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Evaluation of the Effect of different Process Parameters of Air Curtain through CFD Analysis

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Abstract: An air curtain or an air door is a device that inhibits air or contaminants from seeping from one region to another. In other words, an air curtain is a device driven by a fan that creates an invisible air barrier at the entrance to efficiently separate two different environments, without restricting access by people. Different process parameters like air velocity, temperature, air jet angle effect the performance of air curtain to optimize and analysed the effect of these parameters in this work effect of these parameters were analysed through CFD analysis in Ansys Fluent. For calculating the effect of different pressure difference condition, it considered different pressure difference condition across the door and calculate volume flow rate of air. In order to analyse the effect of different air jet angle, it considered 0, 5, 10, 15 and 20 degree inclination angle of air jet and also calculates the effect of different air jet velocity that are 5, 7, 9, 12 and 15 m/s.
Keywords: Air curtain, Jet velocity, Jet angle, Pressure difference, Environment temperature

I. INTRODUCTION

Air infiltration is the uncontrolled outflow of outside air to buildings through the slots in the building envelope or through large openings such as doors. The loss of air, the movement of air inside or outside the buildings, is mainly due to the difference in pressure between the various elements of the building enclosure. Pressure differences can be caused by many factors, such as wind, chimney effect and / or imbalances in the HVAC system (ASHRAE, 2010). The construction sector (residential, institutional and commercial buildings) consumes around 41% of primary energy consumption for maintaining the inside building temperature comfortable during summer season. In general, for different types of commercial buildings, estimates rise in power consumption due to continuous loss conditioned air is near up to 18%. As building materials and construction methods develop, modern buildings are built with greater strength and are better insulated. In more recent buildings (modern and well insulated), most of the heat losses contribute to air infiltration. It is estimated that on average, air infiltration is responsible for around 25% of the heating loads of modern buildings. New studies confirm that with increasing equipment and building efficiency, energy loss due to air infiltration is increasingly significant: a larger portion of heat loss contributes to air infiltration. With even more casings and casings than buildings, one of the main sources of air infiltrations that remain in commercial buildings are the entrance doors and infiltrations related to their frequent use. An air curtain unit (ACU) is a device that produces a jet that collides with the plane that acts as an environmental separator. The application of ACU in the refrigeration and HVAC sectors implies the need to determine the efficiency of these devices to avoid dragging heat and humidity into the protected areas. The jet produced by the ACU and its sealing capacity largely depend on the difference in pressure and / or temperature between indoor (protected) and external (ambient) spaces and the wind effect. In short, the air curtain produces a coherent sheet of air created by the flow of air that restricts the flow of outside air. This sheet of air can be bent and resist the heat exchange on an opening. Dahai et.al [2018] in this research, he had presented a parametric study of air barrier performance based on small-scale experiments and large-scale numerical simulations. Viegas et.al [2018] this research project proposed an air curtain designed to guarantee an adequate separation between two areas, one clean and one contaminated. Goubran et.al [2016] this research paper had presented an experimental study to verify and deepen the characteristics of the flow of the entrances of buildings equipped with air barriers. A small-scale chamber of 2.44 m × 2.44 m × 1.3 m (L × B × H) was constructed for infiltration / extraction and differential pressure measurements, which were then used to develop the model empirical through the operational air curtain. Sherif et.al [2016] this paper had introduced the validation of CFD modelling of air infiltration through double leaf doors through experiments. Garcia et.al [2015] the main objective of this thesis is to study and optimize the sealing efficiency of air curtains. The performance of air curtains depends on different process parameters like air jet velocity, jet angle and many others. Here in this work we have analysed the effect of different process parameters of air curtain. For analysing the effect of different air jet angle on volume flow rate of air at the outer outlet, here we have considered five different air jet angles that are 0, 5, 10, 15 and 20 degree. Here in this work we have also analysed the effect of different velocity of air jet and for analysing the effect of different velocity of air jet here we have considered five different velocity that are 5, 7, 9, 12 and 15 m/s. Air curtain is also used as a thermal insulator. Each of the above mentioned case is analysed at different pressure differences that is 0, 1.5, 3, 4.5, 6, 7.5, 9, 10.5 and 12 Pa and measured the volume flow rate of air at the outer outlet. For better stability of air jet during different working environmental condition, here in this work, the air jet angle is turned toward the outer outlet direction.

II. DEVELOPMENT OF NUMERICAL MODEL

For developing the numerical model of air curtain, first it develops the solid model of air curtain. The solid model of air curtain was developed on the basis of geometric dimension given in the base paper. The geometry dimension of complete setup considered during analysis were shown in the below fig.

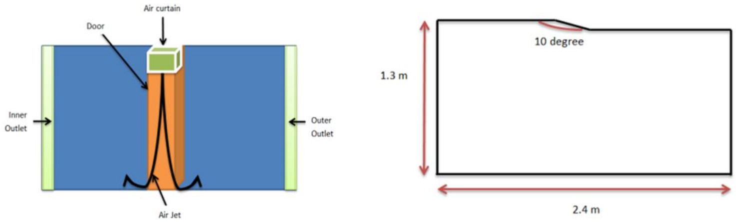

Fig.1 schematic diagram of analysis zone

A. Meshing

For performing the numerical analysis, discretization of 2D model of air curtain were perform In order to get the perfect mesh different tools was used to refine the mesh of the geometry. The mesh of the given geometry is shown in the below figure.

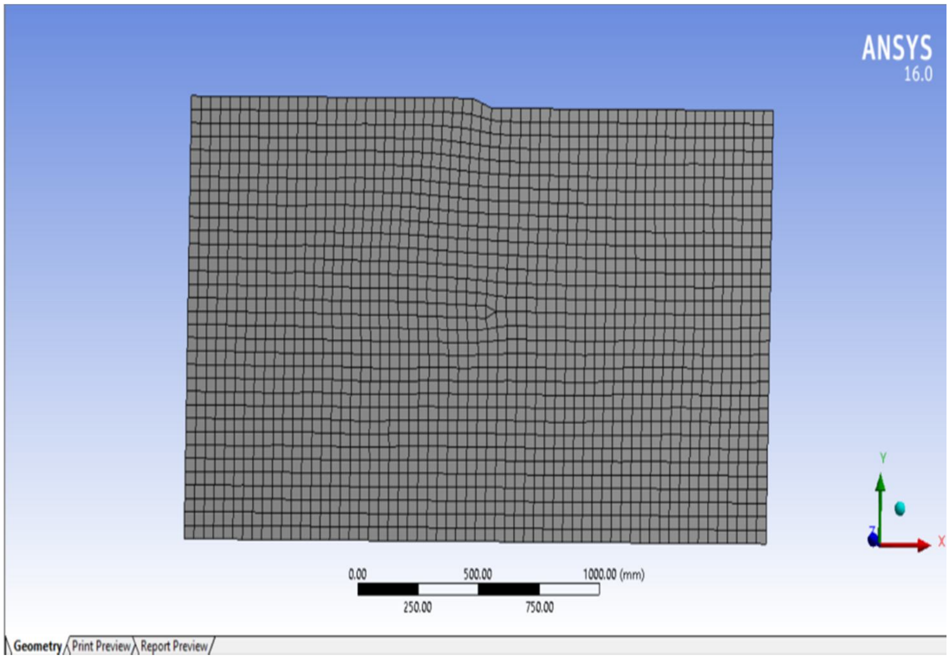

Fig.2 mesh of computational zone of air curtain

For analysing the effect of different numbers of nodes and elements, here in this work it perform the numerical analysis of air curtain system with different number of nodes and elements and calculate the volume flow rate of air at outer outlet for a given velocity of air curtain jet.

B. Selection Of Model And Boundary Condition

For performing the numerical model of air curtain here in this work K-epsilon standard wall function model was used. In order to validate the numerical model of air curtain, first it performs numerical analysis of system having air curtain with considered different pressure difference across the door. Air jet velocity 9.1m/s is considered for the initial analysis of air curtain.

C. Validation Of CFD Model

For validating the CFD model of air curtain, velocity profile of complete system considered during analysis for different pressure difference that is 0.2, 3.6, 6.4, 7.3 and 8.7 Pa were taken and then it is compared with the velocity profile obtained during the experimental analysis performed by Goubran et.al [1]. Through numerical analysis, the value of volume flow rate of air at outer outlet of door during intrinsic and extrinsic condition is calculated. The velocity profile of air curtain jet for different pressure difference were shown in the below fig.

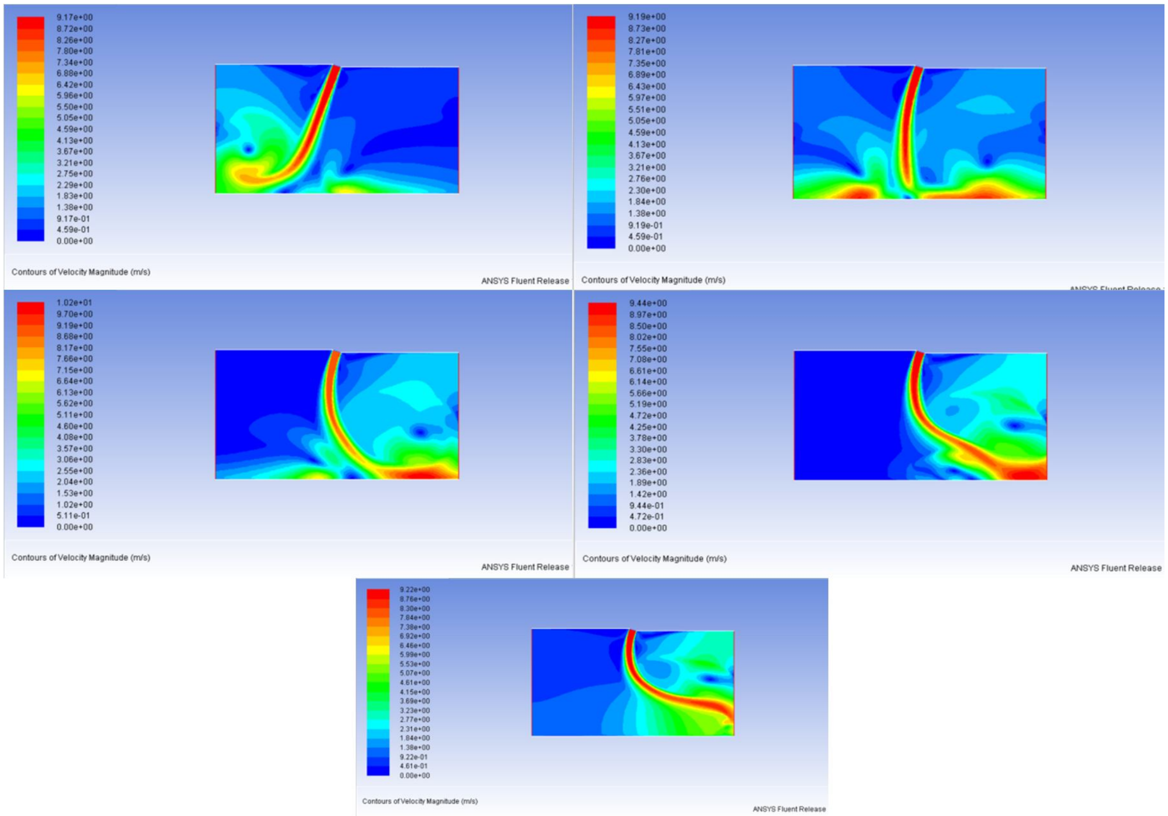

Fig.3 (a) velocity profile of air curtain jet for 9.1 m/s velocity at 0.2 Pa pressure difference, (b) velocity profile of air curtain jet for 9.1 m/s velocity at 3.6 Pa pressure difference (c) velocity profile of air curtain jet for 9.1 m/s velocity at 6.4 Pa pressure difference (d) velocity profile of air curtain jet for 9.1 m/s velocity at 7.3 Pa pressure difference (e) velocity profile of air curtain jet for 9.1 m/s velocity at 7.3 Pa pressure difference

Through numerical analysis it calculates the value of volume flow rate of air at the outer outlet. In order to validate the numerical model of air curtain here in this work, volume flow rate of air obtained from the numerical analysis is compared with volume flow rate of air obtained through experimental analysis performed by Goubran et.al [1].

D. Comparison Of Volume Flow Rate Of Air

The comparison of value of volume flow rate of air is shown in the below fig.

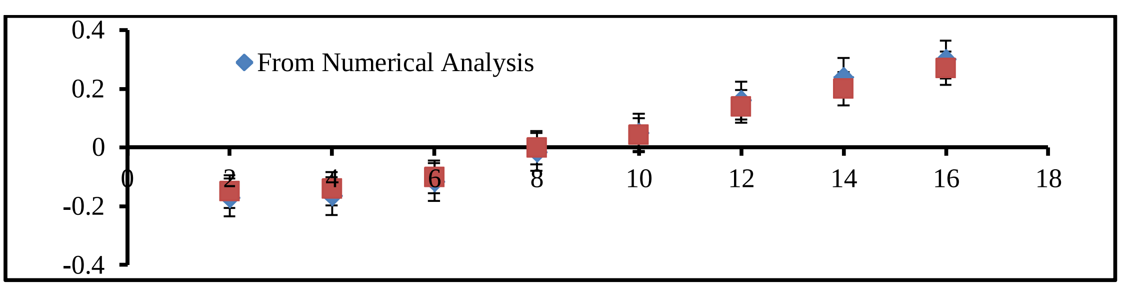

Fig.4 comparison of volume flow rate of air for different pressure difference at 9.1 m/s velocity of air jet

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From the above graph it is found that the value of volume flow rate of air at outer outlet obtained from the numerical analysis is very close to the value of volume flow rate of air at outer outlet obtained from the base paper at each pressure differences. There is very small variation in the value of volume flow rates of air for different pressure difference therefore the CFD model of air curtain is correct. So after validating the CFD model of air curtain, here in this work it analysed the effect of different air jet angle and change in velocity of air jet coming from the air curtain on the performance of air curtain at different pressure difference across the door. The effect of different process parameters were analysed in the below section. It also uses air curtain as a thermal insulator to restrict the flow of heat.

III. EFFECT OF DIFFERENT AIR JET ANGLE

For analysing the effect of different air jet angle on air curtain performance, here in this work we have considered different air jet angle that are 0, 5, 10, 15 and 20 degree angle. During the analysis of different air jet angle, velocity of air jet coming from the air curtain was remaining same for different air jet angle at different pressure difference. For analysing each angle at different pressure difference here in this work we have considered nine different pressure differences that are 0, 1.5, 3, 4.5, 6, 7.5, 9, 10.5 and 12 Pa.

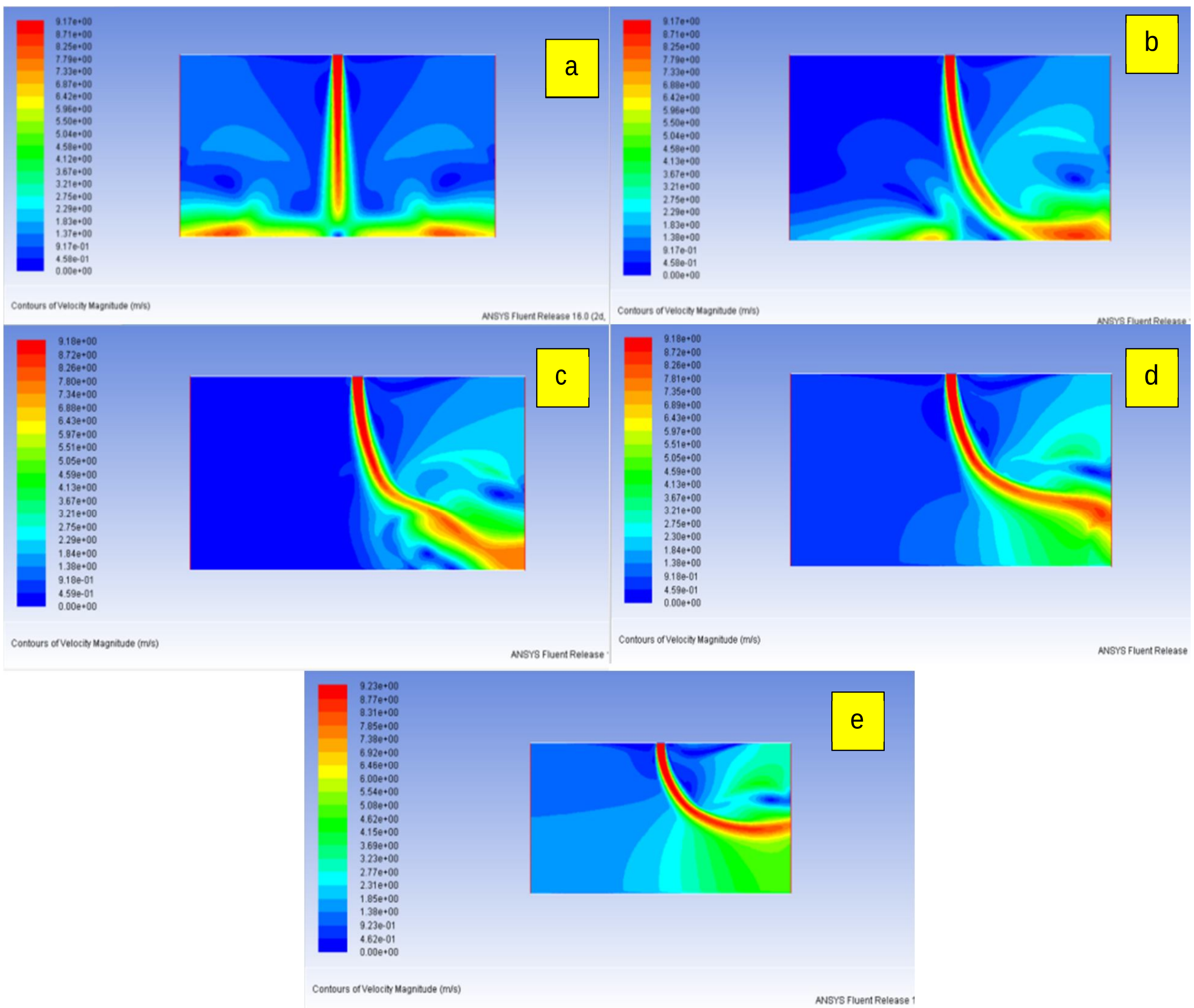

Fig.5 shows the contours of velocity for 0 degree inclination of air jet, (a) At 0 Pa pressure difference, (b) At 3 Pa pressure difference, (c) At 6 Pa pressure difference, (d) At 9 Pa pressure difference, (e) At 12 Pa pressure difference

Through CFD, it is found that at 0 degree angle of air curtain jet, air jet is stable at 0 pressure differences across the door as shown in fig 4.1 (a). Whereas as the pressure difference increases the jet start to bend toward the inner outlet which means that it allows the intrinsic flow of outside air into the system, which means that air curtain cannot fulfil its purpose.

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A. Comparison Of Volume Flow Rate Of Air For Different Air Inclination Angle Of Air Jet

During the flow of air jet some back pressure generated by air jet due to which some very less amount of air flows at inner outlet, which may be negative as well as positive for different pressure difference. The value of volume flow rate of air for different inclination angle of air jet at different pressure difference is shown in the below fig.

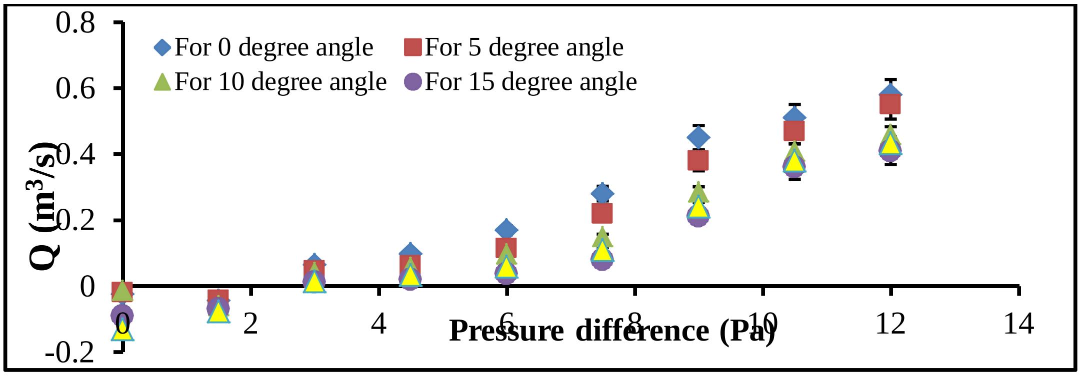

Fig.6 shows the comparison of different air jet angles of air curtain at different pressure difference

Above graph shows the volume flow rate of air at different pressure differences and at different inclination angle of air jet. Through graph it is found that up to 3 Pa pressure difference, air curtain jet for all angle of inclination is restricting the flow of outside air, whereas as the pressure difference increases above 3 Pa pressure difference, positive volume flow rate of air is found with respect to increase in pressure difference. Through analysis it is found that at higher pressure difference, the difference in volume flow rate of air for different inclination angle of air curtain is more as compare to lower pressure difference, which concludes that air curtain jet is more sensitive with higher pressure difference as compared to lower pressure difference. At higher inclination angle of air curtain jet and at lower pressure difference, the negative volume flow rate of air is more as compared to lower inclination angle of air certain jet. At each pressure difference it is found that with 15 degree inclination angle of air curtain the volume flow rate of air is minimum as compared to other inclination angles which means that air curtain jet with 15 degree inclination angle shows the most efficient inclination angle.

IV. EFFECT OF CHANGE IN VELOCITY OF AIR JET ON THE PERFORMANCE OF AIR CURTAIN

For analysing the effect of different air jet velocity on air resistance, here in this work, it considered four different air jet velocities that are 5, 7, 9, 12 and 15 m/s. At each given velocity different pressure difference conditions are considered and the value of volume flow rate of air is calculated.

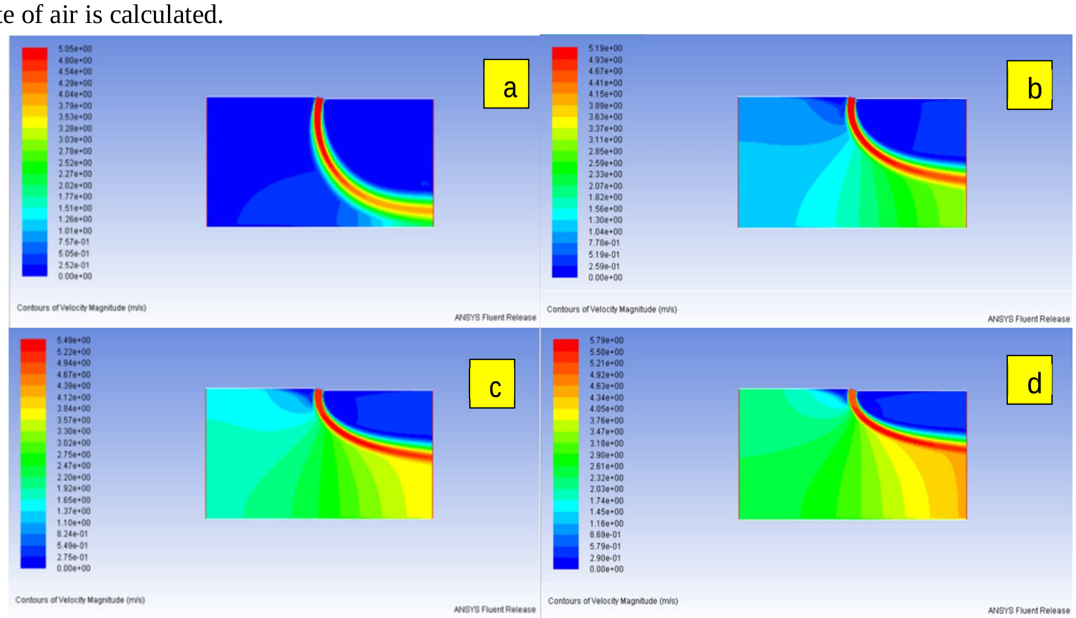

Fig.7 shows the contours of velocity at 5 m/s air jet, (a) At 3 Pa pressure difference, (b) At 6 Pa pressure difference, (c) At 9 Pa pressure difference, (d) At 12 Pa pressure difference

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For analysing the different pressure differences is considered same as considered during the analysis of effect of air jet angle that are 0, 1.5, 3, 4.5, 6, 7.5, 9, 10.5 and 12 Pa. The analysis of different air jet velocity is performed in the below section. During analysis air jet angle is considered as 15 degree which shows the minimum flow rate of air as mention in the above case.

V. COMPARISON OF DIFFERENT VELOCITY OF AIR CURTAIN JET AT DIFFERENT PRESSURE DIFFERENCES

In order to compare the variation of velocity of air jet coming from the air curtain, here we have compared the volume flow rate of air for different pressure difference at different velocity of air jet. The value of volume flow rate of air for different velocity of air jet for different pressure difference is mentioned in the below section.

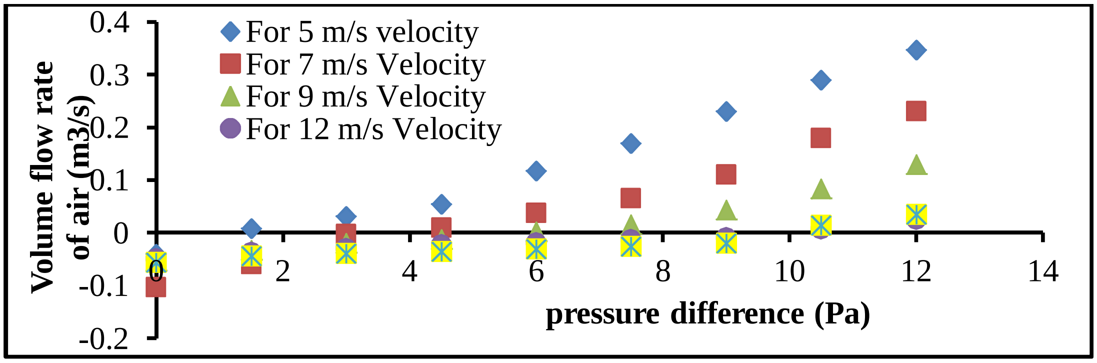

Fig.8 comparison of different velocity of air jet at different pressure difference

Through graph it is concluded that as the velocity of air jet increases, the ability of air jet to remain stable at higher pressure difference becomes stronger. Through graph, it is found that with higher air jet velocity air curtain jet restrict the flow of air that is intrinsic and extrinsic flow of air across the door at much higher pressure difference as compared with the low air jet velocity. With 12 m/s and 15 m/s velocity of air jet, air curtain jet remains stable up to 9 Pa pressure difference, whereas at lower pressure difference it shows less value of volume flow rate of air as compared to 5, 7 and 9 m/s velocity of air jet. So here it is concluded that according to the use of air curtain in different areas, air curtain parameter can be variable to achieve desire output.

VI. AIR CURTAIN USE AS A THERMAL INSULATOR

After analysing the effect of jet angle and different air jet velocity .Here in this work it is also analysed the use of air curtain as a thermal insulator. In order to use air curtain as a thermal barrier in between two systems, we have considered 40 degree outside environment temperature whereas the inside room temperature is kept at 22 degree. At different pressure differences (3, 6, 9 and 12 Pa) air curtain as a thermal barrier is analysed. During analysis velocity of air jet remains constant that is 12 m/s. The temperature contours of the system at different pressure difference are shown in the below figures.

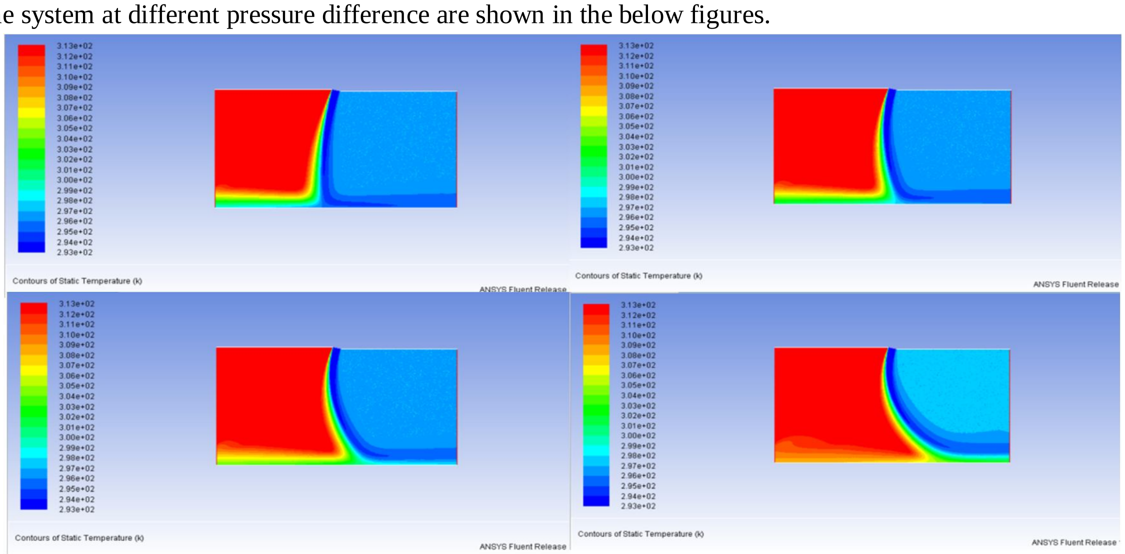

Fig.9 (a) Temperature contour at 3 Pa pressure difference, (b) Temperature contour at 6 Pa pressure difference, (c) Temperature contour at 9 Pa pressure difference, (d) Temperature contour at 12 Pa pressure difference

VII. CONCLUSION

Performing the numerical analysis of air curtain provides the detail working of the controlled system having air curtain. Through analysis it is found that at higher pressure difference, the difference in volume flow rate of air for different inclination angle of air curtain is more as compare to lower pressure difference. At higher inclination angle of air curtain jet and at lower pressure difference, the negative volume flow rate of air is more as compared to lower inclination angle of air certain jet. It is found that with 15 degree inclination angle of air curtain the volume flow rate of air is minimum as compared to other inclination angles which means that air curtain jet having 15 degree inclination angle is most efficient inclination angle. It is concluded that as the velocity of air jet increases, the ability of air jet to remain stable at higher pressure difference becomes stronger. It is found that with higher air jet velocity air curtain jet restrict the flow of air that is intrinsic and extrinsic flow of air across the door at much higher pressure difference as compared with the low air jet velocity. After CFD analysis of system having different outside temperature it is found that air curtain can be used as a thermal insulator, which restrict the flow of heat in between two systems.

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