CFD Analysis of Auditorium Using Ansys Fluent

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Abstract- *The heating, ventilation and air conditioning (HVAC) is the prime aspect in any building design and management. Such systems play very important role in building construction and then the comfort of the occupants of buildings. Hence proper design of such HVAC system is necessary and is essential for efficient and green buildings the HVAC equipment perform the duty of heating and/ or cooling for residential and commercial buildings. Such HVAC system also provide fresh outdoor air to dilute the air contaminants such as odor from occupants of buildings, volatile organic compounds , chemicals etc. Air conditioning equipment is one of the major components in HVAC system. In the project work, an effort has been made to analyses the HVAC system used in seminar hall of Mechrise at Telangana which has sitting capacity of 100 people. It is very much essential to have comfortless for people participating in events like seminar, conferences, commercial presentations in seminar hall. Good cooling of seminar hall is essential especially in summer season and moderate warmness is necessary in winter season. In sitting arrangements, the 10 chairs are arranged in 10 rows. The Computational Fluid Dynamic analysis of HVAC system available in seminar hall is carried out by using ANSYS FLUENT software both summer and winter seasons. Parameter studies have been carried out by varying inlet velocity of air in the range 0.1 to 0.5 m/s. the results have been presented in the form of velocity, pressure and temperature contours. As it is observed that as inlet air velocity increases from 0.1 to 0.5 m/s. the outlet temperature decreases from 307 to 302 K.*

Keywords- CFD, HVAC, Seminar Hall, summer and winter seasons.

I. INTRODUCTION

1.0 Preamble

Nowadays heating, ventilation and air conditioning systems (HVAC) are gaining utmost most importance due to expectation of the man and machines to live in comfort zone of specific temperature which is lower than the surrounding temperature (summer season) and higher than surrounding temperatures (winter season).Discomfortness in working zone may affect the performance/ work output of a system or a machine or human beings who work for long period of time. Therefore the designing of proper HVAC system for individual environment to give the desired comfort zone for better working condition is essential. In such systems the analysis plays important role to know the better working condition based on environmental operating conditions. HVAC system is a common facility for maintaining indoor air quality. This necessitates the proper designing of buildings in which these systems are housed. A simple schematic diagram of HVAC system is shown in figure.

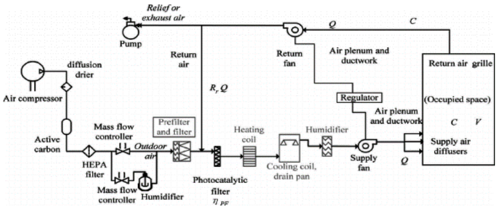


Fig.1. Schematic of the HVAC System

Air handling units in typical HVAC Systems generally contain following components:

a) Outside air intakes, plenums, ducts, and outdoor air
b) Heating and cooling coils
c) filters
d) Chiller and boiler (to supply hot and chilled water for the coils);
e) Cooling towers;
f) Humidifier or Dehumidifier;
g) Supply fans;
h) Supply ducts;
i) Distribution ducts, boxes, and plenums;
j) Damper;
k) return air plenums or ducts;
l) Return fan and
m) Exhaust outlets.

The primary function of typical HVAC systems is to control the temperature (thermal comfort) and relative humidity (RH) of the supply air. The components in a HVAC system that are capable of removing the air pollutants contain the filters and prefilter. The mechanical (or electrostatic) filters is used for the control of the particulates. Some HVAC systems may be equipped with sorbent filters such as active carbon filters to remove gaseous contaminates or vapor emitted from the building elements.

1 Types of HVAC Systems:

There are four types of HVAC Systems in use which are listed below.

i) Heating and Air Conditioning Split System

Split systems are the most classic type of the heating and air conditioning systems. These are the traditional types of HVAC system where one can have components of the whole system that are both inside and outside the building. HVAC split systems typically have:

- An air conditioner that cools the refrigerant.
- Furnaces and a fan or evaporator coil to change the refrigerant phase and circulate the air.
- Ducts that carry air all through the building.
- A control panel/thermostat to manage the temperature of the system.
- The occasional optional accessories for quality indoor air such as air cleaners, purifiers, humidifiers, UV lamps and so on.

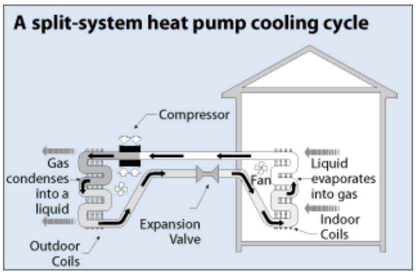


Fig. 2. Cooling split system

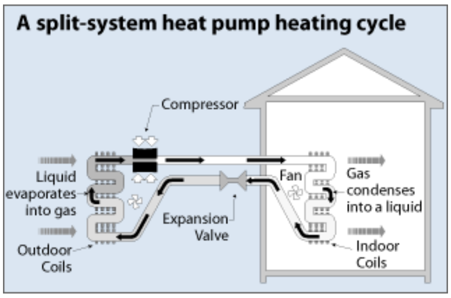


Fig.3. Heating Split System

ii. Hybrid Heat Split System

The hybrid heat split system is an advanced version of the classic HVAC split system that has an improved energy efficacy. When included in these types of HVAC systems, a heat pump will allow the option of having an electrically fueled HVAC up and above the typical gas furnaces.

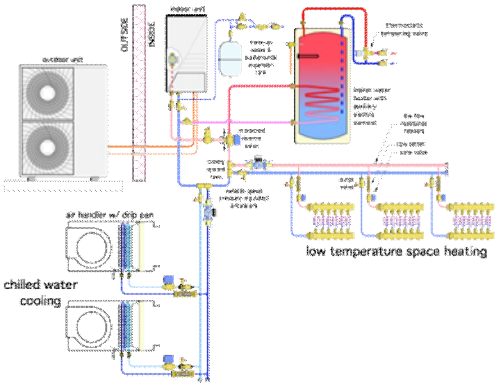


Fig. 4. Hybrid Heat split system

An ideal hybrid heat split system that is cost effective will have:

- A heat pump that heats or cools the refrigerant
- Furnaces plus the evaporator coil for conversion of the refrigerant and circulation of air
- the ducts to channel the air around your building
- Your interface for adjusting and controlling the system
- Optional accessories for more quality indoor air

iii. Duct- Free Split heating & Air Conditioning System

A duct-free HVAC provides good installations for places and areas where the convectional systems with ducts can’t go. These systems are also ideally great compliments to existing ducted types of HVAC systems. Duct-free systems will have the following;

- The heat pump or an air conditioner to heat\cool the refrigerant
- A fan coil that is compact
- Wires and tubing for the refrigerant, connecting the outdoor unit to the fan coil
- The thermostat or control panel
- Optional accessories to clean the air and make it more pleasant before its distribution through the house.

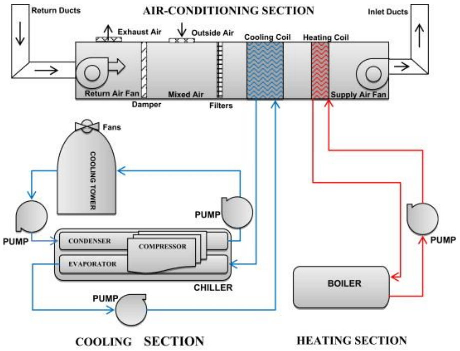


Fig. 5. Duct-Free Split Heating & Air Conditioning System

iv. Packaged Heating & Air Conditioning System

A packaged HVAC system is the solution to those homes and offices without adequate spaces for all the separate multiple components of the split systems. Packaged heating and air conditioning systems will sort out confined spaces that range from entire homes to the one-roomed units, all in one package. Packaged HVAC systems will contain:

- The air conditioner/heat pump together with the evaporator/fan coil in one unit
- Thermostat/control interface for a complete control of the system
- Optional air quality improvers. Things like the air purifiers, cleaners, ventilators or UV lamps, which gear towards making the air extra clean before it circulates your home or office.

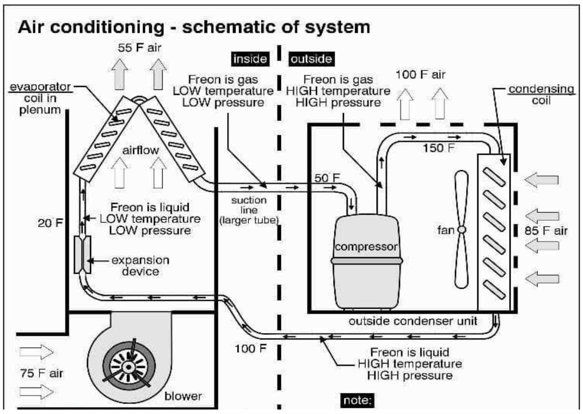


Fig. 6. Packaged Heating & Air Conditioning System

1.5 Objectives of the study

The main objective of the present study are listed below

1) To carry out the thermal and flow analysis of the heat ventilation and air conditioning (HVAC) system used in seminar hall of HYDERABAD PG Center , Kalaburagi.
2) to obtain velocity contours and pressure and temperature contour for various operating conditions.
3) to study the effect of inlet temperature and the performance of HVAC system considered
4) to investigate the performance of HVAC system considered for both summer and winter environments.

II. LITERATURE REVIEW

Sharma *et. al.* [1] designed a duct for an air system in an office building and analyzed the importance of duct design which creates an impact of system performance. Improper duct designs led to problems such as frictional loss, uneven cooling in the building, increased installation cast, increased noise level and power consumption. The above problems highlighted the need for an optimum duct design and effective layout of the duct. The authors used hand calculation and software tool both for designing the duct. They found that the circular duct has a less pressure drop than the rectangular duct.

Whalley *et. al.* [2] considered HVAC modeling methods for large scale, spatially dispersed systems. In this paper, they discussed existing techniques and proposals for the application of novel analysis.

Xu et. al. [3] did field study on the performance of five thermal distributed systems in four large commercial buildings. They studied about the air leakage from duct, and concluded that the air leakage in large commercial systems varied significantly from a system to system. The energy loss due to a leak can be minimized by using duct sealing and duct insulation.

BarisOzerdem et. al. [4] studied the energy loss related to the air leakage by using power law model. The measurements were made on different types of duct having different diameter. After measurements, they concluded that the most of the air leakage was from the joint and this air leakage was reduced by about 50% by using sealing gaskets.

Michal Krajcík et. al. [5] have studied experimentally air distribution, ventilation effectiveness and thermal environments, in a simulated room in a low-energy building heated and ventilated by warm air. The measurements were performed at different outdoor conditions, internal heat gain, air change rates. Their study showed that the warmair heating and floor heating system did not affect the significant risk of thermal discomfort.

Fisk et. al. [6] did field studies in large commercial buildings and they investigated the effective leakage areas ELAs, air-leakage rates, and conduction heat gains of duct systems. Air leakage rates were measured by using different method and their result were compared. They found that the air leakage rate varied from 0% to 30%. Also, heat gains between the cooling coils and the supply registers caused supply air temperatures to increase, on average, by 0.68°C to 28°C.

Liping Pang et al. [7] determined the ratio of fresh air to recirculation air. The conditioned temperature of different types of inlets were designed carefully to achieve the high air quality, thermal comfort and energy saving. Furthermore, some experiments were conducted and their performances were compared with the other systems. Their results indicated that, the improved pattern maintain high air quality, because it transported more fresh air directly to the breathing zone and circulated it around the upper body of passengers.

Srinivasan et al. [8] gained an experience for evaluation of air leakages in components of air conditioning systems by designing and testing of orifice plate-based flow measuring systems. The coefficients of discharge were evaluated and compared with the Stolz equation which value were higher, the deviations being larger in the low Reynolds number. It was observed that a second-degree polynomial was inadequate to relate the pressure drop and flow rate.

Huan-RueiShiu et al. [9] designed an exhaust duct system using the dynamic programming method in semiconductor factory which considered system pressure equilibrium the least life-cycle cost to originate the duct size and fan capacity. Their results showed that the outcomes value satisfied the requirements on the range of duct diameter. Also, the differences between the design and simulation (actual operation) resulted under DPM were found to be much lower than those of other methods.

Wanyu R. Chan et al. [10] analyzed the air leakage measurements of 134,000 single-family detached homes in the US, using normalized leakage. They performed regression analyses to examine the relationship between NL and various house characteristics. Their results indicated that the regression model predicted 90% of US houses had NL between 0.22 and 1.95, with a median of 0.67.

Dongliang Zhang et al. [11] studied the energy saving possibility of digital variable multiple air conditioning system and compared to the other the air systems with constant air volume and primary air fan coil system. Their results revealed that the energy saving of DVM air conditioning system was significant under only part load condition and this system was significant when building area was less than 20,000 m^2.

A. Gallegos-Muñoz et al. [12] studied the effect in the measurements of flow in air conditioning system caused by fitting. They developed numerical simulation using CFD where the Reynolds Averaged Naviere Stokes equations were solved through an approach of finite volume method using several turbulence models. Their results indicated that the mass flow rate was decreased when no of joints were increased. Also, the work gave information about the behavior of flow measurements made downstream.

IsakKotcioglu et al. [13] found out an optimum value of design parameters in a rectangular duct by using Taguchi method. Their analysis was performed with an optimization process to reach the minimum pressure drop and maximum heat transfer. After some experiments they gave a suitable designed parameter which satisfied the condition i.e. less friction drop, maximum heat transfer. ***Omer Kaynakli et al***. [14] gave a review study to find economic thermal insulation thickness for pipe and ducts with different geometries in various industries. The purpose of their study was to determine the critical thickness insulation for different geometries. The basic result, economic analysis method, heat transfer method, optimization procedure were used for comparison. After that the effective parameters of the optimal thickness were examined.

Tabish Alam et al. [15] studied the effect of turbulators for friction characteristic and heat transfer in air ducts. Turbulators were used to improve the performance of air heater and heat exchanger. The relationship was presented in terms of non-dimensional parameter for friction factor and heat transfer in air duct. Also they examined heat transfer increase and flow structure in air ducts.

III. METHODOLOGY

3.1 Problem Description

An seminar hall of HYDERABAD center for pg studies is fitted with a Hvac system of blue star company.

Its approximate dimensions are 12 X 9 X 3.6 m. Where 12m is the total length of the Volume that is designed to analyze 9m is the width of the auditorium that is Expanded and 3.6 is the height of the room that is required to design a Volume that is feasible to analyze initially The conditions of Summer are simulated in the fluent i.e., with 45C Temperature as environmental temperature an AC of the 3 ton is Fitted at the either side of the wall i.e., 6 no's Heat generated by 100 people in the auditorium should be cooled in order to reduce the internal temperature of the auditorium while considering the Environment as summer similarly the same procedure is followed for winter also. To determine the Pressure Velocity and temperature contours.

In general the process of setting up a problem in the FLUENT is Common for most of the case

1) Pre processing

In preprocessing the description of the problem is understand with suitable criteria or values then the model is designed in either 2D or 3D on Authors interest After completion of the model the Design is the imported into the ANSYS module to modify in a way to setup the design for meshing all the process including meshing and named selections are also done in the Pre processing following are the steps to complete the Preprocessing

Step-1

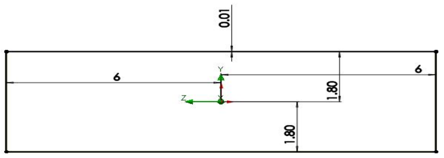


Fig.7. Initial Length and height of the Volume designed in solid works.

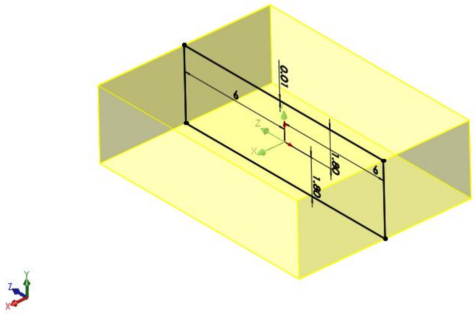


Fig.8. Width is added to complete the Volume

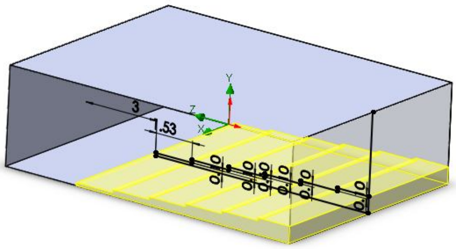


Fig.9. Necessary Changes to be done for the volume

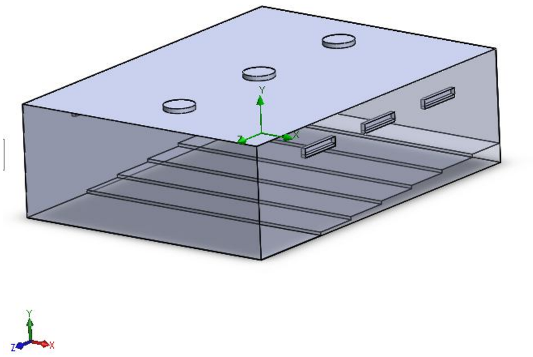


Fig 10. Completed model with necessary inlet and outlet ducts

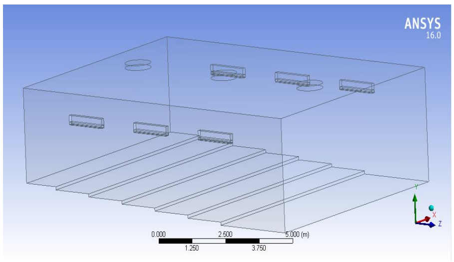


Fig.11. Imported model For Setup and solution on Fluent

The Volume Extraction is the Key in all the Problems including HVAC the Empty space that is created in the Computer aided designing is Converted in to Volume to generate required Dimensioned volume for the simulation.

3.1.1 Meshing

Meshing is the important aspect in defining the solution a finely discretized mesh will give the better results than Coarsely discretized mesh in general meshing means dividing the large volume to finite set of control volumes which predicts the flow of the in side or outside of the volume the below mesh occurred by performing several mesh methods like tetrahedron and edge sizing to define lowest skewness possible.

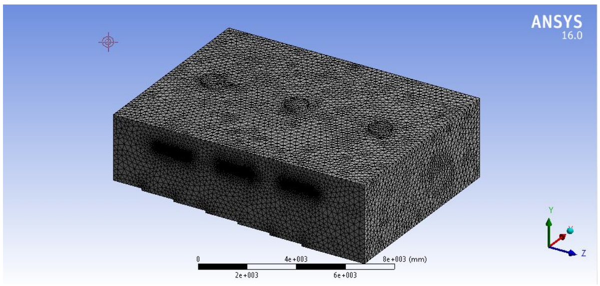


Fig.12.Discretized Domain

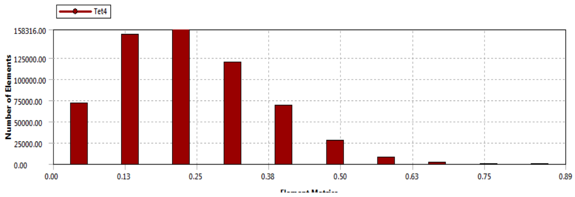
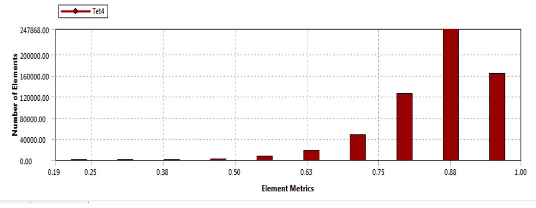


Fig.13. Skewness Factor

The above represented figure is the Skewness of the mesh where u can observe that the most of the Mesh elements are present in the acceptable factor area so we can determine this as a good quality mesh



Orthogonal quality

The above represented figure is the Skewness of the mesh where u can observe that the most of the Mesh elements are present in the acceptable factor area so we can determine this as a good quality mesh.

Table 1 Mesh Statistics

Statistics	
Nodes	117324
Elements	609399
Mesh Metric	Orthogonal Quality
Min	0.18685
Max	0.99732
Average	0.85557
Standard Deviation	8.7124e-002

3.1.2 Boundary Conditions

Assuming the Required Boundary conditions is key for Accurate problem solving by assuming the Realistic conditions We are trying to simulate possible Accurate simulation there Giving the Boundary conditions will play a very important role in solution.

Below Mentioned Figure is the representation of the Boundaries that are mentioned in the problem and later we will give the Values for that

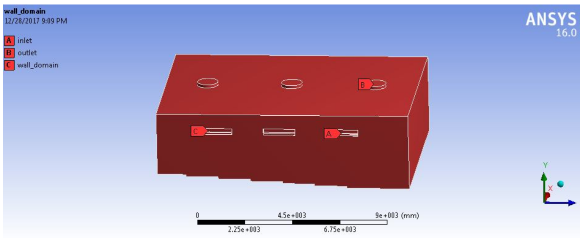
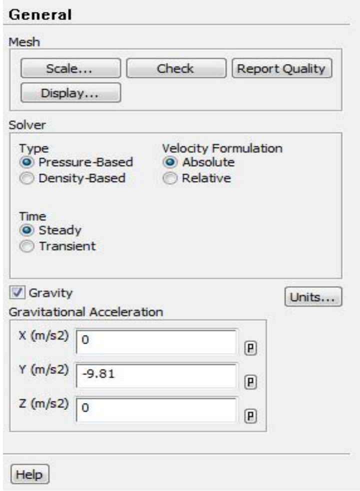


Fig.14. Boundary Representation using named selections.

2) Solution Setup

In order to define the setup it is important to define the physics of the problem in setup the main steps we consider for setting up a problem is in which friction the flow is happening and in which direction The gravity is acting , is the Flow laminar or turbulent Weather the Fluid is Newtonian or non Newtonian to determine these conditions we need to Select some options in the Fluent Setup below is the Step by step process of the Setup



Solver

Type
● Pressure-Based
○ Density-Based

Velocity Formulation
● Absolute
○ Relative

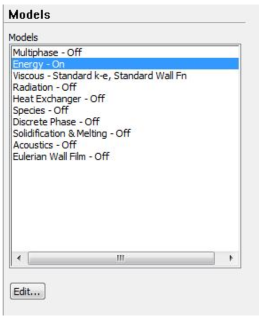
Time
● Steady
○ Transient

☑ Gravity

Gravitational Acceleration
X (m/s2) 0
Y (m/s2) -9.81
Z (m/s2) 0

Fig.15. General in setup

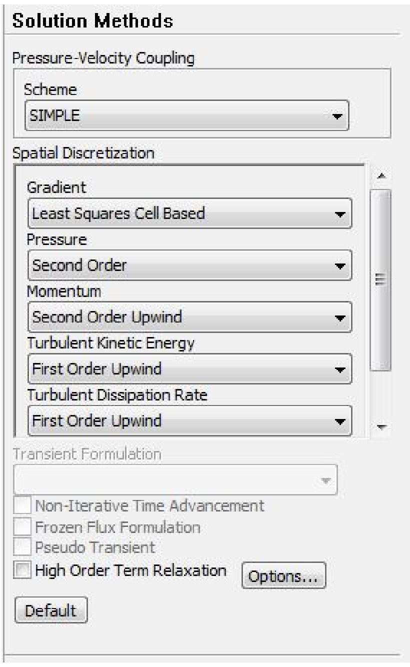
Here we select pressure Based solver because we are assuming fluid as a normal Fluid and the Gravity acting on it is in Negative y direction and this problem is a time independent solver.



Multiphase - Off
Energy - On
Viscous - Standard k-e, Standard Wall Fn
Radiation - Off
Heat Exchanger - Off
Species - Off
Discrete Phase - Off
Solidification & Melting - Off
Acoustics - Off
Eulerian Wall Film - Off

Fig.16. Models

Models is the tab where we need to define the important aspects of the problem like temperature equation and type of flow here we are turning on the temperature effects and considering the Flow as a turbulent flow I.e., K-epsilon



Solution Methods

Pressure-Velocity Coupling

Scheme: SIMPLE

Spatial Discretization

Gradient: Least Squares Cell Based

Pressure: Second Order

Momentum: Second Order Upwind

Turbulent Kinetic Energy: First Order Upwind

Turbulent Dissipation Rate: First Order Upwind

Transient Formulation

☐ Non-Iterative Time Advancement

☐ Frozen Flux Formulation

☐ Pseudo Transient

☐ High Order Term Relaxation

Fig.17. Solution methods

The above figure represents the Solution methods which are using to solve this problem the scheme used to solve this problem is simple.

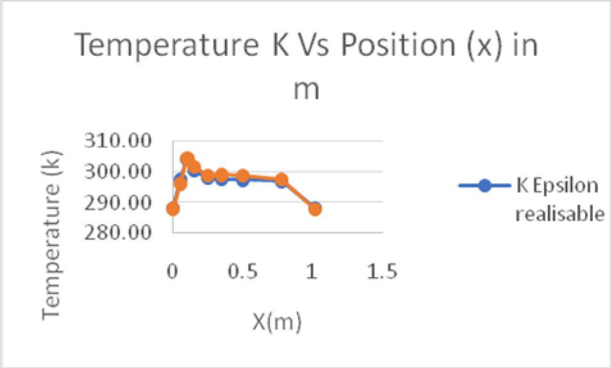
IV. RESULTS AND DISCUSSIONS

4.1 Introduction

As we discussed in the methodology and abstract the total analysis is done for an auditorium model in summer and winter conditions for different velocity inlet conditions and different outside temperature as per the regional temperature considered in summer and winter. Below are the result contours of Different Cases.

Validation

X(m)	K Epsilon realisable	Blay 1992
0	288.16	288.16
0.05	297.44	296.32
0.1	303.94	304.56
0.15	300.41	301.66
0.25	297.89	298.91
0.35	297.43	299.17
0.5	297.29	299.01
0.78	296.92	297.6
1.02	288.16	288



The above Graph represents the temperature Vs Distance X in m for a Square Cavity with Length 1.04m of a mixed convection model proposed by Blay et al in 1992 To get more confidence in our results this validation is proposed

4.2 Analysis of the HVAC model in summer Conditions

In this Analysis the model is designed for an auditorium and the regional summer temperature is taken as 320K outside temperate with varying inlet velocities

Case 1 Velocity at 0.1m/s

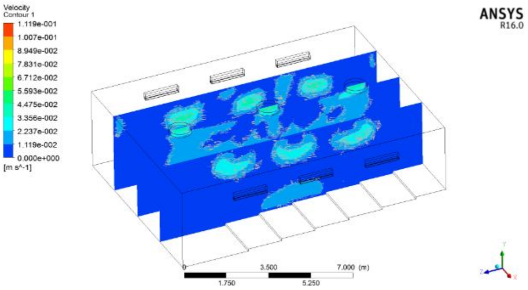


Fig.18. Velocity Contour of the model at 0.1 m/s

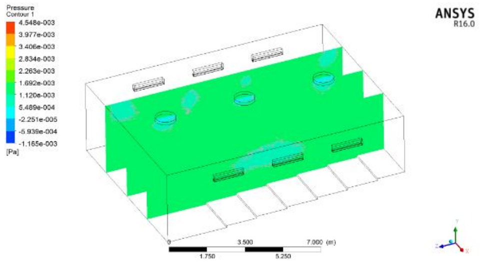


Fig.19. Pressure Contour of the model at 0.1 m/s

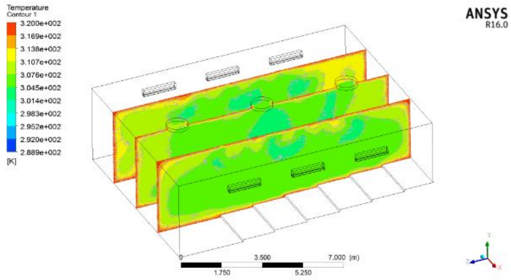


Fig.20. Temperature Contour of the model at 0.1 m/s

Case 2 Velocity at 0.2 m/s

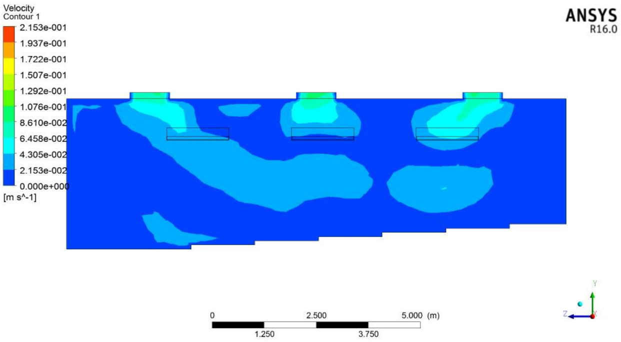


Fig.21. Velocity Contour of the model at 0.2 m/s

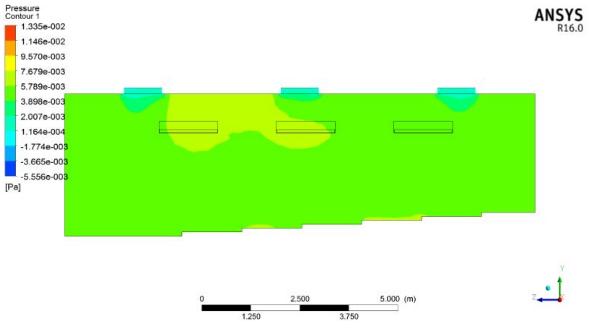


Fig.22. Pressure Contour of the model at 0.2 m/s

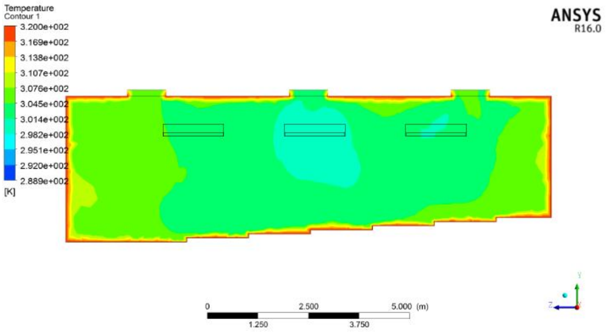


Fig.23. Temperature Contour of the model at 0.2 m/s

Case 3 Velocity at 0.3 m/s

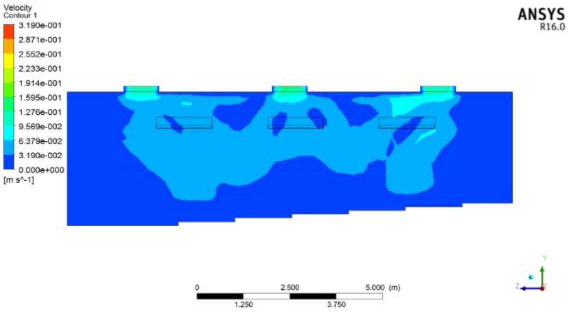


Fig.24. Velocity Contour of the model at 0.3 m/s

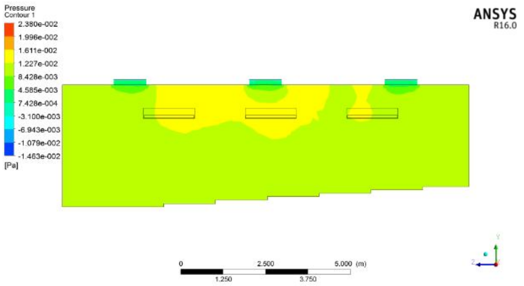


Fig.25, Pressure Contour of the model at 0.3 m/s

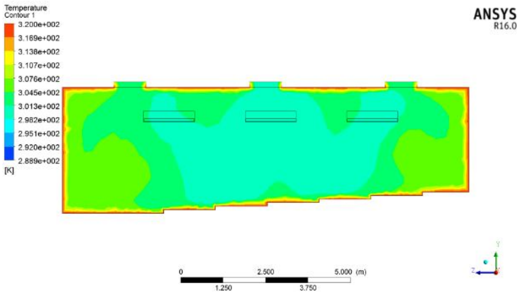


Fig.26. Temperature Contour of the model at 0.3 m/s

Case 4 Velocity at 0.4 m/s

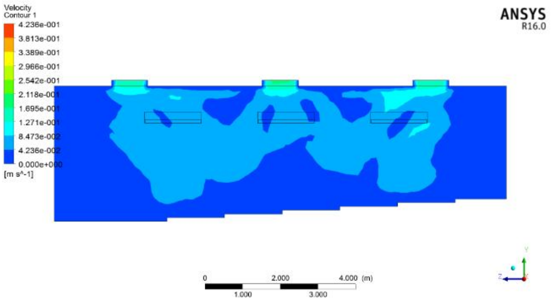


Fig.27. Velocity Contour of the model at 0.4 m/s.

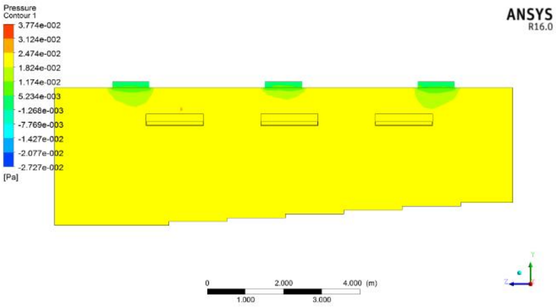


Fig.28. Pressure Contour of the model at 0.4 m/s

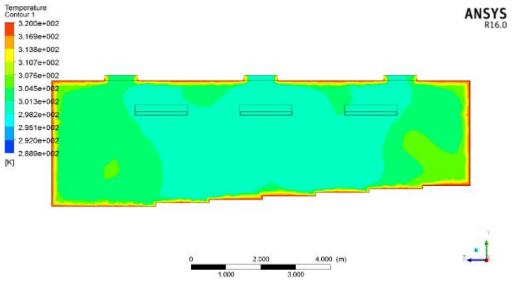


Fig.29. Temperature Contour of the model at 0.4 m/s.

Case 5 Velocity at 0.5m/s

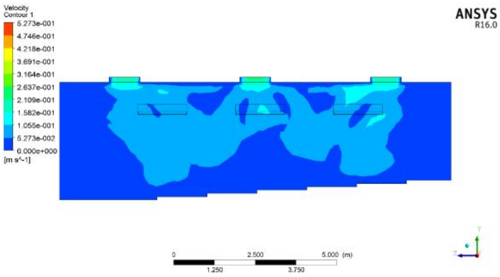


Fig.30. Velocity Contour of the model at 0.5 m/s

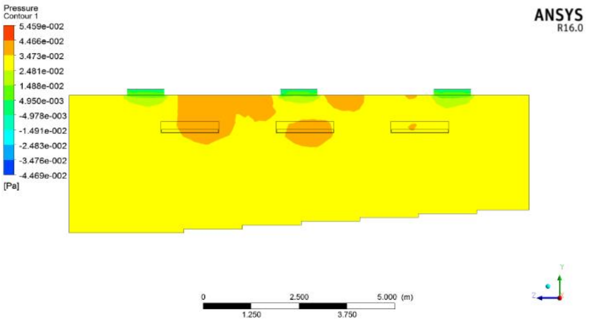


Fig.31. Pressure Contour of the model at 0.5 m/s

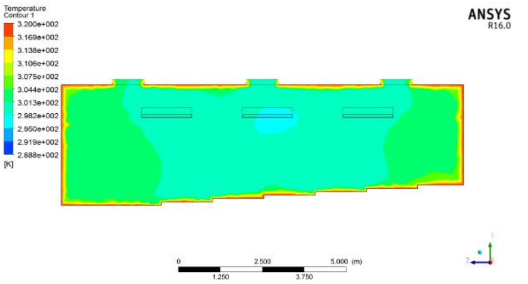
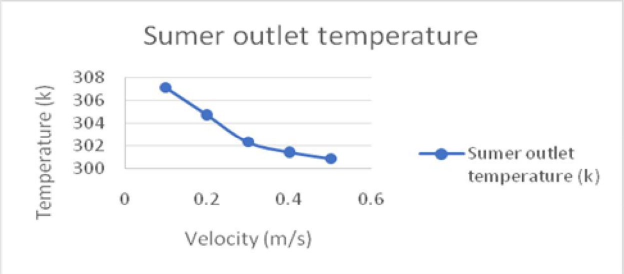


Fig.32. Temperature Contour of the model at 0.5 m/s

Velocity (m/s)	Sumer outlet temperature (k)
0.1	307.101
0.2	304.731
0.3	302.303
0.4	301.425
0.5	300.861

Table 2 Velocity V/s Summer Outlet Temperature



Graph 1 :Velocity V/s temperature at summer conditions

4.3 Analysis of the HVAC model in Winter Conditions

In this Analysis the model is designed for an auditorium and the regional summer temperature is taken as 298K outside temperate with varying inlet velocities

Case 1:Velocity 0.1 m/s

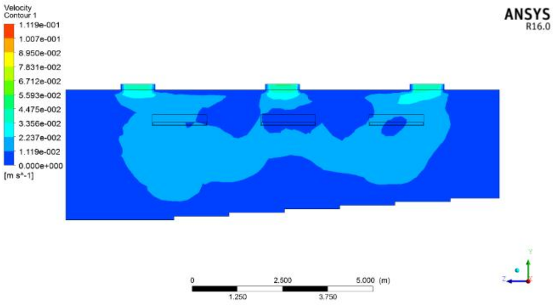


Fig.34. Velocity Contour of the model at 0.1 m/s

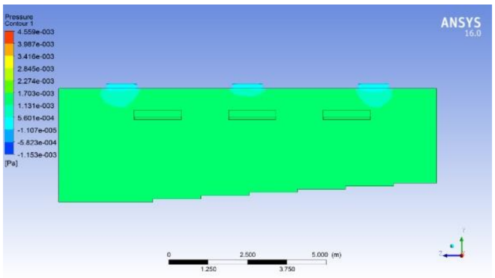


Fig.35. Pressure Contour of the model at 0.1 m/s

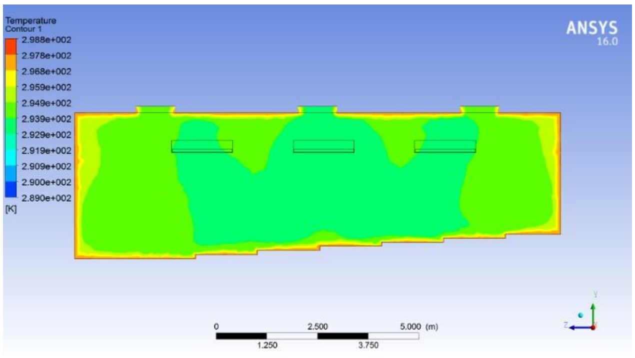


Fig.36. Temperature Contour of the model at 0.1 m/s

Case 2: velocity at 0.2 m/s

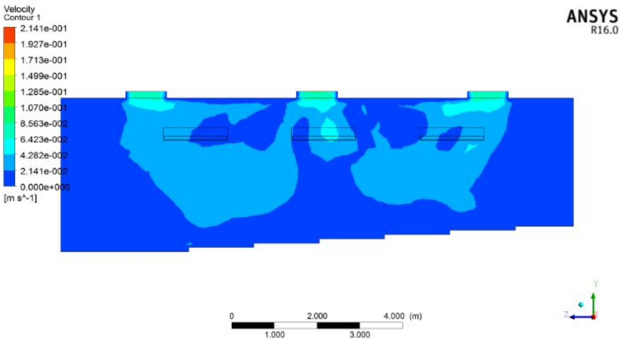


Fig.37. Velocity Contour of the model at 0.2 m/s

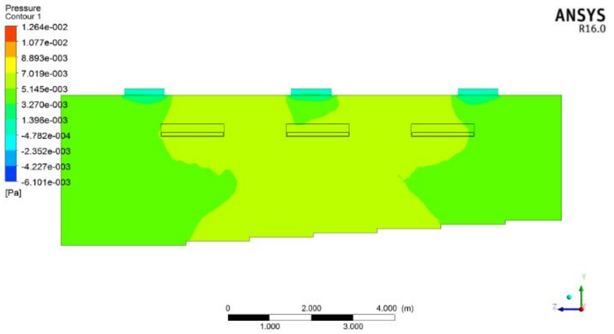


Fig.38. Pressure Contour of the model at 0.2 m/s

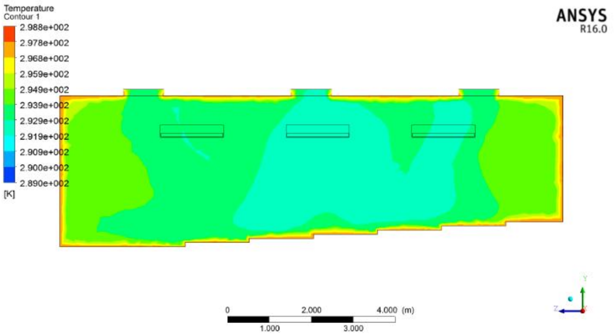


Fig.39. Temperature Contour of the model at 0.2 m/s

Case 3: Velocity at 0.3m/s

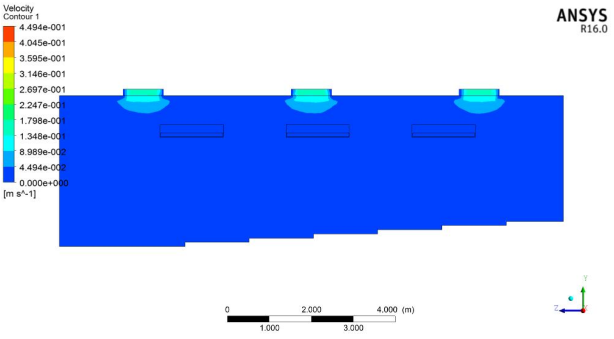


Fig.40. Velocity contour of the model at 0.4m/s

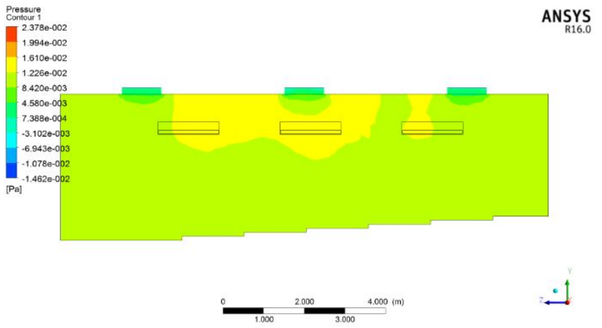


Fig.41. Pressure contour of the model at 0.4m/s

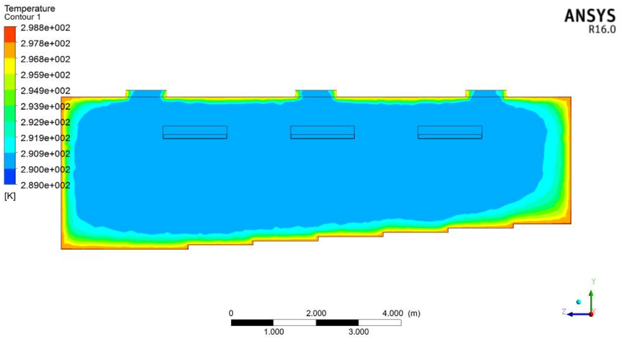


Fig.42. Temperature contour of the model at 0.4m/s

Case 5: Velocity at 0.5m/s

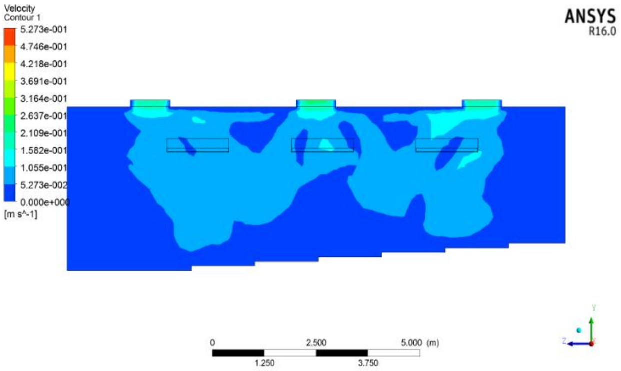


Fig.43. Velocity contour of the model at 0.5m/s

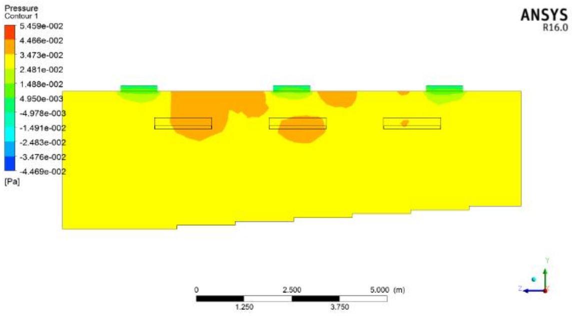


Fig.44. Pressure contour of the model at 0.5m/s.

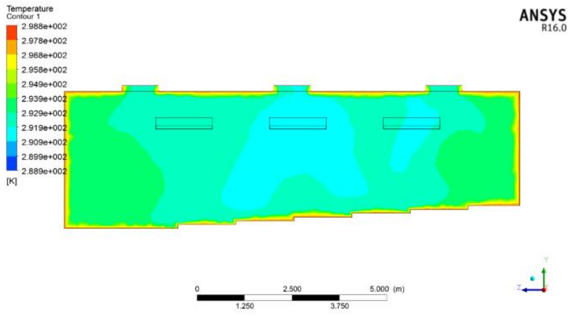
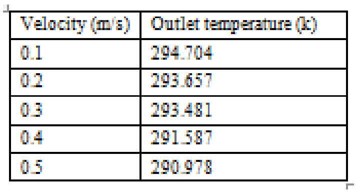


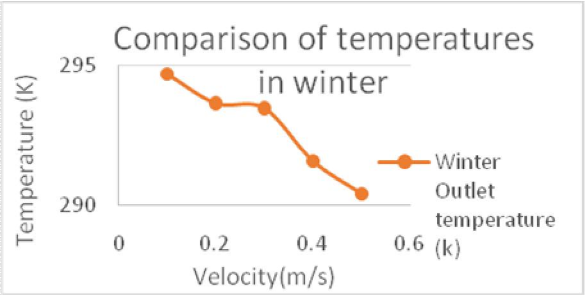
Fig.45. Temperature contour of the model at 0.5m/s.

Graph of the Temperature Outlet Values



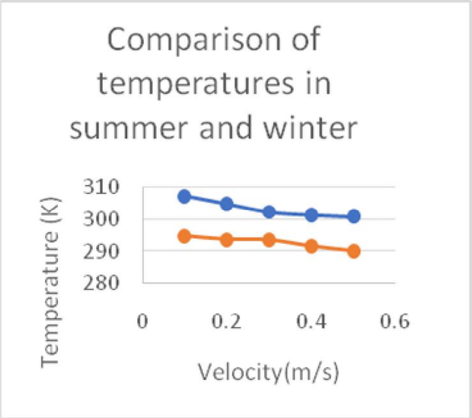
Velocity (m/s)	Outlet temperature (k)
0.1	294.704
0.2	293.657
0.3	293.481
0.4	291.587
0.5	290.978

Table3 Velocity V/s winter Outlet Temperature



Graph 2 Velocity V/s temperature at winter conditions

COMPARISON OF TEMPERATURES IN SUMMER AND WINTER



Graph 3 Velocity V/s temperature at summer and winter conditions

V. CONCLUSION AND FUTURE WORK

5.0 Conclusion

- In the Current project a thorough investigation of heat transfer in HVAC at summer and winter time is carried out.
- From the Results obtain and plotted Graphs is clear that when the Velocity at the Inlet system increases the Heat transferred to the Fluid decreases it is clear in both summer and winter Times.
- Whereas an increase in Final Temperature of the winter is observed is is known that there will be the

minimum heat transfer of the collected mass of the fluid transferred in to the system.

- The contours obtained in both summer and winter is showing the area at the corners are showing minimum heat dissipation when compare to the area in between The colored representation is observed clearly to state the conclusion that the temperature at the center of the auditorium is minimum when compare with the total heat dissipation at orners.

5.1 Scope for future work

1) The current project is done for environmental conditions of summer and winter in a seminar hall of Hyderabad center for postgraduate studies, Kalaburagi. This work can be extended for different input air temperatures.
2) The project can be extended by varying the different input velocity.
3) The work can be extended to multiple HVAC system installed in the seminar hall.

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