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Evaluating the Effect of Outside Environment Temperature and Person Movement on the Performance of Air Curtain

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Abstract: ***Air curtain are used to restrict the flow of intrinsic and extrinsic of air. It is also use as a thermal insulator, mainly used in dash board of sweets and other perishable items. Here in this work it investigates the effect of different environmental temperature on the performance of air curtain. For evaluating the effect of different environment temperature here in this work it considered 10, 20, 30 and 40 degree Celsius of outside environment temperature. ANSYS fluent is used to numerically investigate the effect of different parameters on air curtain. This study also investigates the effect of persons moving across the door on air curtain, for that it considered four different positions of person. Through analysis it is found that air curtain can be used as thermal barrier as it restrict the flow of temperature and there is no any effect of person movement across the door on the performance of air curtain.***

Keywords: Air curtain, thermal barrier, person movement, pressure difference, volume flow rate

I. INTRODUCTION

Air curtains are also used to reduce the energy consumption of air conditioning equipment, air curtains also act an insulator to protect from outside dust particles, insect and other agent to come inside the control environment. Condition air inside the building where continuously loss due to the opening and leakage of building due to which equipment used for providing comfort conditioning air run continuously which consume lot of energy, to prevent the loss of condition air and reduce the energy consumption of equipment's air curtains were used. Many researcher name air curtain as a thermal insulator which protect inside cold environment from outside hot environment, air curtains were mounted on the top of window and door to reduce the loss of condition air form the opening and closing of doors and windows. Air curtains produces jet of air which creates a protecting wall in between inner and outer atmosphere.

Guyonnaud et.al [2000] the persistence of this study is twofold: (1) to demonstrate the effectiveness of the air curtain. (ii) How to use a reduced model for installing large installations. This device has air curtains. The plane was used as a digital screen to reduce the greater heat and transmission from one area to another, under geographical or weather circumstances. Lu et.al [2006] in this work, a preliminary analyse of the air curtain moves on the door and is crushed to a commercial vehicle. Studies have found that the flow of air curtains is well closed in a plane along its path but is widespread in a passenger plane. Bosbach et.al [2006] in this article, he used the velocimetry of particle images for the measurement of large-scale flows, in particular for the study of convective air flows. Dragomirescu et.al [2009] Finding the best solution to reduce the level of pollution is still their capture near the source. When this option is lost, a high degree of pollutant dispersion makes it difficult and expensive, as is any process of capture and cleaning. Cheng et.al [2009] this work provides a computational model for calculating the effects of compulsive and compulsory ammonia dispersion. It provides an effective method of implementing a curtain reduction system and can reduce public safety concerns and safety around the ammonia. Xiaodong et.al [2014] this document introduces a simple PIV technology guide that is used to measure the indoor atmosphere and thus summarizes the latest generation of the PIV program to measure the flow of air in. Giraldez et.al [2016] this study was dedicated to determining the proficiency of air curtain systems (ACU) used to insulate heat and moisture in refrigerated rooms.

Swain et.al [2001] this document demonstrates the importance of creating air curtains to ensure the best performance. The air cushion effect installed at 1.36 meters in a cool room was measured and predicted using two-dimensional analysis and CFD models. Navaz et.al [2005] in this study, experimental and computational methods was used to address those variables, which had a significant effect on the amount of hot air in the case of open refrigerator. Lecaros et.al [2010] in this research, the capability of DS-TJ curtains to restrict heat throughout tunnels has been researched by equally numerically and then experimentally. Rivera et.al [2011] In this study, the negative effects of the flow effect on the double curtain effect produced by the cooling stream in line with

the flow of heat were investigated. Vempati et.al [2011] the objective of this research was to study the speed and temperature distribution inside a room equipped with two active cold beams (TROX 612B-HC active cold-beam unit) using numerical simulations.

Goncalves et.al [2012] this work had presented a numerical and experimental study on the enactment of air curtains in the aerodynamic sealing of the access doors of the refrigerated spaces. Luo et.al [2013] in this work, the Curtain with dual jet (ODAC) is advised to determine smoke exchanger and smoke evacuations during high incidents. Segarra et.al [2013] this work is dedicated to analyzing and forecasting the effect of air curtains. Important is the improvement of the existing half-analytical methodology with information on CFD testing and measurement. Garcia et.al [2015] the main dispassionate of this thesis is to study and optimize the sealing efficiency of air curtains. Both experimental and numerical approaches are used. Goubran et.al [2016] the intention of this study was to scrutinize the effectiveness of different entrance doors to reduce indoor air infiltration. Viegas et.al [2016] this article shows the water samples of water analysis and experimental water. In the context of this study, it is recommended to use a drop-down to prevent the flow of smoke that will not affect the temporal outlook. Outside temperature changes as the season changes, in India there is a wide variation of atmospheric temperature. During winter season temperature ranges from 10 to 20 degree Celsius whereas during summer season it reaches to 40 to 45 degree Celsius. Here in this work, effect of outside temperature and person moving across the door where analyzed. Up to our knowledge on any other have reported the effect of outside temperature and person moving across the door on the performance of air curtain.

II. DEVELOPMENT OF CFD MODEL OF AIR CURTAIN

For analyzing the different process parameter and achieve objectives of the work, here first it has to develop the CFD model of air curtain mounted at the top of the door. The geometrical parameters on which the solid model of numerical analysis was developed were considered same as considered during the experimental analysis performed by Goubran et.al [35]. The geometric parameters were shown in the below table. Geometric parameters considered for solid model, Room length, Room width, Room height, Nozzle slot are 2.44, 2.44, 1.3 and 0.08 m. Here in this work it perform the 2D analysis of air curtain the solid model of air curtain considered for the numerical analysis were shown in the below fig.

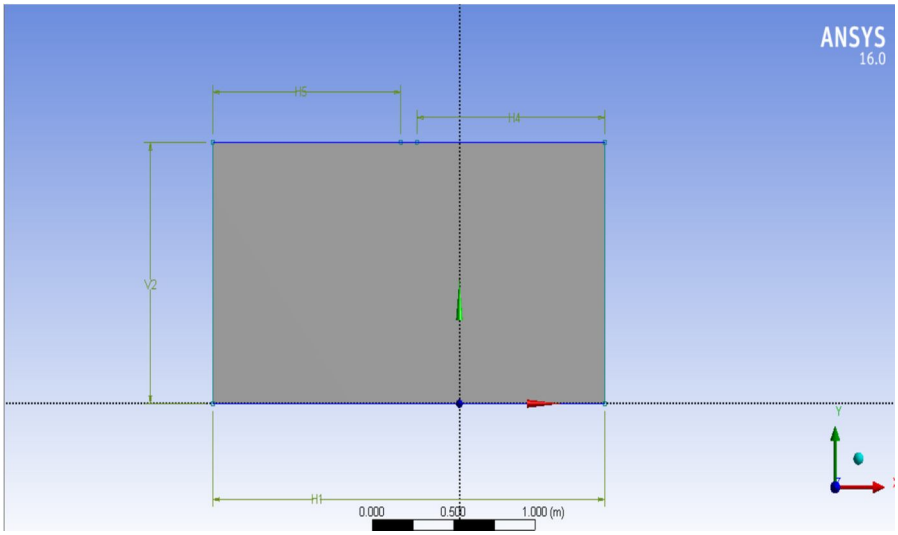

Fig.1 2D solid model of air curtain with atmosphere

A. Mesh

In order to perform numerical analysis it is necessary to discretize the complete body in to number of nodes and elements. For performing the numerical analysis it is necessary to find the optimum number of nodes and elements to get good result and also perform the mesh independence test. Mesh independence test shows the dependency of numerical result on number of nodes and elements. In order to perform the independence test of numerical analysis here it considered five different numbers of nodes and elements to perform mesh and see the contours of velocity and jet length which is able to restrict the flow of air in both sides that is intrinsic and extrinsic. In order to get the more refinement here we have considered refinement tool and give 8 mm size of element for meshing. The mesh with the given condition is shown in the below fig.

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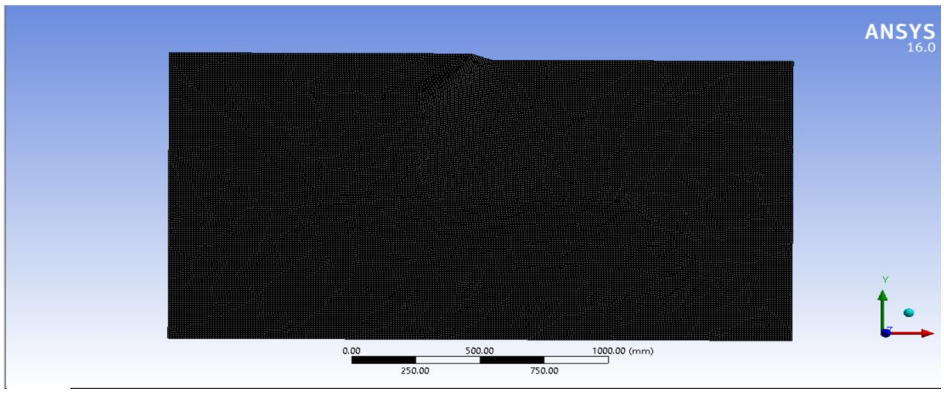

Fig.2 mesh of the geometry with 78958 numbers of elements

With this number of elements here we have find the contours of velocity and jet of air coming from the air curtains.

B. Selection of Model

For finding the optimum model for the numerical analysis of air curtain here in this work it perform the CFD analysis of air curtain with different model and find out the optimum model for the numerical analysis of air curtain. In order to find the optimum model here we have considered numerical analysis of air curtain based on the geometric conditions as mention in above section. With the same geometric parameters and boundary condition that is pressure different 2, 4, 6, 8 and 10 Pa at air velocity 9.1 m/s coming from air curtain it perform the numerical analysis and calculate the discharge (Q (m^3/s)) from the door. Through analysis it is found that the volume flow rate of air for K-epsilon Realizable model is in between the value of volume flow rate of air obtained with the different model used for the CFD analysis. Here in this work for further CFD analysis K-epsilon Realizable turbulence model is used as a turbulence model, and the pressure velocity coupling were adopted the SIMPLE algorithm. Here it also considered the standard wall function parameters with full buoyancy effect. During the CFD analysis of air curtain air was assumed as incompressible ideal gas. To get the more accurate result during the CFD analysis here convergence will reach when the residual was less than 10^{-3}.

C. Boundary Condition

During the analysis spatial discretization scheme were used for the analysis. For pressure interpolation, momentum and energy interpolation second order were chosen for the CFD analysis. Different numbers of elements and nodes were considered during the CFD analysis as mention in the above section. For the initial analysis of air curtain here it considered different pressure difference in between the inner and outer atmospheric condition. Air coming from the curtain at a velocity of 9.1 m/s and 13.75 m/s was considered for the initial analysis of air curtain. For validating the CFD model of air curtain velocity profile for different pressure difference that is 0.2, 3.6, 6.4, 7.3 and 8.7 Pa as considered during the experimental analysis performed by Goubran et.al [35] were find out through numerical analysis.

III. EFFECT OF OUTSIDE ATMOSPHERIC CONDITION ON AIR CURTAIN

So in order to analyze the effect of different atmospheric temperature on air curtain performance here in this work it analyzes the effect of different atmospheric temperature on air curtain. In order to analyze the effect of different temperature of outside condition, here it considered four different atmospheric temperatures that is 10, 20, 30 and 40 degree Celsius. During analysis the velocity of air supply remain constant that is 11 m/s, whereas the supply angle consider for the analysis is 15 and 20 degree and the temperature of inside conditions were remain same that is 298 K. Other boundary conditions were same as considered for different parameters analysis like effect of change in velocity and others. Velocity profile of air jet for different atmospheric temperature at different pressure difference were analyze, pressure difference were same as considered in the above analysis.

The temperature of air coming from the air curtain was considered as 21 degree Celsius. The velocity and temperature contours of system at different outside pressure condition and at different temperature were shown in the below figure. Here in this section it analyzed the effect of change in outside temperature of atmosphere on infiltration and exfiltration of air. Temperature contours for different pressure difference at different temperature conditions were also shown in the below figure.

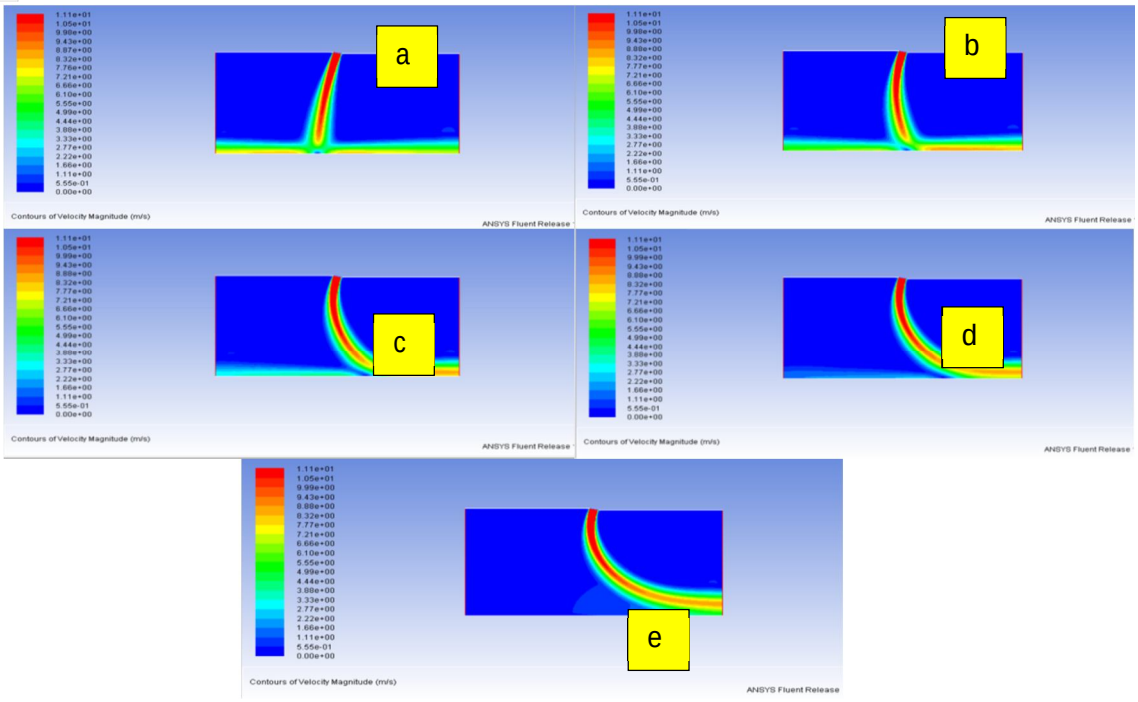

Fig.3 velocity contours for 15^0 supply angle with 10^0 C outside temperature (a) at 2 Pa pressure Difference, (b) at 6 Pa pressure Difference, (c) at 10 Pa pressure Difference, (d) at 12 Pa pressure Difference, (e) at 14 Pa pressure Difference

From the above analysis it is found that change in outside atmospheric temperature conditions of environment does not affect the volume flow rate of air across the door. Through above mention graph it can say the change in temperature of environment done not affect the air jet length. But through analysis it is also found that air curtains are not even stopping the outside dust, pollutant and air to flow inside, it also protect the temperature of inside environment. Through analysis it is found that the air curtain also act as a thermal insulator, which protect the inside environment temperature from the outside environment as shown in the below figure. The temperature contours for inside, outside and air jet is shown in the below fig. Here it analyzed the different seasonal condition in India that is winter and summer season.

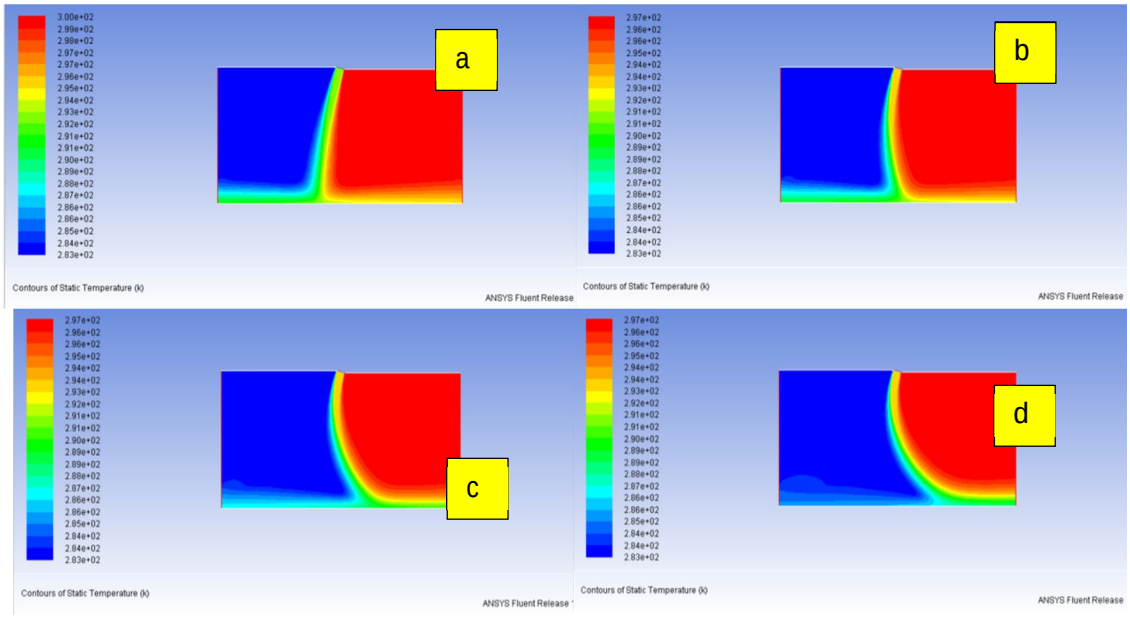

Fig.4 temperature of system during winter season with 10^0 C outside temperature (a) at 2 Pa pressure Difference, (b) at 6 Pa pressure Difference, (c) at 10 Pa pressure Difference, (d) at 12 Pa pressure Difference

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The above figure shows the contours of temperature during winter season with outside temperature 10^0 C. here in this case air curtain were act as a thermal insulator and protecting the inside hotter air to move outside and restricting the outside air to move inside that is intrinsic flow. After analyzing the winter season conditions of India here it also analyzed the summer conditions of India. In order to analyze the summer condition here it considered 40^0 C temperature of outside environment. The velocity contours for difference pressure difference at 40^0 C outside temperature condition is shown in the below fig.

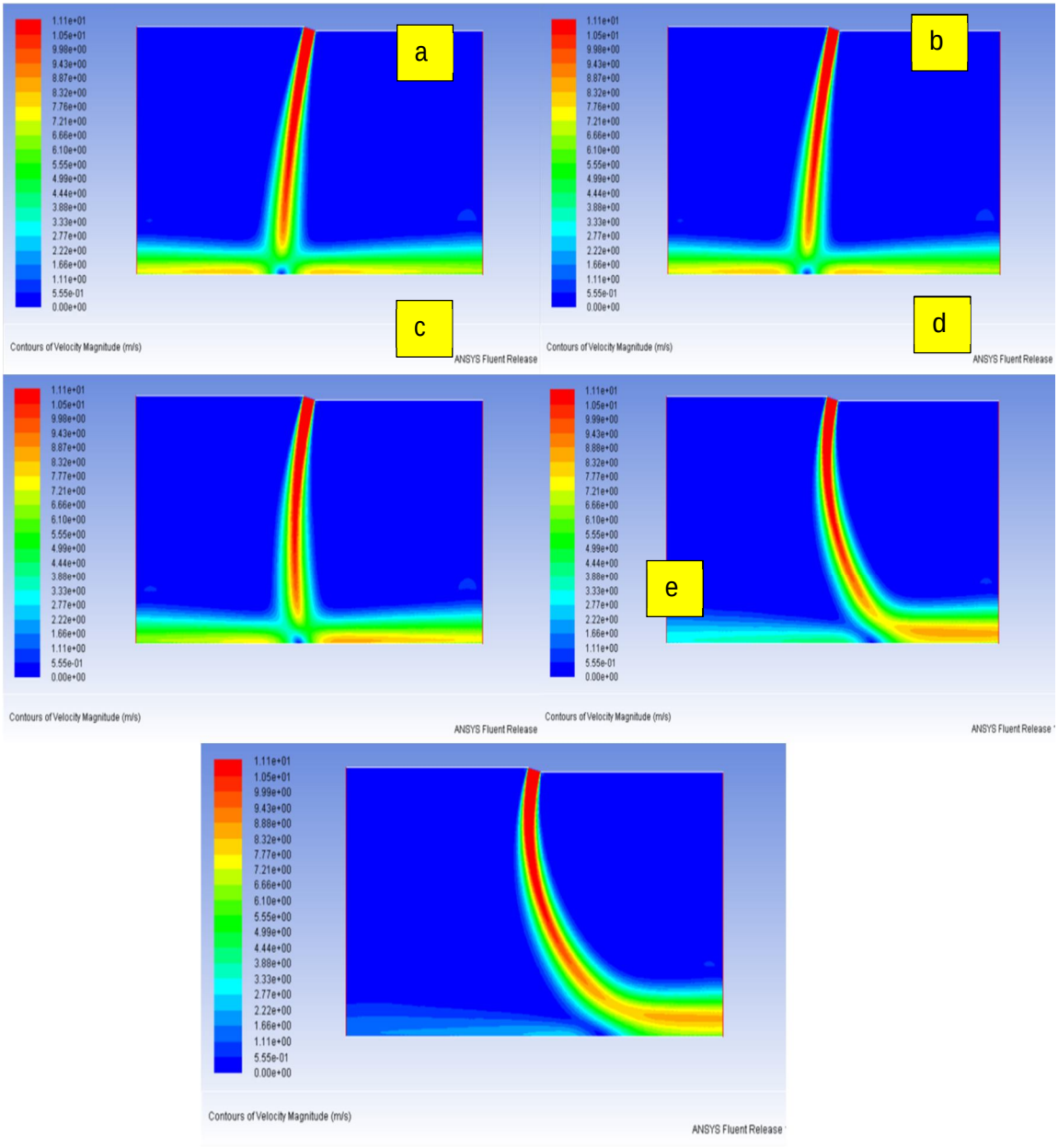

Fig.5 velocity contours for 15^0 supply angle with 40^0 C outside temperature (a) At 2 Pa pressure Difference, (b) At 6 Pa pressure Difference, (c) At 10 Pa pressure Difference, (d) At 12 Pa pressure Difference, (e) At 14 Pa pressure Difference.

Above graph shows the velocity contours for 15 degree supply angle at 40^0 C outside temperature condition. Through contours it can say that as the temperature of environment increases there is no such effect on the volume flow rate of air at different positive pressure difference. Means it shows that increase in atmosphere temperature condition give only slight effect on the intrinsic flow of air. The temperature contours for different pressure difference at 400 C outside temperature condition is shown in the below fig.

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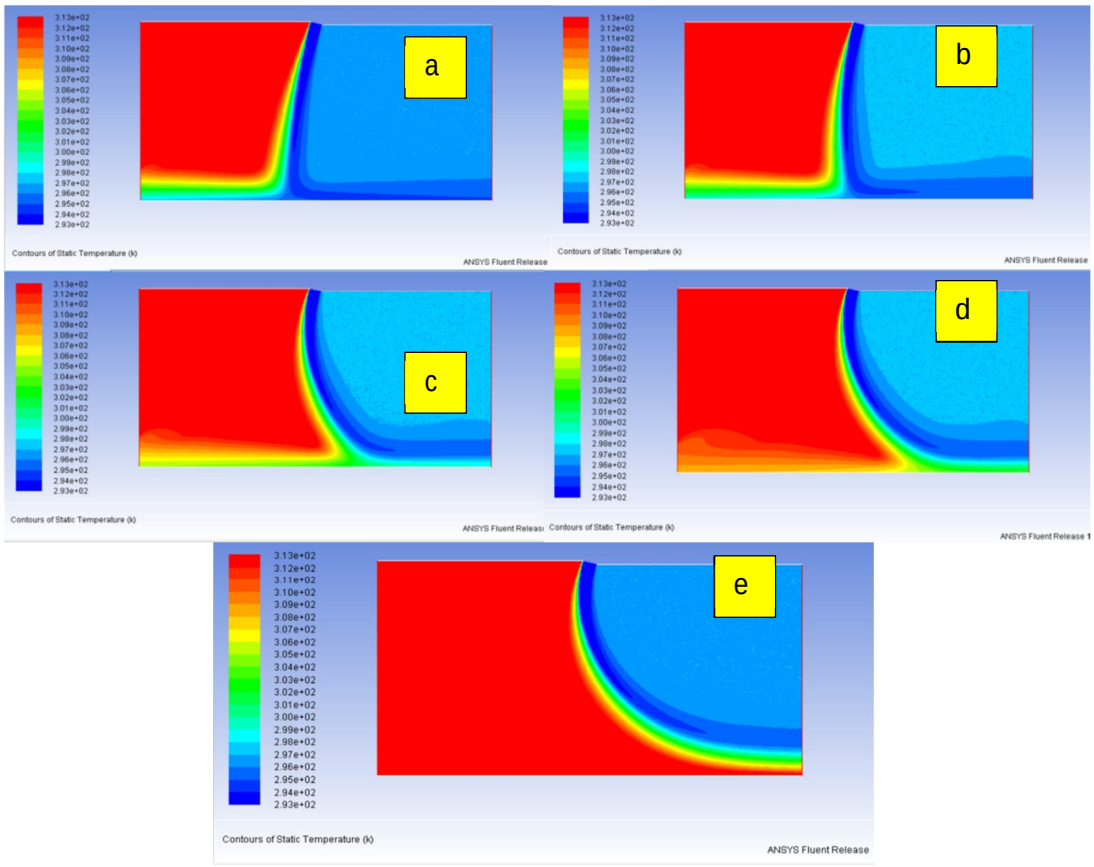

Fig.6 temperature of system during summer season with 40^0 C outside temperature (a) At 2 Pa pressure Difference, (b) At 6 Pa pressure Difference, (c) At 10 Pa pressure Difference, (d) At 12 Pa pressure Difference and (e) At 14 Pa pressure Difference.

From the above contours it conclude that air curtain act as a thermal insulator, during summer season also where the outside temperature is so high as compared to system temperature it protect the inside environment. Air curtain despite restricting the intrinsic flow, it also restrict the outside heat to transfer inside. Through this analysis it can say that air curtains are also used as a thermal separator or barrier in sweets dash board and vegetable market to maintain the cooling environment. There are lots of applications where air curtain can be used as a thermal insulator.

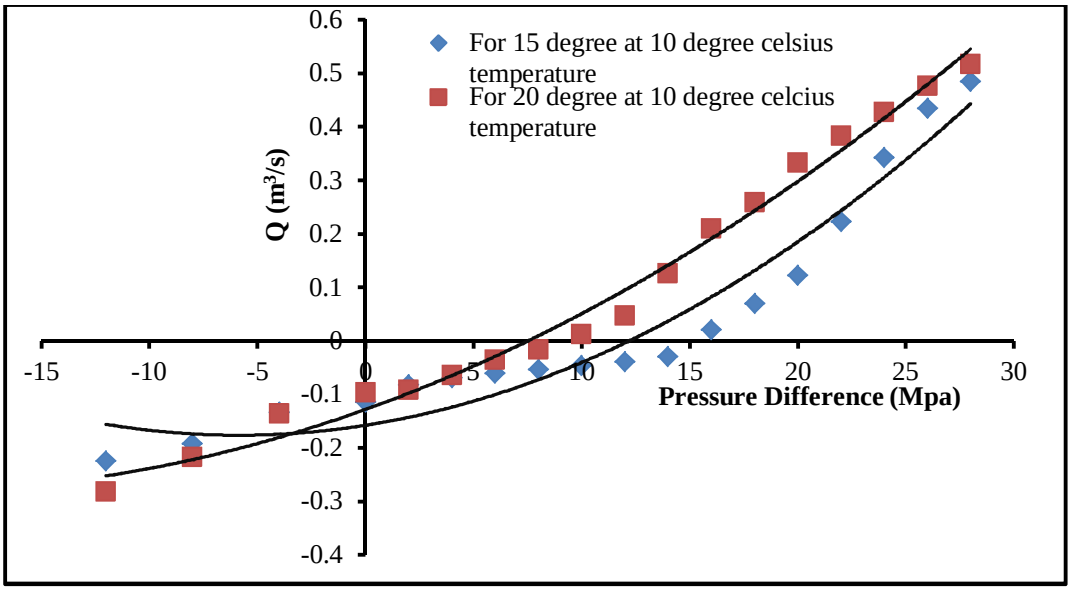

Fig.7 Comparison of volume flow rate of air at 10^0 C temperature for different supply angle.

Through graph it is found that the value of volume flow rate of air at 10^0 C temperature of outside environment where same as volume flow rate of air at 25^0 C temperature of outside environment. There is very small variation in volume flow rate of air. This means that the atmospheric temperature does not affect the volume flow rate of air, but change in temperature affect the heat transfer from the system. This concludes that the air curtain were not even used to restrict the flow of air, but it is also used for the restriction of heat means act as a thermal barrier. Through above analysis it is found that air curtain can also be used to thermal insulator to isolate the system inside environmental temperature form the outside environmental temperature. During summer condition in India environmental temperature is in the range of 45 degree centigrade, due to continuous openness of door in mall and big corporate building there is a flow of condition air from inside building to atmosphere, which causes to work air conditioners continuously which consume lot of power. So in order to reduce the consumption of energy by conditioner air curtains can be place at the top of opening which restrict the flow of heat in to the conditioned building. After analyzing the effect of environmental temperature on the performance of air curtain, it also analyzed the effect of man standing below the air curtain on the performance of air curtain. For analyzing the effect of man standing on the performance of air curtain, different position of man standing were analyzed as discuss in the below section.

IV. EFFECT OF PEOPLE STANDING IN DOOR WAY 1`

For analyzing the effect of people standing at the door way, here it considered 11 m/s velocity of air jet coming from the air curtain at an angle of 15 degree and other conditions were remain same as considered during the analysis of effect of outside temperature on the performance of air curtain. For analyzing the effect of man inside the air curtain, it considered 4 different positions that is (a) Analyzing the air curtain without person, (b) analyzing the air curtain with person standing before air curtain jet, (c) Analyzing the air curtain with person standing below the air jet and (d) Analyzing the air curtain with person standing after air curtain jet. For each position of person standing, different pressure difference were analyzed and calculate the value of volume flow rate of air.

A. Analyzing The Air Curtain Without Person

Here in this condition no any person is standing during the operation and volume flow rate of air at the inner outlet were calculated at different pressure difference. The velocity contour for this case were shown in the below fig.

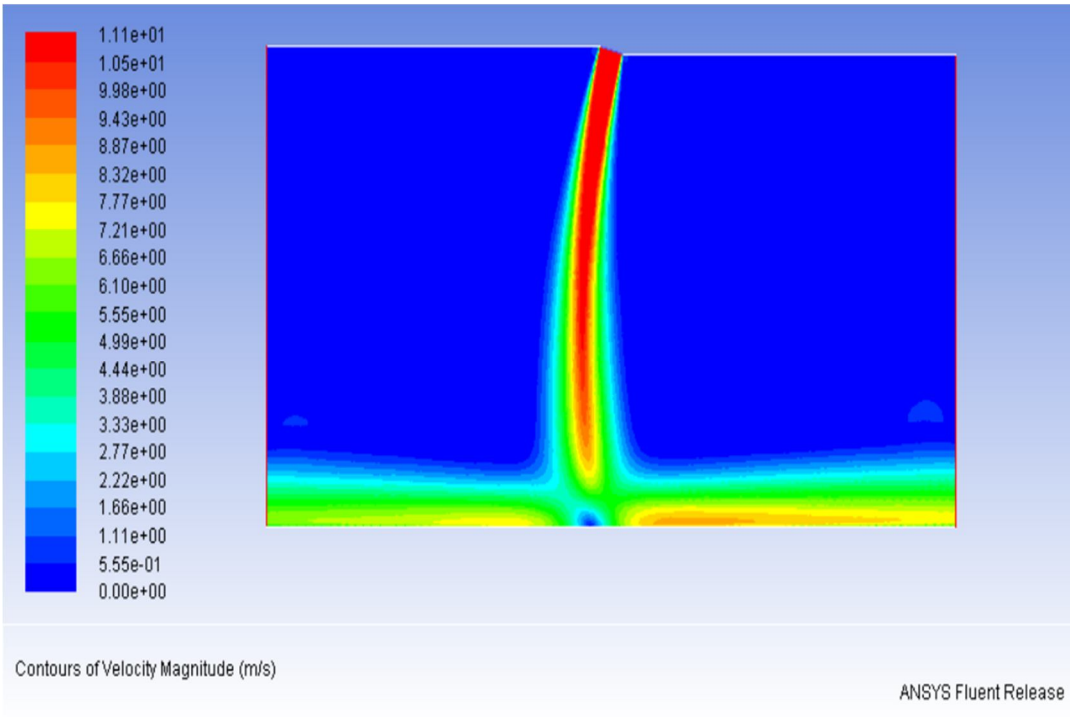

Fig.8 contours of velocity during without person condition at 10 Pa pressure difference

Above figure shows that at 10 Pa pressure difference across the door, air jet coming from the air curtain remain stable and restrict the intrinsic and extrinsic flow of air, which shows the stability of air jet.

B. With Person Standing In Front Of Air Jet

Here in this case a person is standing just before the air jet falling towards outer atmosphere and calculated the flow rate at inner outlet. The velocity contours of air during this conditions were shown in the below fig.

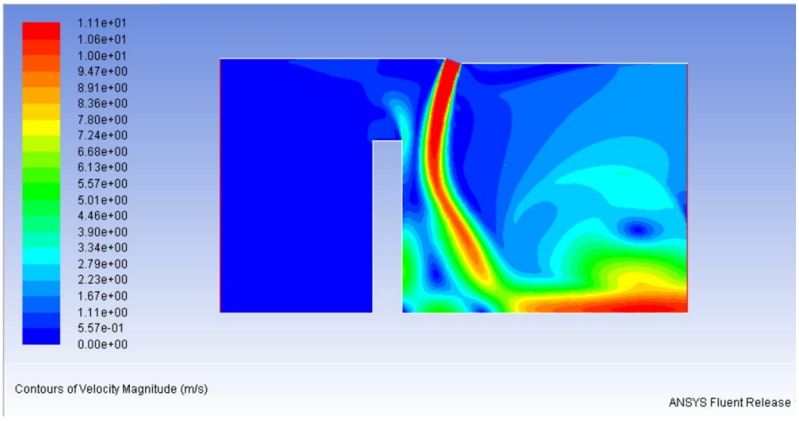

Fig.9 velocity contour of air when person standing just before the air jet at 10 Pa pressure difference

Through analysis and above contour it is found that as the person reaches towards the air curtain, air jet get little sift towards the inner outlet, but still it act as a barrier to restrict the flow of outside air to move inside the system where as there is very slight difference in volume flow rate of air in this case with respect to no person standing case. Here in this case at 10 Pa pressure difference the volume flow rate of air is 0.251 m^3/s whereas during no person condition at same pressure difference it is near about 0.271 m^3/s, which shows very slightly variation in mass flow rate of air. For better analyzing the behavior of air curtain during person movement at different positions with respect to change in different pressure difference across the door, here it calculates the value of volume flow rate of air at different pressure difference that is 2, 4, 6, 8 and 10 Pa for each position.

C. With Person Standing Below The Air Jet

During this case a person is exactly standing below the air curtain, air jet coming from the air curtain is just falling on at the top of person. The velocity contour for this case is shown in the below fig.

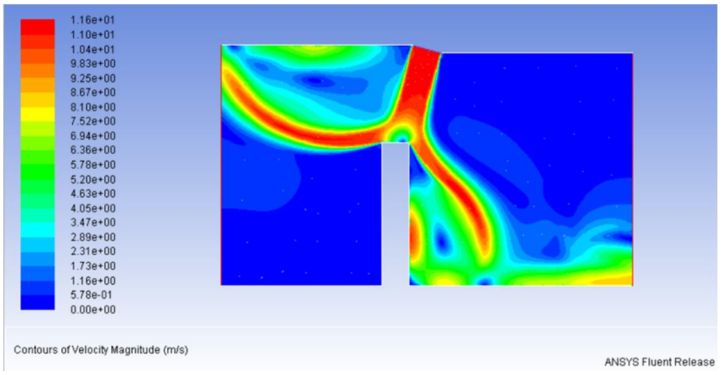

Fig.10 velocity contour of air when person standing just below the air jet at 10 Pa pressure difference

Above contours show that, half of the air get diverted towards the outer outlet whereas half of the air jet get diverted towards the inner outlet. Due to the diversion of air jet toward the inner outlet, the volume flow rate of air at outer outlet get increased, but no any outside environmental air where allowed to enter inside the system. Above contours indicates that when a person is standing below the air jet, three different flow pattern of air jet were observed that is inflow break through, outflow break through and optimum condition. Though the air jet gets diverted towards the inner and outer outlet, but still it restricts the intrinsic flow of air.

D. With Person Standing After Air Curtain Jet

During this case, a person just crosses the air jet and stand at some distance, the pressure difference and velocity of air jet coming from the air curtain were remain same as considered during the different position of person. The velocity contour for this case is shown in the below figure.

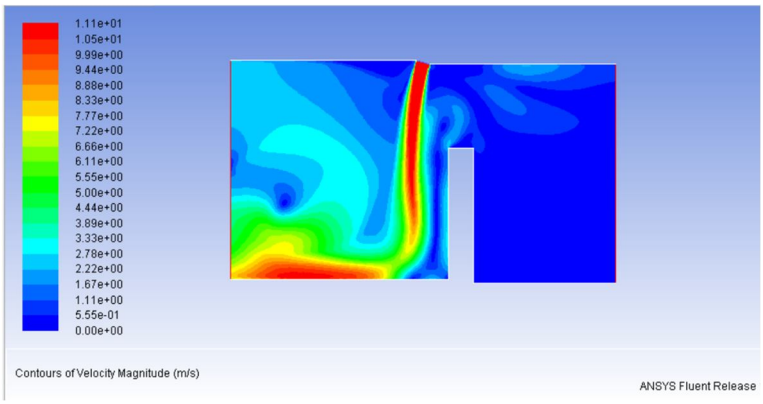

Fig.11 velocity contour of air when person standing after the air jet at 10 Pa pressure difference

The value of volume flow rate of air at inner outlet for different position of person at different pressure difference across the door were mention in the below table.

Table.1 Value of volume flow rate of air for different position of person

S.No	Pressure difference (Pa)	Without person (Flow rate of air (m^3/s))	In-front of air jet (Flow rate of air (m^3/s))	Below air jet (Flow rate of air (m^3/s))	After air jet (Flow rate of air (m^3/s))
1	4	0.037	0.031	0.044	0.024
2	6	0.087	0.08	0.092	0.071
3	8	0.154	0.149	0.165	0.131
4	10	0.271	0.251	0.289	0.245
5	12	0.326	0.304	0.345	0.291

The comparative graph of volume flow rate of air due to the disturbance of different position of person movement across the door at different pressure difference is shown in the below fig.

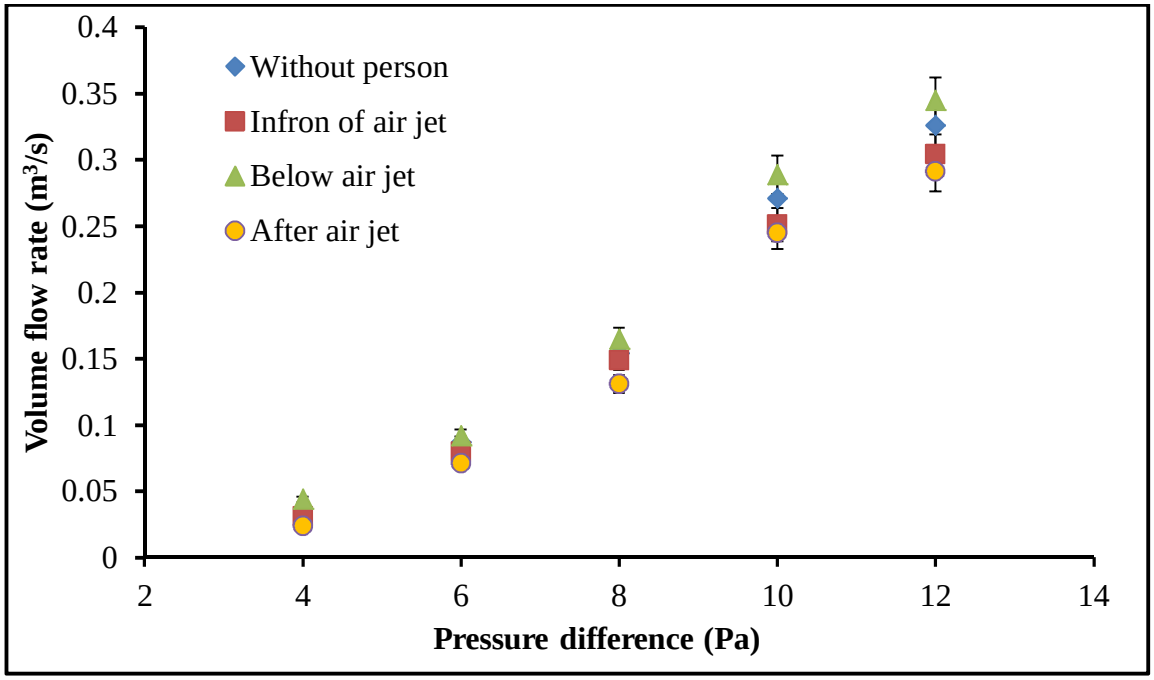

Fig.12 comparison of volume flow rate of air due to the disturbance of person movement across the door at different pressure difference

Through CFD analysis it is found that when the person is moving through the door there is some disturbance in air jet coming from the air curtain. During movement of person across the door there exist three different flow patterns of air jet that are inflow break-through, outflow break-through and optimum condition. When the person in exactly below the air jet, some part of the jet get diverted toward the outer outlet which shows the extrinsic flow behavior of air jet, at the same time some part of the jet get diverted towards the inner outlet and shows the intrinsic flow behavior. Due to this nature of flow behavior there is slight improvement in volume flow rate of air at the outlet when person is below the air jet, but still there is no any flow of outside air particle to flow inside the system as shown in the velocity contours when person is exactly blow the air jet. When a person is standing in front of air jet or after the air jet, it has little influence on the exfiltration/ infiltration of air, even it help or contributes to more restricting the infiltration of air across the door. Person standing before air jet, at the middle of jet and after the air jet help in blocking the intrinsic flow of outside air particle and helps in the reduction of outside air intrinsic flow.

V. CONCLUSION

The volume flow rate across the door is not largely influence by the change in outside temperature conditions, but is act as a thermal barrier to restrict the inside or outside heat to flow across the door. Air supply jet at certain temperature is able to maintain the inside temperature at given condition. Using air curtains reduces the consumption of energy which is required to maintain inside temperature in a comfort zone. This concludes that the air curtain were not even used to restrict the flow of air, but it is also used for the restriction of heat means act as a thermal barrier. Through analysis it can be concluded that person movement across the door is not majorly affected at the lower pressure difference across the door, whereas at higher pressure difference it is affected at greater extent. It shows that the sensitivity of air curtain performance during the movement of people is more at higher pressure difference whereas low at lower pressure difference.

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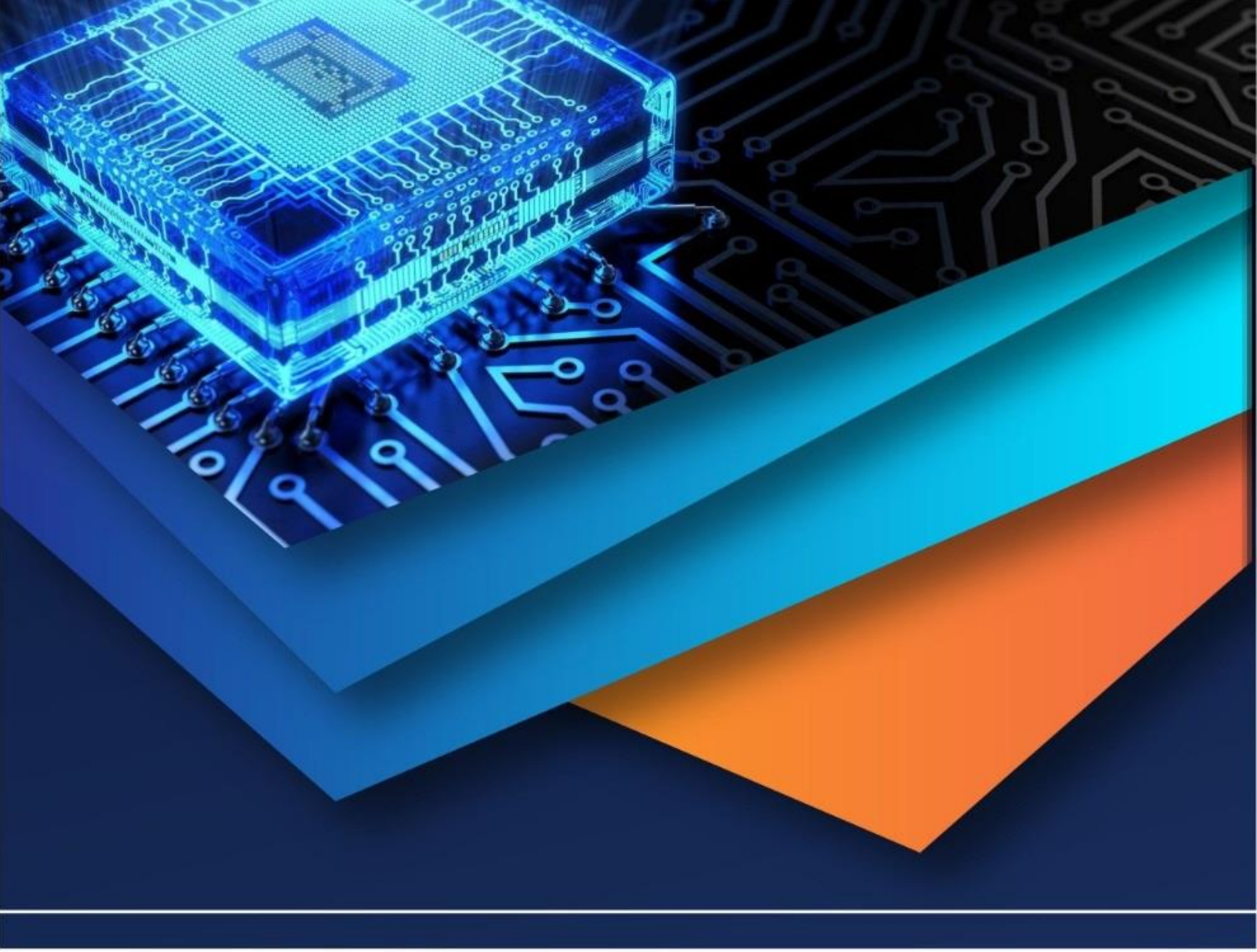

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