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CFD Analysis of Air Conditioning Equipment of CAD Lab for Enhancing its Performance

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***Abstract*— Thermal displacement ventilation (TDV) is a promising technology for all types of buildings. The potential energy efficiency, health, and acoustic benefits offer promise government of various countries are prepared to spend billions on new educational institutes and major modernization. This paper presents some results from Computational fluid dynamics (CFD) analysis which is needed in order to model and study the complex flows associated with TDV.CFD is an established, state-of-the-art scientific approach for quantitative prediction and analysis of fluid flow, heat and mass transfer in a multiplicity of conditions.**

In 1995, the Government Accounting Office concluded that 25% of the nation's schools are inundated by indoor air quality (IAQ) problems. A few years later the Environmental Protection Agency reported that an even higher percentage of buildings have IAQ problems. Most of these IAQ problems can be recognized to poor ventilation. TDV, which has been used since the late 1980s in Northern Europe and only more recently in U.S., disproves the common perception that improving IAQ in an air-conditioned space should effect the higher energy consumption.

***Keywords*— TDV, CFD simulation, ventilation, heating, temperature, thermal comfort.**

I. INTRODUCTION

Thermal displacement ventilation (TDV) is a promising technology for every building.

Most classroom air conditioning systems deliver air at the ceiling at a temperature of about 55º F. Air is supplied at high velocity to provide efficient mixing of supply air with room air to provide uniform temperature throughout the space and to dilute contaminants with fresh supply air. By contrast, thermal displacement air conditioning systems deliver air near the floor instead of at the ceiling. The air is heated or cooled so that it enters the room at about 65º F, comparatively warmer than with a conventional air conditioning system. Control is provided by varying the volume of air that is delivered to the space. The diffusers are larger so that air speed is lower. Since the 65ºF air is cooler than the rest of the air in the room, it spreads by gravity all along the floor, thereby forming a continuous layer of cool air. The cool air rises as it is heated by the occupants and other heat generating sources. The effect of air rising up over a warm object is called a thermal plume.

Since the air moves straight up and all supply air is delivered at the floor level, each person basically has his or her own private supply of outside air ventilation.

Traditional design methods are not effective for classrooms with TDV, because they are based on the assumption that the space has a uniform temperature from floor to ceiling and that the air is well mixed. TDV works because there is a substantial temperature difference between the floor and the ceiling which drives air movement through buoyancy.

When the room requires heating, warm supply air (75 to 80°F) is provided from the diffusers, at a sufficient velocity to provide a fairly uniform temperature throughout the occupied zone.

Computational fluid dynamics (CFD) analysis is needed in order to model and study the complex flows associated with TDV. CFD is an established, state-of-the-art scientific approach for quantitative prediction and analysis of fluid flow, heat and mass transfer in a multiplicity of conditions. For this study, a commercially-available CFD software tool was used (Airpak 2.1.10 2002) whose solver engine is Fluent. The Airpak/Fluent package employs a finite-volume formulation of the governing differential equations used in CFD. The package can model basic fluid flow, heat transfer, turbulence, radiation heat transfer, and contaminant transport.

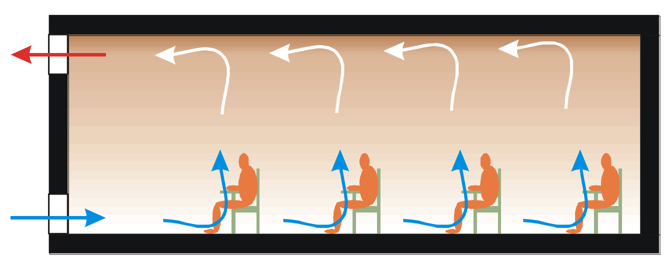

Fig 1. TDV Concept

II. WHAT IS CFD?

Computational Fluid Dynamics (CFD) is a computer-based analysis technique used to predict various physical and chemical phenomena like fluid flow, heat transfer, mass transfer, chemical reactions, phase change, combustion, and flow acoustics etc.

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It solves the mathematical equations governing these phenomenons. CFD is becoming a powerful tool, in combination with usual design techniques, to analyze the problems.

Advantages of CFD simulation

- Visualizing designs
- Complete Information
- Making prediction using results.
- Improved design ability
- Low Cost
- Ability to Simulate Real Conditions

Steps of CFD

- Preprocessing
- Solving
- Specifying the fluid and flow properties
- Choosing the discrete scheme
- Post processing

Fluids Dynamics are derived from the basic physical laws of conservation of mass, momentum, and energy. Logical solutions of such problems are possible only for very simple flow domains with certain assumptions made. For usual designs designers have to trust the empirical formulae, rules of thumb, and experimentation. Though, there are many intrinsic problems associated with these usual designs. Empirical formulae and rules of thumb are extremely precise to the problem and are not globally used because of the non-linearity of the governing equations thus making experimentation the leading design technique.

Limitations of experimentation technique:

- Measurement of flow variables may cause these variables to change by themselves, which is not possible at all (in very small or unreachable spaces), and can be expensive.
- Experimental data has less detail.
- Experimentation may take a long time to set up, which sometimes lasts for a very short time, and may cost more, as in the case of supersonic wind-tunnel runs.

All these limitations are overcome by CFD, as it is a numerical simulation technique which does not require a model to be built, is not dissatisfied by measurement capabilities, and can provide extremely detailed data as and when required.

Using CFD, you can create a computational model that represents a system or device that you want to study.CFD analysis not only complements testing and experimentation, but leads to a saving of time as a large number of options can be tested much before the prototyping stage.
CFD is, thus, a tool for compressing the design and development cycle.

Preprocessing:

It consists of input of the flow problems to CFD program by means of operator and to prepare a cad model and geometry dimensions as shown in figure

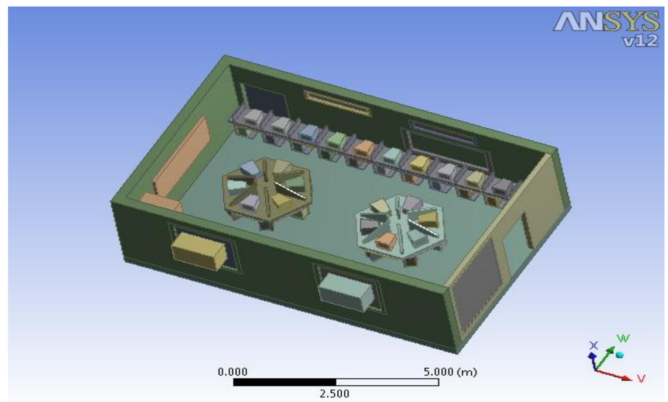

Figure 2.1 Geometry dimension of our solution domain

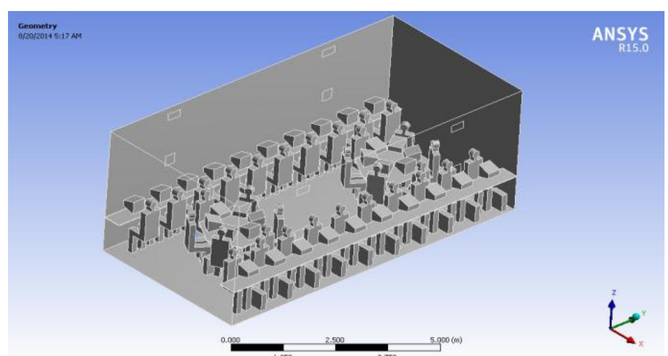

Figure2.2 Geometry for CFD analysis

Meshing

The meshing of cad model is symmetrically and elementary length is 0.1 m and mesh type is tetrahedral.

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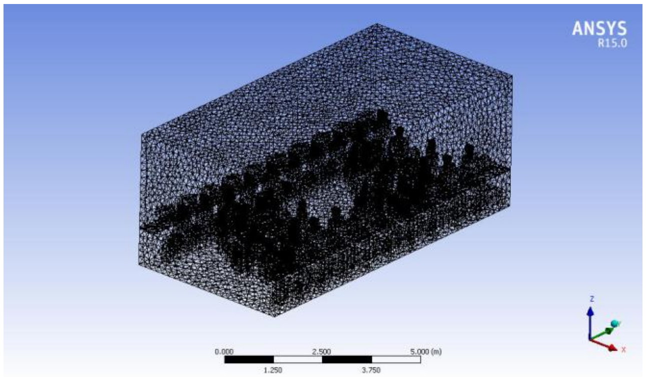


Figure 2.3 Meshing of domain air distribution system

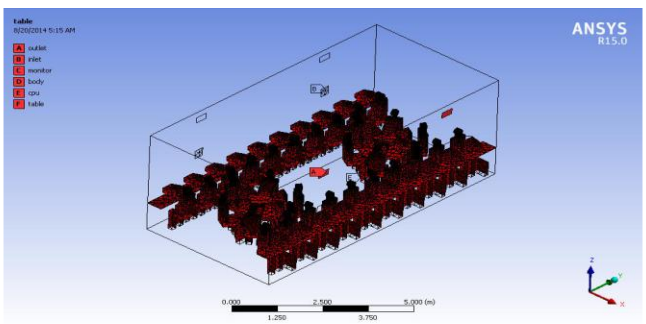
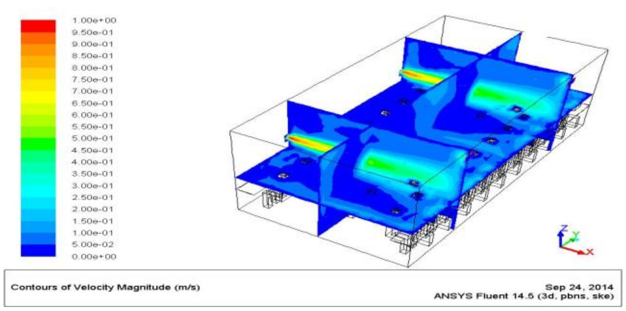


Figure 2.4 Meshing of interior involved in analysis

No. of nodes=107360
No. of elements= 600782

III. RESULTS AND DISCUSSIONS

3.1 Result of rainy season air distribution system



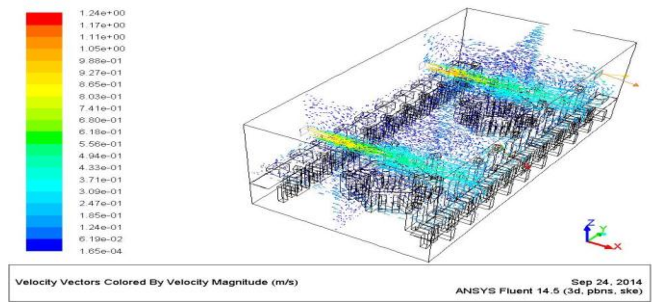


Figure 3.1 Analysis of air velocity and distribution

Graph between velocity and temperature

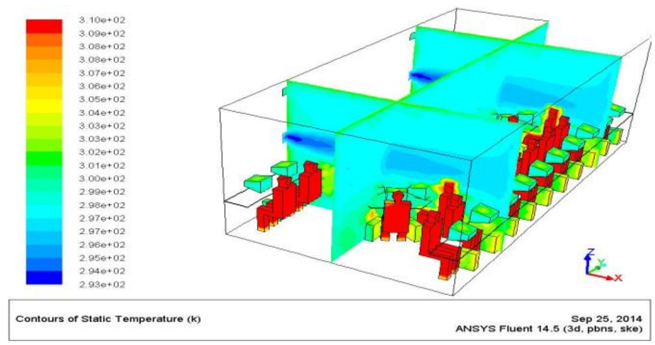


Figure 3.2 Analysis of air temperature

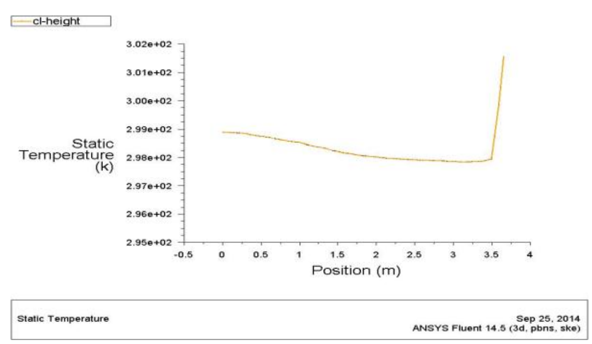


Figure 3.3 Analysis of air temperature with respect to ceiling height

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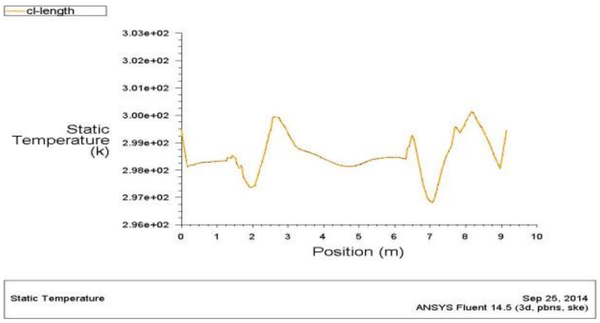

Figure 3.4 Analysis of air temperature with respect to ceiling length

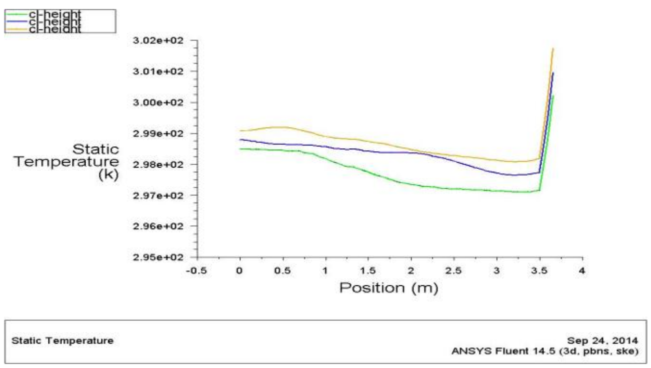

Figure 3.5 Analysis of air temperature with respect to ceiling height at different velocities

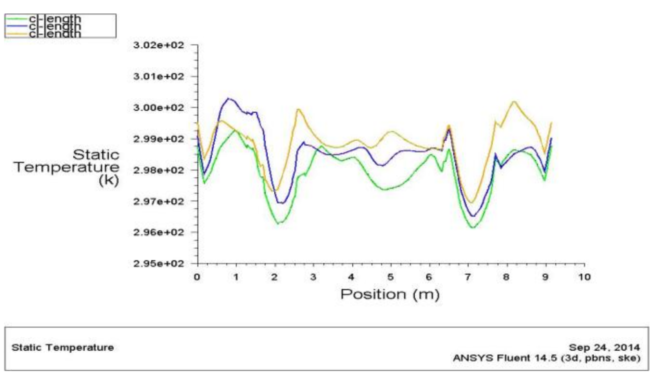

Figure 3.6 Analysis of air temperature with respect to ceiling length at different velocities

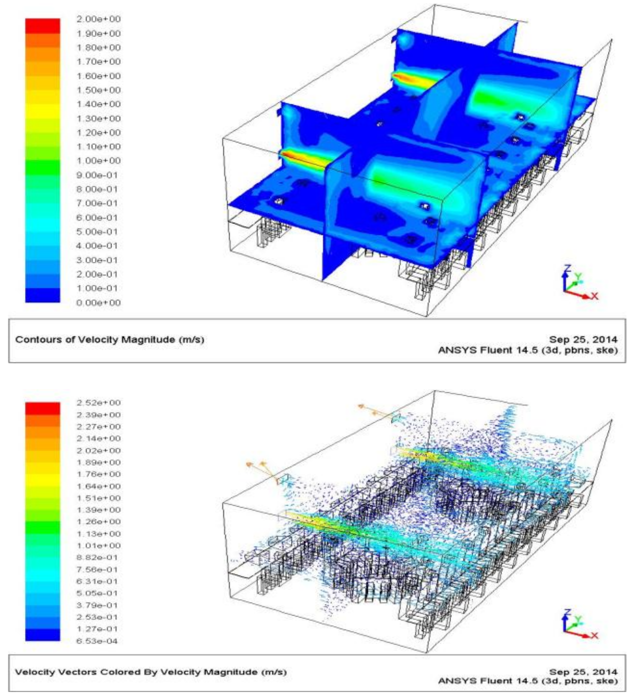

Figure 3.7 Analysis of air velocity and distribution

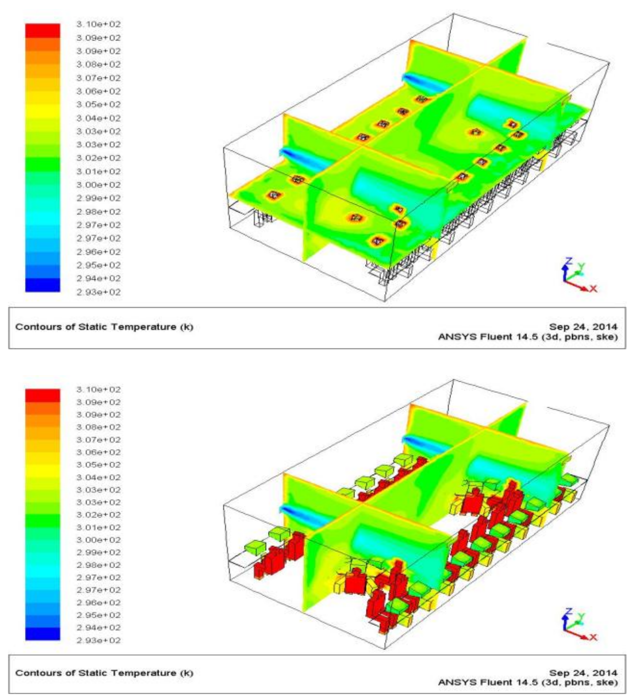

Figure 3.8 Analysis of air temperature

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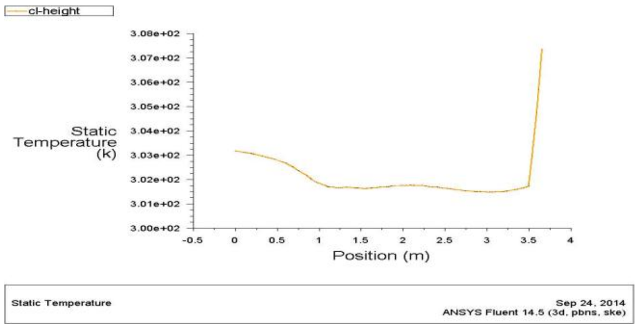


Figure 3.9 Analysis of air temperature with respect to ceiling height

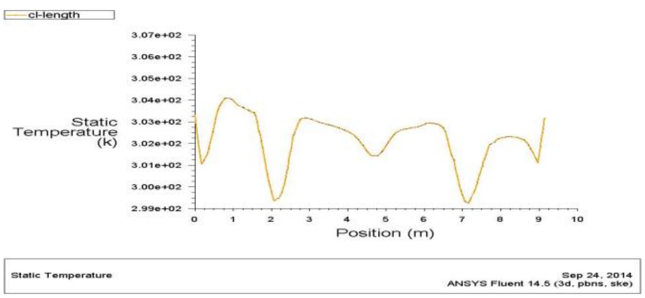


Figure 3.10 Analysis of air temperature with respect to ceiling length

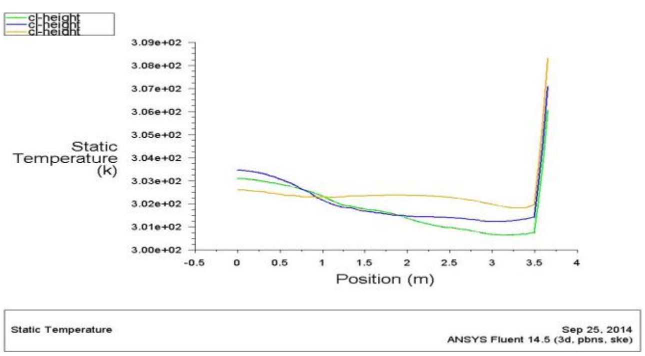


Figure 3.11 Analysis of air temperature with respect to ceiling height at different velocities

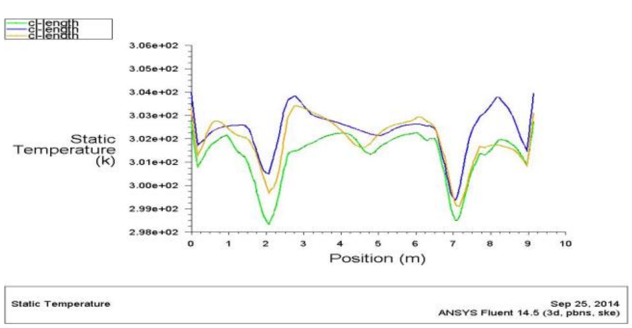
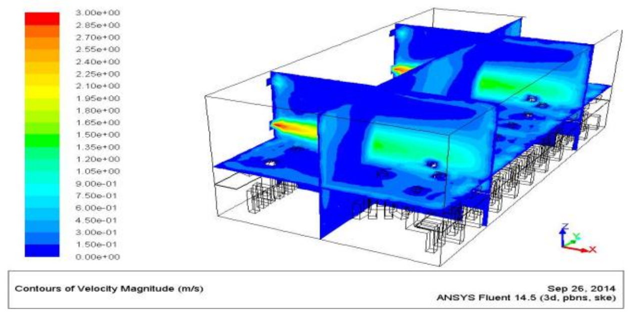
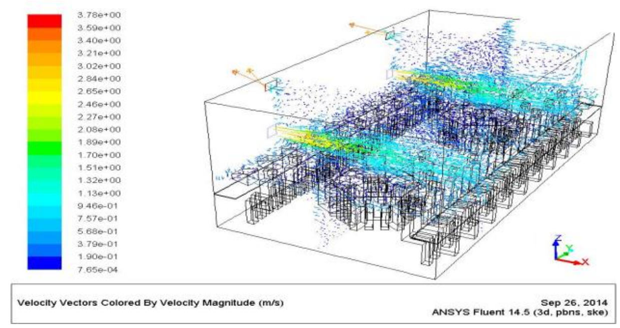


Figure 3.12 Analysis of air temperature with respect to ceiling length at different velocities

3.2 Results of winter season air distribution system





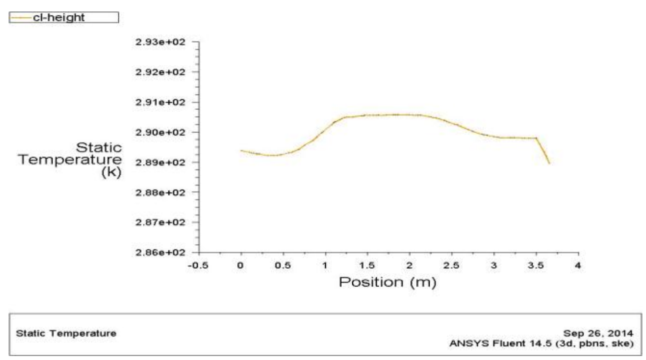


Figure 3.13 Analysis of air temperature with respect to ceiling height

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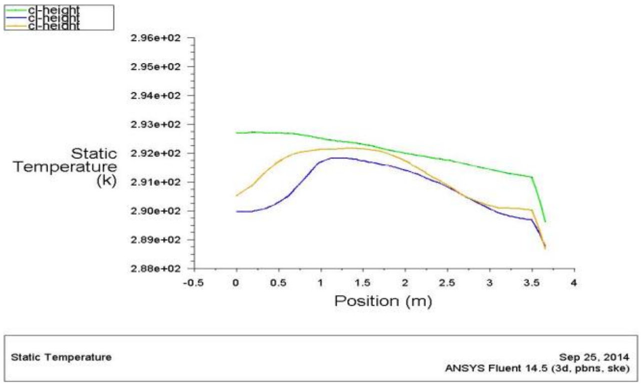

Figure 3.14 Analysis of air temperature with respect to ceiling height at different velocities

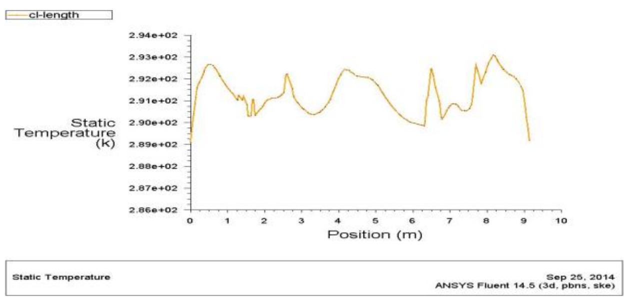

Figure 3.15 Analysis of air temperature with respect to ceiling length

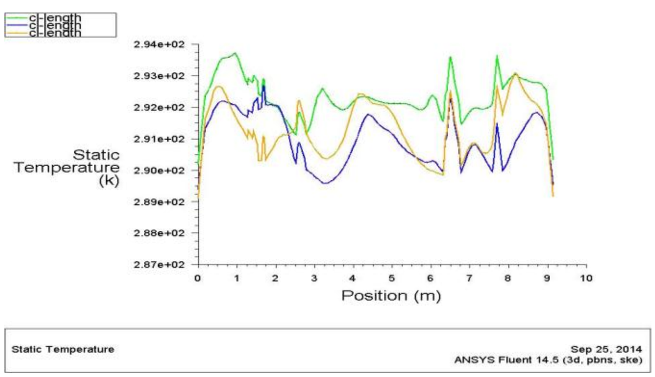

Figure 3.16 Analysis of air temperature with respect to ceiling length at different velocities

IV. CONCLUSION

There are several different points that must be taken into account while determining a mechanical system. The velocity of air and the position of air system in terms of height and length will be able to provide the elasticity required for future technology within the facility and is favorable on an operating cost basis.

For this reason, enthusiastic recommendations come from the project team which discuss the priorities and determine which option suits the project better. This study used the methodology and field measurements in order to develop a 3D CFD model which gives complete vision on environmental conditions of a naturally ventilated office meeting room. Moreover, the validated CFD model and field measurements were used to evaluate thermal comfort index for the occupants of the meeting room. The satisfactory and optimal operation of thermal environment has been confirmed. This paper is done in order to study the indoor airflow characteristics and thermal comfort of a room with nearby window openings under general position of window openings.

All range of the analysis will allow good resident comfort. Comfort and control both are achieved in different conditions depending on the type of work inside the system. The air velocity fields obtained from the CFD study show that a local discomfort at feet/ankle zone was observed but with good values of air velocity for the rest of the test room. The results reported confirm that the cooling ceiling has advantages like low vertical air gradient and that the thermal comfort is obtained even for higher metabolism rates or clothing insulation. The specification of confirmation criteria based on the purpose of the model proved to be a clear and straightforward way of validating CFD results with measurements. Solar radiation played a significant role in the highly-glazed room, even if only the diffuse part of solar irradiance was considered in the analysis. The indoor air temperature was mostly influenced by the inlet velocity vertical component, solar radiation through the windows, inlet velocity horizontal component and outdoor air temperature. In short, the CFD model calibration methodology bridges the gap between understanding and application of CFD simulation and field measurement for natural ventilation systems. This is done through a systematic utilization of the best practice guidelines and standards. This study was conducted to provide enhanced predictions to implement design strategies for radiant cooling ceilings with mechanical ventilation systems employing CFD, and showed that the proposed system operated with reasonable satisfaction.

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