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CFD analysis of Indoor thermal and flow characteristics for air distribution with varied return air location

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Abstract:

Air conditioning of spaces requires the air to be supplied in the conditioned space of desired thermal quality and at flow rate of specific requirement. It is essential in providing human comfort in commercial and residential spaces to have the desired characteristics of the supplied air. The main characteristics of the air among others are the supply air temperature and its flow velocity. The objective of air conditioning of spaces is that, the conditioned air provided comfort to the occupants of the spaces and goods are protected from being deteriorate. The conditioned air is required to be maintained at certain desired physical condition with defined temperature, humidity and velocity of flow. The objective of this paper is to present the numerical simulation of the temperature and velocity variation in an air conditioned space. Three cases have been taken into consideration for three different locations of the return air vent. The conditioned air is supplied through one of the wall of the room through an opening. The air is returned through the return air vent placed on the opposite side of the wall. Temperature and velocity distribution for three cases of return air vent locations have been presented. The numerical results show that the supply air vent at a position near the ceiling provides the more uniform temperature and velocity distribution and thus the comfort.

Keywords: Air conditioning; Air Distribution; Numerical simulation

1. Introduction

The air condition is divided into the summer air conditioning and the winter air conditioning on the basis of requirement. In the summer air conditioning, apart from cooling the space, in most of the cases, extra moisture from the space is removed, whereas in the winter air conditioning, space is heated and since in the cold places, normally the humidity remains low, moisture is added to the space to be conditioned. The summer air conditioning thus uses a refrigeration system and a dehumidifier. The winter air conditioning uses a heat pump (refrigeration system operated in the reverse direction) and a humidifier. Depending upon the comfort of the human beings and the control of environment for the industrial products and processes, air conditioning can also be classified as comfort air conditioning and industrial air conditioning. Comfort air conditioning deals with the air conditioning of residential buildings, offices spaces, cars, buses, trains, airplanes, etc. Industrial air conditioning includes air conditioning of the printing plants, textile plants, photographic products, computer rooms, etc. Thermal comfort is defined as the condition of mind which expresses satisfaction with thermal environment [1]. The thermal comfort includes two personal factors and four environmental factors. The personal factors include activity level and thermal insulation of clothing while the environmental factors are the temperature, velocity and humidity. All these factors are required to be controlled in order to provide comfortable environment in indoor spaces for both the living and non living beings.

2. Air Distribution

Air distribution is the process of transferring conditioned air into the conditioned spaces. The required amount of the conditioned air is supplied into the conditioned space through supply air diffusers or supply air vents in order to distribute it properly so that required thermal environment could be established in the conditioned space. The design of the air distribution system is needed to fulfill the following requirements:

- Create a proper combination of physical parameters of the air creating thermal environment such as temperature, velocity and humidity
- To avoid localized feeling of cooling or warmth.

A proper combination of temperature, humidity and velocity or air motion is needed for the comfortable thermal indoor environment in the occupied zone. The occupied zone is defined as the space in the conditioned zone that is from the floor to a height of 1.8 m and about 30 cms from the walls. In the occupied zone, the maximum variation in temperature should be less than 1o C and the air velocity should be in the range of 0.15 m/s to 0.36 m/s.

The need of research in the design of air distribution system to provide comfortable indoor environment is motivation for the authors of this dissertation. Thermal comfort has close relation to the indoor air movement [2] and temperatures in the conditioned zone. However, air movement within a room depends upon several factors [3]. Indoor air movement is often induced by the forced convective airflow [4] from the supplied air. Also, due to the natural convention or the temperature difference between the supply air and the walls of the conditioned space also cause air movement. Air movement caused by a differential pressure across the indoor structure may be considerable. The existence of doorways and apertures inside a room could have great impact on the indoor air movement. The opening and closing of doors coupled with people's movement may have important influence on the indoor air distribution. Owing to the urgent demand of comfortable living indoors, a number of numerical studies related to the prediction of indoor air distribution [4],[5],[6],[7] within a ventilated room have been conducted in the past in undergoing with objective of finding ways to improve thermal environment and scope for energy savings in air conditioning.

3. Numerical Simulation

With the rapid increase in computational power in the last 20 years CFD has gained significant popularity and modeling is often considered more illuminating and cost effective than lab or field experiments[8],[9].

The present work is divided into two parts, in one part the model of the computational field will be developed using FLUENT software. Meshing of the model and boundaries will be set with required boundary conditions. For the analysis and solution of the problem in second part commercial CFD codes of FLUENT will be used. The results will be obtained in the forms of temperature and velocity contours. The temperature and the velocity distribution in the conditioned space will be plotted in the form of two dimensional plots for the various test locations in the computational domain.

4. The Geometrical Model

The geometric model of the conditioned space taken into consideration is assumed of 4 m length and 3 meters high. The air is supplied into the room at a height of 2.5 meters from the floor and returned through the opposite side at three different location as

Location 1: 0.5 m below the ceiling
Location 2: 1.5 m below the ceiling
Location 3: 2.5 m below the ceiling

The 2 D geometrical model and test locations are shown in figure 1.

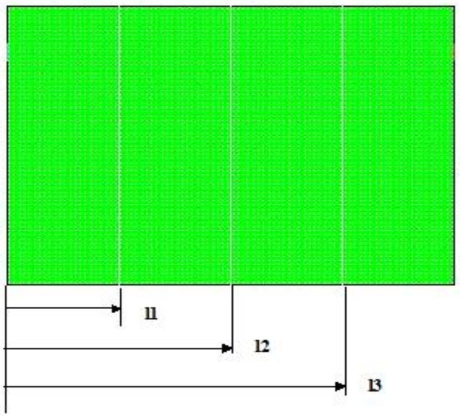


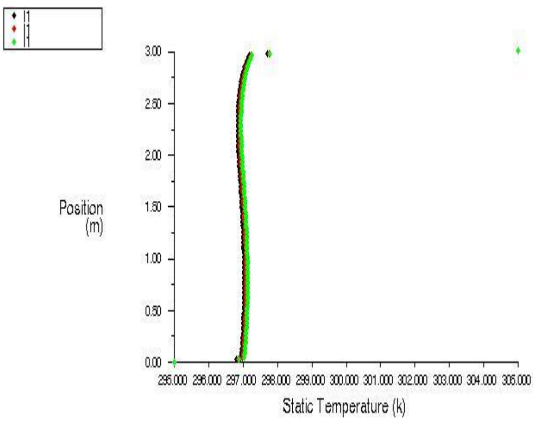
Figure 1

The Standard k-ε model is used in this numerical simulation with SIMPLE approach of pressure velocity compounding. The convergence of solution of the continuity, energy and momentum equation is obtained within the set standard criterion.

5. Comparative Temperature plots for three cases

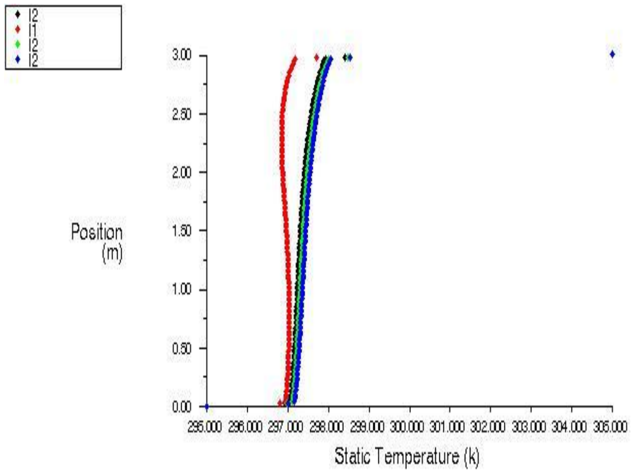
To show the comparative temperature variation for the three cases at the various test locations temperature plots have been obtained and shown in the figure 2 (a) - (c).

(i) At test location l1



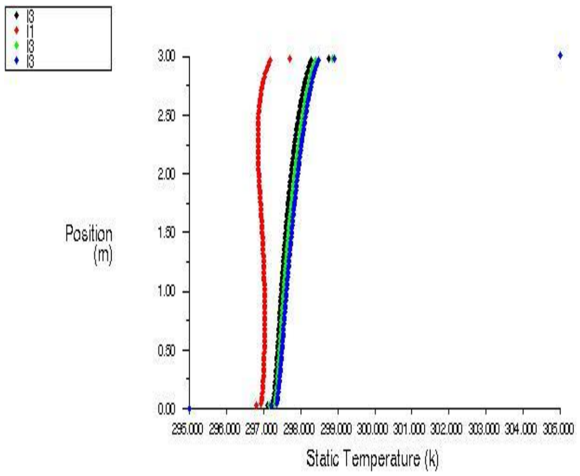
(a)

(ii) At test location l2



(b)

(iii) At test location l3



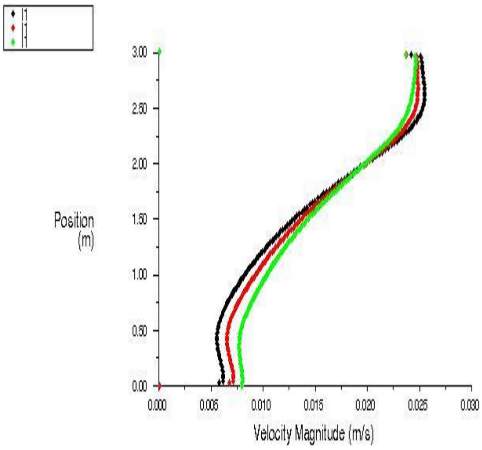
(c)

Figure 2 (a) - (c)

6. Comparative Velocity plots for three cases

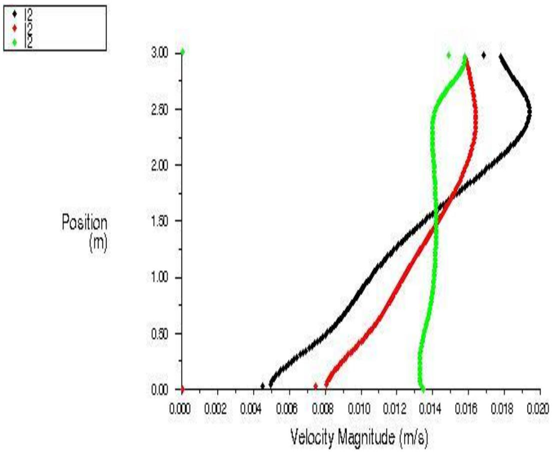
To show the comparative velocity variation for the three cases at the various test locations velocity plots have been obtained and shown in the figure 3 (a) - (c).

(i) At test location l1



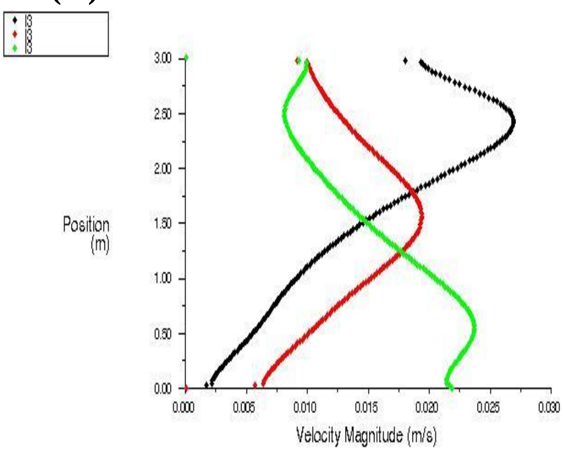
(a)

(ii) At test location l2



(b)

(iii) At test location l3



(c)

Figure 3 (a) - (c)

7. Conclusion

The air conditioning is aimed to provide thermal comfort to the occupants. The indoor thermal environment is affected by the position of the supply and return air locations. In this paper numerical results of temperature and velocity patterns are compared for the three different locations of the return air vent. The supply air diffuser position is kept fixed. The results of simulation are compared for the three cases. The results show that as the supply air vent location is moved upwards while the location of the return air vent is kept fixed, the temperature and velocity distribution is obtained with better uniformity. Thus it is concluded that the supply air vent at a position near the ceiling provides the more uniform temperature and velocity distribution and thus the comfort.

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