually a nozzle or an orifice which exhibits a characteristic that, "the ratio of width to axial distance is a constant". The jet may also be defined as a continuous fluid flow issuing from an orifice into a medium of lower speed fluid. As the jet fluid travels further away from its origin, it slows down due to mixing with slower speed ambient fluid. This is due to the boundary layer at the nozzle exit which develops roll up structures, or ring vortices, which grow in size when they move downstream, due to the entrainment of ambient fluid into the jet stream. Thus, mass flow at any cross-section of the jet progressively increases along the downstream direction. Hence, to conserve momentum the centerline velocity decreases with downstream distance. The resulting centerline velocity decay is proportional to the gradient across the shear layer and is a strong function of the distance downstream of the jet exit. The vast quanta of knowledge presently available and the continuous research currently being carried out stand testimony to the importance associated with the jet flows. This is owing to their extensive nature of applicability, from household appliances to hi-tech rockets. In terms of academic interest, studies on jets have provided insight into the understanding of the dynamics of free shear layers and vortex structures.

When a jet of water issues from an orifice, it drags the surrounding air along with it due to the viscous action. The instability of the tangential separation causes eddy formations, which move in a disorderly fashion, both along and across the jet stream. This brings about an exchange of matter between neighboring layers i.e. there is transverse transfer of momentum, heat and constituents. Thus the mass of the air moving downstream increases as we move farther from the orifice. This phenomenon is called entrainment. This phenomenon of transfer of momentum that will cause entrainment we shall refer to as a shear layer effect. The decay of the jet is a critical phenomenon. Many applications can be designed around it.

1.1.1 CLASSIFICATION OF JETS

Basically jets can be classified into two categories namely; incompressible and compressible jets (figure 1.1). The jets with Mach number less than 0.3, up to which the compressibility effects are negligible are called incompressible jets. Compressible jets can be again subdivided into subsonic, sonic and supersonic jets. Jets with Mach number 1.0 are called sonic jets, which can be correctly expanded or under-expanded. Supersonic jets are the jets with Mach number more than one. These can be further classified into over-expanded, correctly expanded and under-expanded jets.

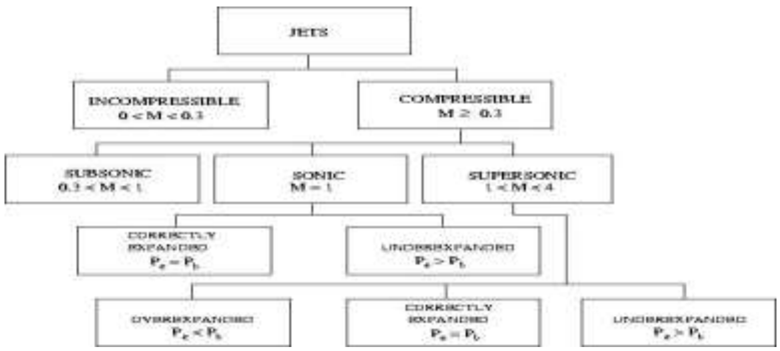

Figure 1.1 Classification of jets

3.1 INCOMPRESSIBLE MEDIUM

3.1.1 EXPERIMENTAL SETUP DETAILS

These experiments were conducted in the college fluid mechanics laboratory on a orifice set up. The set up consists of a reservoir tank and a lever which can be used to adjust the water level such that the different water levels make different heads. The set up consists of a three standard heads which are used for this experiment. The experimental set up is shown in the Fig 3.1 and the three standard heads are shown in the Fig 3.2.

Figure 3.1 Orifice tank

Here the orifices were made according to the dimensions that can fit in the experimental set up. Dimensional plate of thickness 3mm is used to connect both the base plate and the tank. Base plate consists of different cross sectional holes, which are connected by using the whit worth thread. The orifices and the tank are connected by O-ring which was mounted over the orifice and by using bolts and nuts they were connected. Tightly threaded bolts were used to prevent leakages from the tank and the orifice. The settling chamber total pressure which was the controlling parameter in this investigation was maintained constant during a run by controlling the head regulating valve. The stagnation pressure leveling the settling chamber gives the different pressure ratios, defined as the ratio of stagnation pressure to the back pressure required for any study. The settling chambertemperature is the same as the ambient temperature and the back pressure is the ambient pressure into which the water jets were discharged.

The ambient temperature of the room wasalmost constant within 0.5˚C during one experimental run. The stagnation pressure wasmaintained with an accuracy of 0.1%. During the experimental runs, the settling chamberpressure was assumed to be constant.

Water was supplied to the tank by the reservoir which was placed at the bottom of the set up. Initially water must be poured manually into the reservoir. Water must be poured at least half of the reservoir such that to maintain up the head and also it will be difficult for the pump to lift the water if it was below half the reservoir. By using the pump water will be passed to the head over tank. And by using the head regulating valve different heads can be maintained. After starting the experiment, the set up must be leaved for 5minutes until it reaches steady condition. Indicator on the tank shows the level of the water on the tank. This reading gives the head over the tank. This set up consists also a scale to calculate the axial length and also has a radial scales which were fixed to a stand at a distance of 10 cm in the radial direction of the flow. These scales give the exact length at which the width of the flow can be calculated.

3.2 EXPERIMENTAL MODEL

3.2.1 INCOMPRESSIBLE MEDIUM

Non circular shape orifices were used in the present investigation. The different shapes consider here is rectangle with aspect ratio of 1 and 2. These non circular orifices are compared with circular orifice. Here orifices of equivalent area Taken to study the flow. Rectangular models different aspect ratios (L/D = 1, 2 i.e. 10.63x10.63, 7.52x15.04), these can be compared with the circular orifice of 12 mm dia. In addition to this orifices are placed in diffused mixed burners to study the effect of flame exit of the non circular orifices.

Experiments were carried out using rectangular, square and circle orifices. Schematic diagram of orifices with geometric dimensions were given in figure 3.4. Figure 3.5 & figure 3.6. Artistic views of the orifices are shown in figures 3.7 and 3.8 & figure 3.9.

Table 3.1 Geometrical parameters of Incompressible models

Geometry	Dimensions (mm)	Area (mm^2)
Circle	Diameter = 12	113.1
Rectangle	Length = 15.04 Breadth = 7.52	113.1
Square	Side = 10.63	113.1

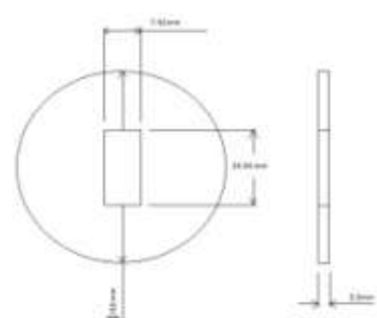

Figure 3.4 Schematic diagram of rectangular orifice

Figure 3.7 An artistic view and a photograph showing rectangular orifice.

RESULTS AND DISCUSSION

4.1 CHARACTERISTICS OF INCOMPRESSIBLE NON CIRCULAR JET

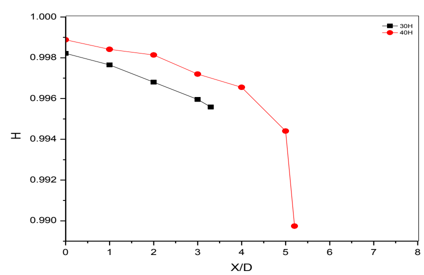

Figure 4.3 Centerline pressure distribution of rectangular orifice

In order to study the Non circular jet flow characteristics, rectangular and square models are chosen for study. Rectangular slot has aspect ratio of 2 is taken for study. These models are designed with equal mass flow rate. Figure 4.3 shows centerline pressure distribution of rectangular model.The pressure drops gradually up to around X/D = 3 for head of 30 cm 0f H_2O and for head of 40 cm of H_2O at X/D = 5.2. Pressure drops significantly thereafter. Pressure drop is significant for pressure head of 30 cm of H_2O compared to 40 cm of H_2O.

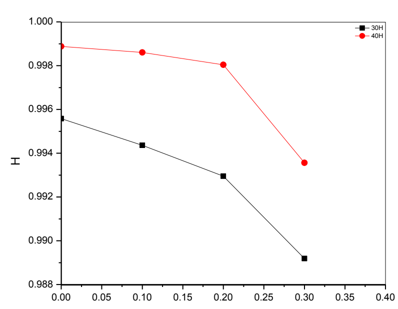

Figure 4.4 Pressure distributions along Y direction for rectangular orifice at exit

Figure 4.4 shows pressure measurements along the Y direction at the orifice exit. These profiles are taken in steps of Y/D 0.1. Pressure drops up to 0.2 for both the pressure heads. Pressure drops significant thereafter. The pressure drop is significant for head of 30 cm of H_2O compared to 40 cm of H_2O.

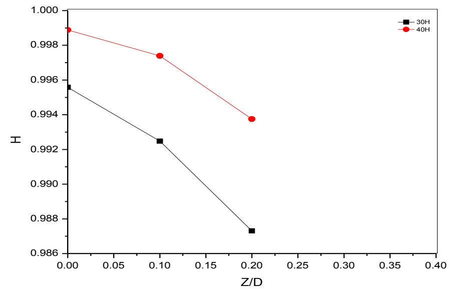

Figure 4.5 Pressure distributions along Z direction for rectangular orifice at exit

Figure 4.5 shows pressure distribution along Z direction at the exit of orifice. These pressure profiles taken in steps of Z/D = 0.1. Pressure drops significantly in these direction. The pressure drops gradually towards outer jet. The pressure drop is significant for 30 cm of H_2O head compared to 40 cm of H_2O.

4.1.1 EFFECT OF NON-CIRCULARITY ON JET DEVELOPMENT

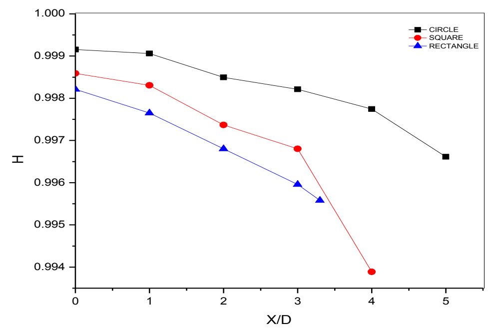

Figure 4.11 Centerline pressure distributions at 30 Head

Figure 4.11 presents the centerline distribution of rectangular and square model along with equal area of circular model at head of 30 cm of H_2O. Figure 4.11 demonstrates the variation of centerline pressure with change of geometry. For this at a particular head, effect of geometry modification is significant for rectangular and square model compared to circle. Rectangular model shows more significant centerline pressure drop compared to other two models.

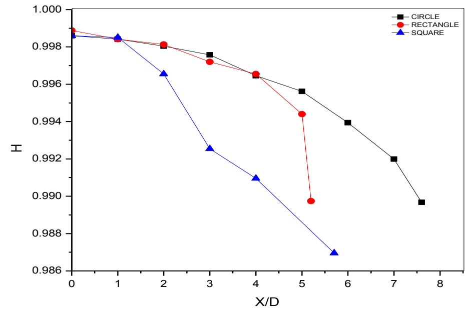

Figure 4.12 Centerline pressure distributions at 40 Head

Figure 4.12 presents the centerline distribution of rectangular and square model along with equal area of circular model at head of 40 cm of H_2O. Figure 4.12 demonstrates the variation of centerline pressure with change of geometry. For this at a particular head, effect of geometry modification is significant for rectangular and square model compared to circle. Square model shows more significant centerline pressure drop compared to other two models.

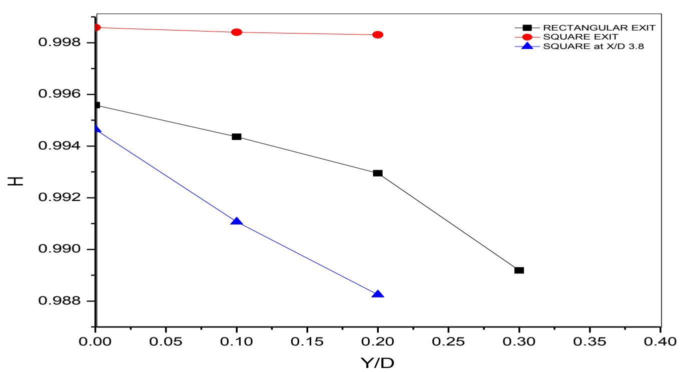

Figure 4.15 Pressure distribution along Y direction for Square and rectangular models at 30 cm of H_2O

Figure 4.15 presents the pressure distribution along Y direction at head of 30 cm of H_2O. Pressure distribution taken at exit of rectangular and square orifices and square jet fall of location. Figure 4.15 clearly demonstrates the pressure variation of the square and rectangular orifice at exit. Rectangular jet has significant pressure drop compared to square jet. At jet fall of location, pressure drop is significant for square jet compared to square jet at exit of orifice.

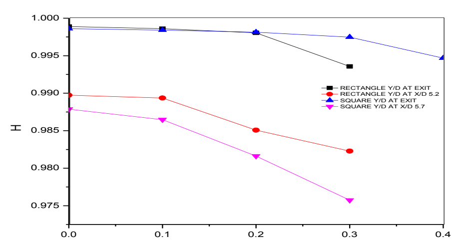

Figure 4.16 Pressure distribution along Y direction for Square and rectangular model at 40 cm of H_2O

Figure 4.16 presents distribution along Y direction for square and Rectangular models at head of 40 cm of H_2O. Pressure is measured at exit of orifice and jet fall of locations. Figure 4.16 clearly demonstrates the geometrical variation and axial location variation on jet characteristics. The effect of geometrical variation is very minimum at exit. At the head of 40 cm of H_2O jet drops for rectangular model at X/D = 5.2 and for square model at X/D = 5.7. Pressure variation is significant for both the models compared to jet location at exit.

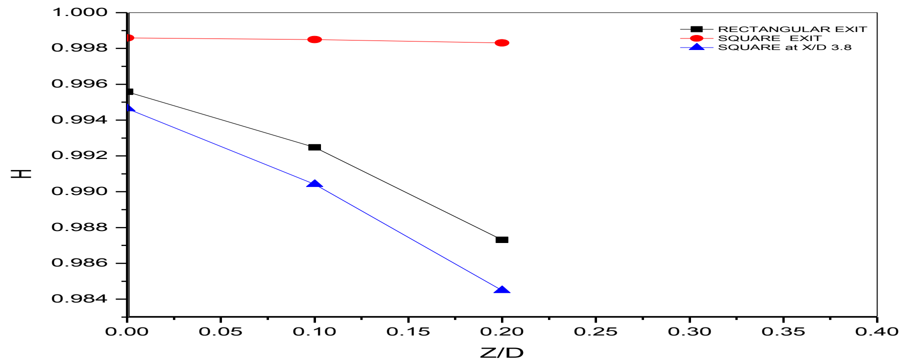

Figure 4.17 Pressure distribution along Z direction for Square and rectangular models at 30 cm of H_2O

Figure 4.17 presents the pressure distribution along Z direction for square and rectangular models at head of 30 cm of H_2O. Pressures are measured at exit of rectangular, square models and square jet fall of location. Figure 4.17 clearly demonstrates the effect of geometrical variation on jet characteristics. Rectangular jet has significant pressure drop compared to square jet at exit of the orifice. Pressure drop is significant for square model at jet fall of location compared exit of orifice.

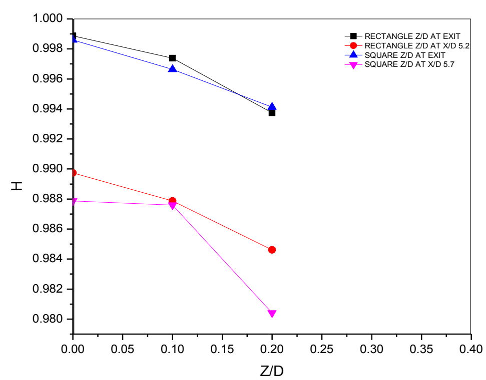

Figure 4.18 Pressure distribution along Z-direction for Square and rectangular model at 40 cm of H_2O

Figure 4.18 presents the pressure distribution along Z direction for square and rectangular models at head of 40 cm of H_2O. Pressures are measured for rectangular, square models at exit and jet fall of locations. Figure 4.18 clearly demonstrates the geometrical variation and axial location on jet characteristics. The effect of geometrical variation at exit of orifice is very minimum. Rectangular jet falls at X/D =5.2 and square jet falls at X/D = 5.7. Pressure drop is significant at jet fall of location compared to exit of orifice for both models.

CONCLUSIONS

The basic flow characteristics and the terminologies involved in the jet flow are explained in detail. The present study focuses on confined isothermal jet for its further analysis. The half width of the jet and the centerline velocity decay are taken as major criteria for the selection of jet in the proposed study. The present study is not intended to go in depth with the theory of development of jets. Effect of geometrical modification is significant for rectangular and square model compared to circle at both the pressure heads. Rectangular jet has significant pressure drop compared to square jet at head of 30 cm of H_2O. Square model shows more significant centerline pressure drop compared to other two models at head of 40 cm of H_2O. The effect of geometrical variation is very minimum at exit for the pressure head of 40 cm of H_2O.Pressure variation is significant for both the models compared to jet location at exit.

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