ID: 2016-ISFT-210

Design, Construction and Performance of Rectangular Duct with Inverse Aspect Ratio

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Abstract: *An investigation has been carried out for determining the performance of rectangular duct with inverse aspect ratio (ratio of width to height). The objective of this investigation is to frame a rectangular duct by joining the edges of two rectangles with inverse aspect ratio, to identify the pattern of flow, pressure recovery & calculation of various parameters like Reynold's number, centre line velocity, average velocity and static pressure. For performing the experiment one rectangular duct with aspect ratio 3 and centre line length 30 cm has been taken. There are 5 pressure tapping at equal intervals on each wall of the duct i.e. top, bottom, left and right. For analysing the performance of the duct graphs are drawn between* P/P_0 *(ratio of pressure at each tapping to the pressure at the tapping at the inlet of the diffuser) and x/L (ratio of consecutive distance of each pressure tapping from the pressure tapping at the inlet of the diffuser to the centre line length of the diffuser) at 6 different velocities 28.05 m/s, 27.63 m/s, 25.68 m/s, 24.29 m/s, 19.83 m/s and 11.28 m/s. From the observations it can be concluded that pressure recovery in the left and right walls is almost same & pressure recovery in the top and bottom walls is almost same but pressure recovery is more in left and right walls with respect to top and bottom walls. Top and bottom walls act as nozzle whereas left and right walls act as diffuser.*

Keywords: *rectangular duct, aspect ratio, pressure recovery, nozzle, diffuser, reynold's number*

1. INTRODUCTION

Ducts are the passage of flow for liquids and gases. They are of various shapes such as rectangular, round and flat oval. Ducts are made of different materials such as galvanized steel, aluminium, polyurethane & phenolic insulation panels, fiberglass duct board etc. The ratio of width of the rectangle to the height of the rectangle is called aspect ratio of rectangle. The ratio of the major axis of the ellipse to the minor axis of the ellipse is called aspect ratio of ellipse. 1:1 is the aspect ratio of a square. They are basically used in heating, ventilation and air conditioning. G.S. Beavers et al. [1], conducted a study in development of laminar flow in rectangular ducts by using a device which allows the analysis of any cross sectional aspect ratio. The main objective of the experiment is to find the relation of pressure field with hydrodynamic development of flow. Because of development of flow both local pressure defect and pressure drop occur. There is a reduction in the lengths of Hydrodynamic development. T-C Jen et al. [2], implemented a mathematical calculation for the increasing laminar velocity and temperature fields at the entry of isothermal rectangular duct rotating about an axis perpendicular to the duct axis at the same time. In this paper the effect of aspect ratio of the rectangular duct is also reported. In order to resolve the governing equations for heat transfer the vorticity-velocity method with the power law scheme is used. C.H. Yu et al. [3], analysed buoyancy-induced vortex flow structures and the related heat transfer in a horizontal rectangular duct of different aspect ratios which is heated from bottom. Results were obtained in terms of Reynolds numbers varying from 5 to 15, Rayleigh numbers till 9000 and aspect ratios varying from 4 to 12. At the entrance of the duct transverse vortex rolls are produced when the aspect ratio is less than 6 which further gets converted into longitudinal rolls when movement is towards downstream. The oscillation of flow is more in the area of transverse rolls in comparison to area of longitudinal rolls. Akira Murata et al. [4], examined how the turbulent heat transfer is effected by two parameters i.e. aspect ratio of the duct and the Coriolis force. The range of values of aspect ratio and rotation number are taken as 0.25-4 and 0-5 respectively in order to implement large eddy simulation. By analysing the result both direct and indirect effects of Coriolis force were observed. The strength of these effects vary with the aspect ratio. Ho-Yeh Ming et al. [5], performed an experiment on upward type baffled solar air heaters related to effect of aspect ratio of the collector on efficiency of collector. Efficiency of the collector is directly proportional to aspect ratio of the collector when the area of the collector is constant. Flat plate heaters without fins and baffles have lower collector efficiency with respect to baffled solar air heaters.

2. EXPERIMENTAL SETUP

The test rig consists of-:

a) Centrifugal Blower

b) Variance (Auto transformer)

c) PVC Pipe

d) Inclined U-tube Manometers

e) Pitot Static Tube

f) Rectangular duct with inverse aspect ratio

g) Settling Chamber

A) CENTRIFUGAL BLOWER

A 1 H.P. centrifugal blower installed on a stand made of angle iron whose suction is open to the atmosphere and the discharge is connected to a pipe. The stand of the blower is kept on rectangular boards in order to reduce vibrations and noise.

B) VARIANCE (AUTO TRANSFORMER)

It is an instrument which is coupled with the blower in order to perform the experiment at varying loads. The loads vary from 220 V to 120 V.

C) PVC PIPE

A 3 inch diameter pipe of 1.5 m is used to connect the exit of the blower with the diffuser. Certain length of pipe is taken in order to stabilize the flow.

D) INCLINED U TUBE MANOMETERS

U tube manometers are the instrument used for measuring pressure. In this experiment we are using three rectangular boards of 18×46 inch dimension is taken for designing the U tube manometers. On each board there are nine U –tube manometers. A graph is pasted on it then tubes of 5 mm diameter and length 2.5 m each are attached and three of such boards are designed in the similar manner. All the manometer boards are inclined at an angle of 45° from the surface and distilled water is filled up to half of the level of tube. One end of the tube is open to the atmosphere and the other end is connected to the pressure tapping of the diffuser. When the air through the pressure tapping passes to the manometer tube a difference in head is generated.

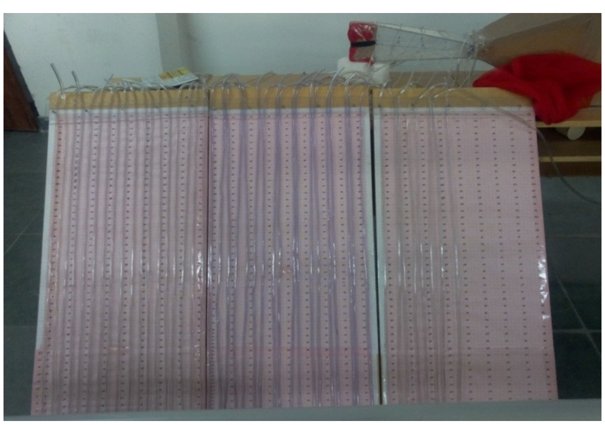

Fig. 1. Inclined U Tube Manometers.

E) PITOT STATIC TUBE

It is an instrument which is used to measure the centerline velocity using total pressure and static pressure. This tube is attached to the pipe just before the diffuser. The Pitot tube is designed from 0.04 inch diameter pipe.

Fig. 2. Pitot Static Tube

F) RECTANGULAR DUCT

A transparent rectangular duct of inverse aspect ratio is designed by drawing top and bottom profile of rectangular duct inlet as taken as 12 cm and exit as taken as 4 cm and left and right profile inlet as taken as 4 cm and outlet as taken as 12 cm with centreline length of 30 cm each in all four cases. Then all four profiles top, bottom, left and right are pasted on 4mm thick acrylic sheet and cut from there. All the profiles are pasted using araldite and the obtained profile is rectangular duct with inverse aspect ratio.

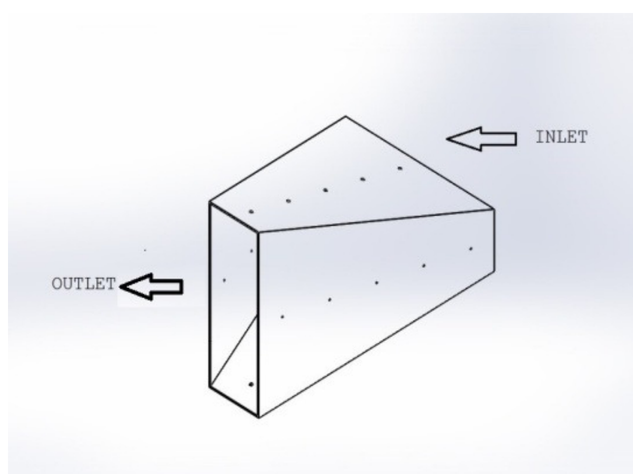

Fig. 3. Rectangular Duct Using Solid Works

Fig. 4. Rectangular Duct.

G) SETTLING CHAMBER

A settling chamber is a box made of ply wood having square cross section of 7.5 cm x 7.5 cm at inlet and rectangular cross section of 12cm x 4cm at the exit and square cross section of 30 cm x 30 cm at the centre. It is basically used to reduce the vibrations induced and make the flow stable before reaching the duct.

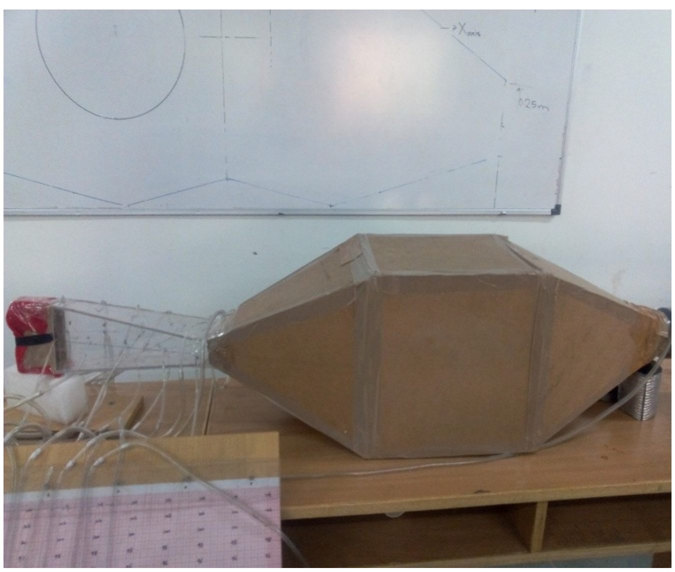

Fig. 5. Settling Chamber.

2.1 WORKING

A 1 H.P. centrifugal blower is installed on a stand made of angle iron. It is coupled to a variance (auto transformer) in order to take readings on different loads varying from 220V to 120V A mesh is attached at the exit of the blower in order to stabilize the flow. A 3 inch diameter PVC pipe connects the blower exit to settling chamber. A settling chamber has a square cross section of 7.5 cm x 7.5 cm at inlet, 30 cm x 30 cm at the centre and rectangular cross section of 12 cm x 4 cm at exit. It is basically used to reduce the vibrations induced make the flow more stable before reaching the duct. It also performs the function of joining the circular cross section of the pipe with the rectangular cross section of the duct. Then the exit of the settling chamber is connected to the rectangular duct with inverse aspect ratio.

The duct has 20 pressure tapping on top, bottom, left, right in total. All the pressure tapping of the duct in addition to the total and static pressure end of the pitot tube are connected to 21 tubes of the U tube manometers. There are 3 rectangular boards of 18×46 inch dimension consisting of 27 tubes filled with distilled water inclined at 45° with the surface. A 6 layer mesh is attached at the end of the diffuser so as to restrict the entry of atmospheric air into it. As the centreline length is 30 cm and five tapping on top, bottom, left and right of the duct are divided into equal length i.e. 7.5 cm each.

Air from the blower enters into the pipe and strikes the Pitot tube where center line velocity is measured by using total pressure and static pressure. Then it enters into the settling chamber where the vibrations and disturbances are reduced and a well stabilized flow enters into the transparent duct. Each pressure tapping on the duct is connected to the U tube manometers in order to measure the difference in pressure head. Each U-tube manometer has its one end exposed to atmosphere and other end to the pressure tapping and H_2-H_1 is calculated i.e. head difference.

Fig. 6. Experimental Setup of Rectangular Duct with Inverse Ratio.

3. RESULTS AND DISCUSSIONS

The result analysis is based on the design of the rectangular duct with inverse aspect ratio. Here the ratio of difference in pressure head of each pressure tapping to the difference in pressure head of pressure tapping at the entry in all four profiles i.e. top, bottom, left and right is plotted against the ratio of the distance of each pressure tapping with respect to pressure tapping at the entry to the centreline length of the duct. This graph is plotted at different centreline velocities such as 28.05 m/s, 27.63 m/s, 25.68 m/s, 24.29 m/s, 19.83 m/s and 11.28 m/s.

A) GRAPHS AT DIFFERENT VELOCITIES

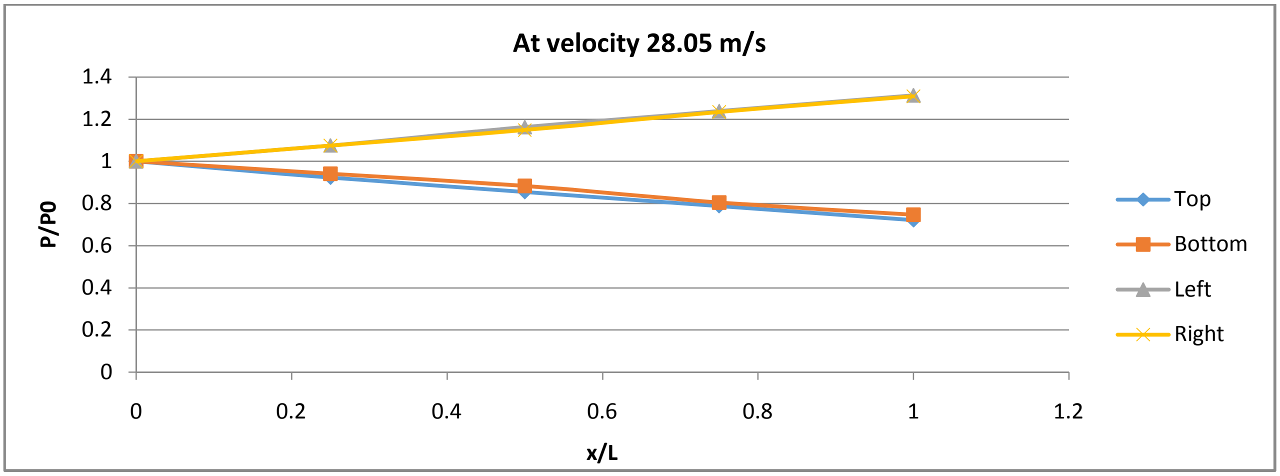

Fig. 7. Graph of P/P_0 v/s x/L at Velocity 28.05 m/s.

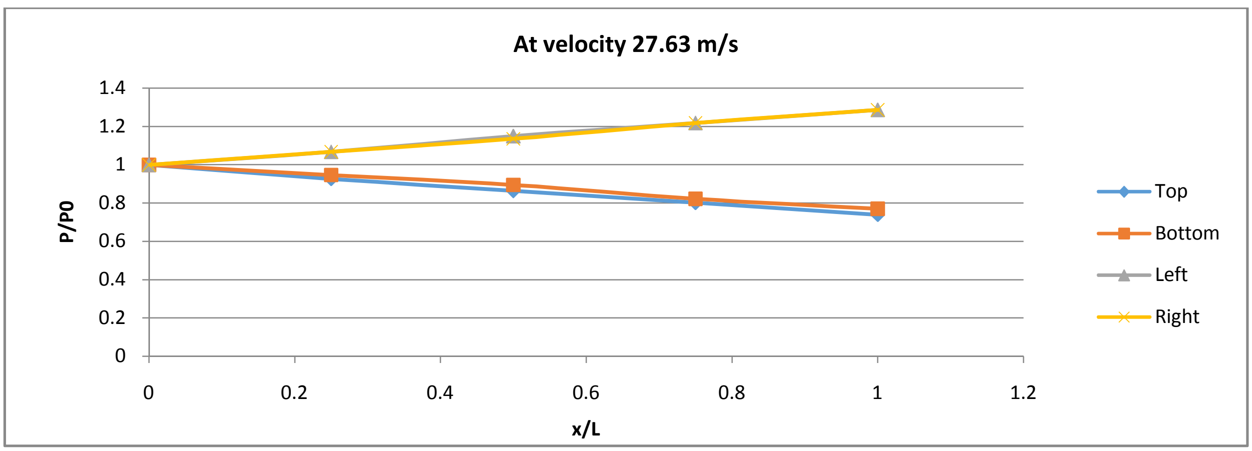

Fig. 8. Graph of P/P_0 v/s x/L at Velocity 27.63 m/s.

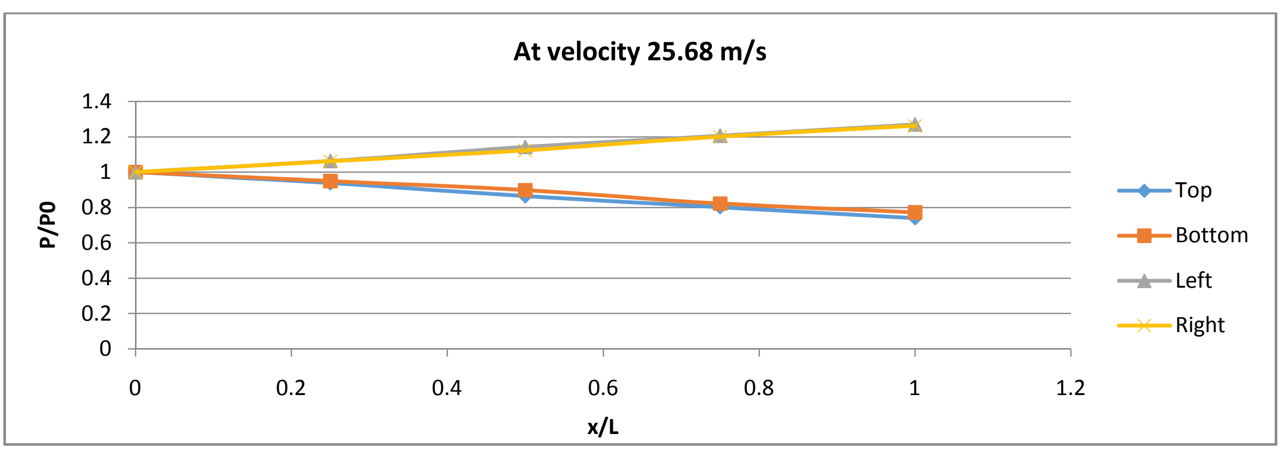

Fig. 9. Graph of P/P_0 v/s x/L at Velocity 25.68 m/s.

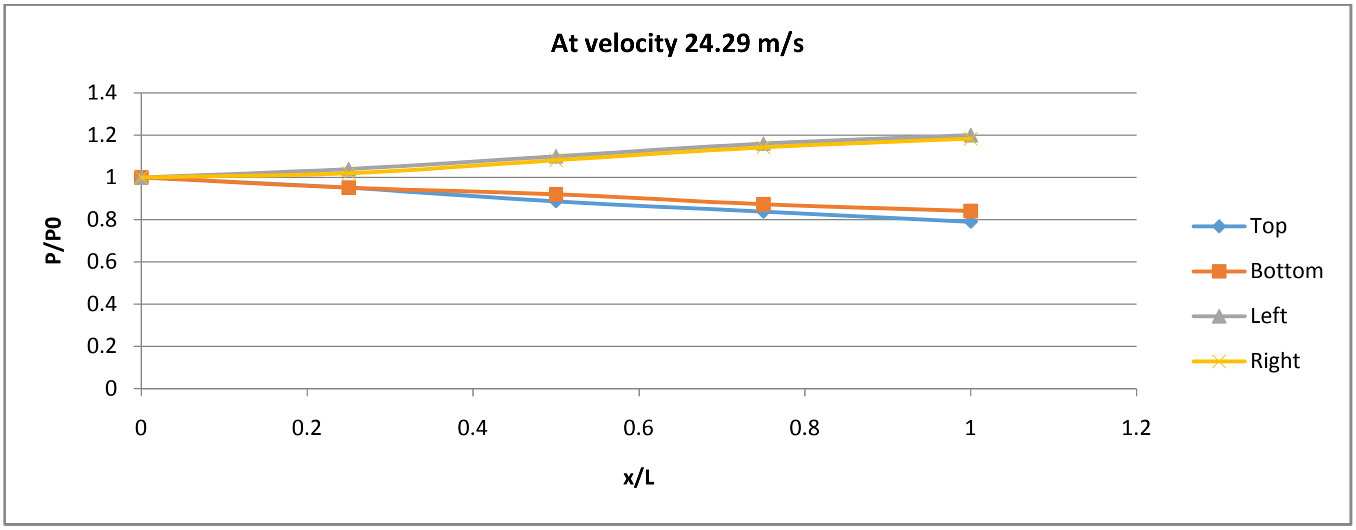

Fig. 10. Graph of P/P_0 v/s x/L at Velocity 24.29 m/s.

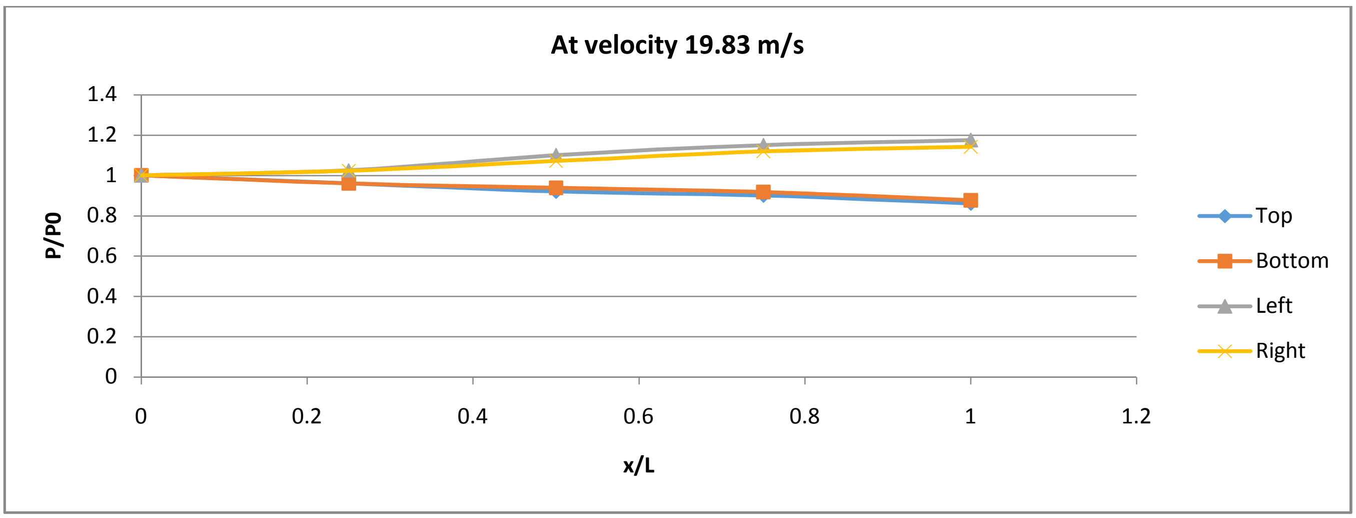

Fig. 11. Graph of P/P_0 v/s x/L at Velocity 19.83 m/s.

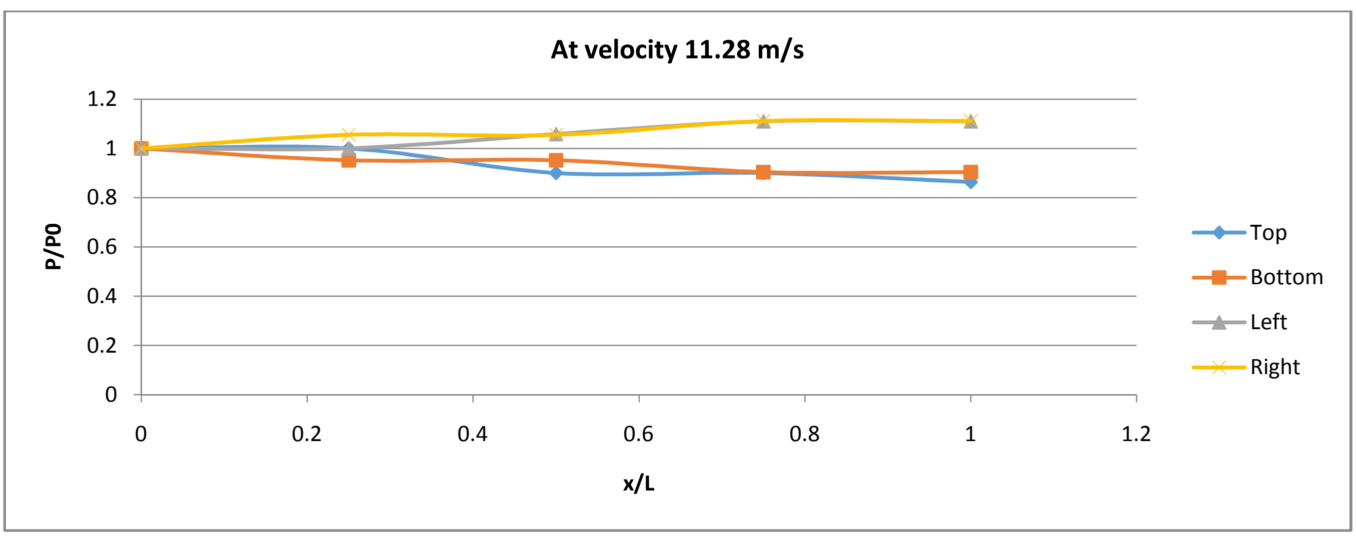

Fig. 12. Graph of P/P_0 v/s x/L at Velocity 11.28 m/s.

4. CONCLUSIONS

From the graphs above it can be analysed that in case of top and bottom profiles there is a decrease in the value of P/P_0 with the increase in the value of x/L but in case of left and right profiles there is an increase in the value of P/P_0 with the increase in the value of x/L. As the velocity decreases the gap between the top-bottom profile and left-right profile decreases. It can be clearly seen that top and bottom walls of the duct is acting as nozzle whereas left and right walls are acting as diffuser. There is pressure gain in the left-right walls and velocity gain in top-bottom walls. The present work is only related to the effect of this design on the flow parameters so as to use this in future duct designs in various commercial fields.

ACKNOWLEDGEMENT

Acknowledgement is not a mere obligations but epitome of humility and ineptness to all those who have helped in the completion of this paper. I am thankful to Dr. A.K. Raghav, Head, Mechanical Deptt., Director I.R.D, Deptt, AUH, Dr. P.B. Sharma, Vice Chancellor, AUH and Mr. Gopal Krishan Asst. Prof, AUH for their constant guidance and encouragement provided in this endeavour. I also thank my parents for their continuous support, understanding and patience without whose support and understanding this endeavour would never been fruitful.

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