Simulation of Thermal Environment of a Conditioned Space at Different Air Supply Conditions by CFD Analysis

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Abstract – Human comfort in conditioned spaces is the prime objective of air conditioning system design engineer. Air distribution in the conditioned spaces affects the human comfort. Several researchers have examined this human comfort in the conditioned spaces for various parameters of air conditioning and proposed the modifications in the system design and operation. Several new technologies have also been proposed by the researchers for it. Research is also reported in literature for the scope of energy savings through alternative technology of air distribution. It is this objective of the present work to simulate the indoor temperature distribution in a typical conditioned room in which air is supplied at a particular typical value of temperature and velocity most commonly used in practice through three case of supply air vent location. For this analysis numerical technique widely used by the researchers in present time, Computational Fluid Dynamics (CFD) has been used. The geometrical model is prepared is prepared in GAMBIT and Fluent is used for analysis purpose. The results are presented in the form of temperature and velocity contours in the room at three planes taken in the conditioned space. Vertical temperature and velocity distribution is shown with the help of plots at various location of the room. For comparison purpose the temperature and velocity plots have been compared for the three different cases of location of supply air vent

Key Words: Air conditioning, CFD, GAMBIT, Temperature, Temperature distribution, Velocity.

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I. INTRODUCTION

Thermal comfort is a combination of a subjective sensation and several objective interactions with the environment. Comfort depends on several physical magnitudes. Person -related. Deep body temperature, always close to 37 °C Metabolic dissipation rate; we must evacuate by unit body mass some 0.5 W/kg - 5 W/kg, depending on activity (around 100 W for an adult in office-work). Skin temperature is usually below 33 °C, allowing the heat evacuation, but it depends a lot on external conditions, clothing, and actual and previous activity levels.

II. AIR CONDITIONING

(a) **Principles of Air Conditioning-** Air conditioning is the process whereby the condition of air, as defined by its temperature and moisture content, is changed. Note that in practice other factors must also be taken into account especially cleanliness; odor; velocity & distribution pattern.

(b) **Simple Air Conditioning-** A fan draws air from the room first through a cooling device, consisting of metal fins extending from a pipe through which cooling fluid circulates, at a rate determined by the thermostat or by the humidistat. The air next passes over a heater, usually electrical, which is energized on instructions from the room.

(c) **Air Distribution-**Central heating and cooling systems use an air distribution or duct system to circulate heated and/or cooled air to all the conditioned rooms in a house. Properly designed duct systems can maintain uniform temperatures throughout the house, efficiently and quietly.

(d) **Duct Design and its Objective-** The efficiency of air distribution systems has been found to be 60-75% or less in many houses because of insufficient and/or poorly installed duct insulation and leaks in the duct system. The objectives of good duct design are occupant comfort, proper air distribution, economical heating and cooling system operation and economical duct installation.

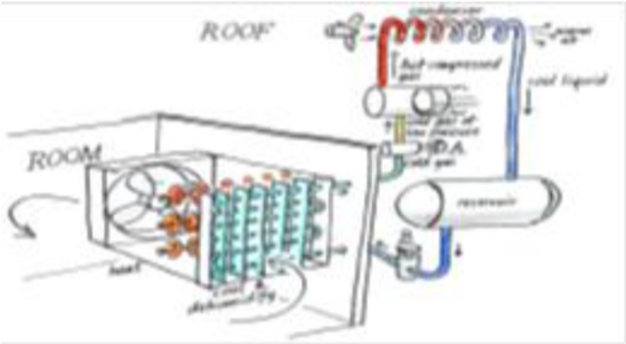


Fig. 1 Simple Air Conditioning System

(e) **Duct and Register Location -**Locating the air handler unit and air distribution system inside the conditioned space of the house is the best way to improve duct system efficiency and is highly recommended. With this design, any duct leakage will be to the inside of the house. It will not significantly affect the energy efficiency of the heating and cooling system because the conditioned air remains inside the house, although air distribution may suffer. Also, ducts located inside the conditioned space need minimal insulation (in hot and humid climates), if any at all. The cost of moving ducts into the conditioned space can be offset by smaller heating and cooling equipment, smaller and less duct work, reduced duct insulation, and lower operating costs.

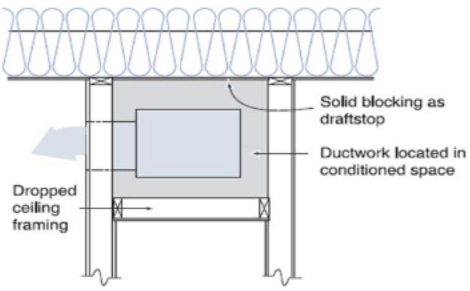


Fig. 2 Registered Locations

III. METHODOLOGY

Computational Fluid Dynamics (CFD) is the simulation of fluids engineering systems using modeling (mathematical physical problem formulation) and numerical methods (discretization methods, solvers, numerical parameters, and grid generations, etc.).

(a) **Importance of Computational Fluid Dynamics-** There are three methods in study of Fluid: theory analysis, experiment and simulation (CFD). As a new method, CFD has many advantages compared to experiments. Please refer table 1.

Table 1

Comparison of Simulation and Experiment

	Simulation (CFD)	Experiment
Cost	Cheap	Expensive
Time	Short	Long
Scale	Any	Small/Middle
Information	All	Measured Point
Repeatable	Yes	Some
Safety	Yes	Some Dangerous

(b) **Applications of CFD-** CFD is useful in a wide variety of applications and here we note a few to give you an idea of its use in industry. The simulations shown below have been performed using the FLUENT software.

(c) **CFD Simulation-** In the present research work numerical simulation of the temperature and velocity variation in an air conditioned space is simulated. Three cases have been taken into consideration for three different locations of the Air supplied diffuser. The conditioned air is supplied through one of the wall of the room through an opening. The location of the supply air vent is changed in three different cases, at the lower side, middle side and upper side.

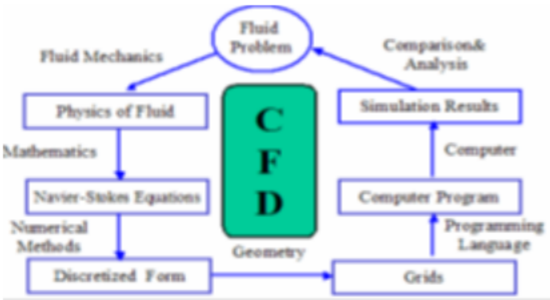


Fig. 3: Simulation Method

The air is returned through the return vent placed on the opposite side of the wall were the air is supplied through. The air is removed through two vents.

Experimental Data Obtained For C F D Analysis:

Table 1

Boundary Conditions

Velocity of supply air	0.7 m/s
Temperature of supply air	$297^{O}K$
Heat input value	$283^{O}K$
Heat input source	Sun Light

Table 2

Wall, Roof, and Floor Temperature:

Floor:	$293^{O}K$
Side Walls	$297^{O}K$
Ceiling	$304^{O}K$

Table 3

Room Dimension

Length	5 meters
Breadth	3.2 meters
Height	3 meters

(i) **Dimensions of supply duct:** 0.25 m x 0.25 m

(ii) **Dimensions of return duct:** 0.20 m x 0.20 m

Respective Temperature Recorded, while doing the Experiment:

Case I: AC is 0.8 meter from the bottom of the ground:

(a) Distance from AC is 1.8 meter:

Temperature at the distance 0.6 meter from the bottom	$295^{O}K$
Temperature at the distance 1.2 meter from the bottom	$296^{O}K$
Temperature at the distance 1.8 meter from the bottom	$297^{O}K$

(b) Distance from AC is 2.7 meter:

Temperature at the distance 0.6 meter from the bottom	$295.5^{O}K$
Temperature at the distance 1.2 meter from the bottom	$296.5^{O}K$
Temperature at the distance 1.8 meter from the bottom	$297.5^{O}K$

(c) Distance from AC is 3.6 meter:

Temperature at the distance 0.6 meter from the bottom	$296^{O}K$
Temperature at the distance 1.2 meter from the bottom	$297^{O}K$
Temperature at the distance 1.8 meter from the bottom	$298^{O}K$

Case II: AC is 1.0 meter from the bottom of the ground:

(a) Distance from AC is 1.8 meter:

Temperature at the distance 0.6 meter from the bottom	$297^{O}K$
Temperature at the distance 1.2 meter from the bottom	$296^{O}K$
Temperature at the distance 1.8 meter from the bottom	$297^{O}K$

(b) Distance from AC is 2.7 meter:

Temperature at the distance 0.6 meter from the bottom	$297.5^{O}K$
Temperature at the distance 1.2 meter from the bottom	$296.5^{O}K$
Temperature at the distance 1.8 meter from the bottom	$297.5^{O}K$

(c) Distance from AC is 3.6 meter:

Temperature at the distance 0.6 meter from the bottom	$298^{O}K$
Temperature at the distance 1.2 meter from the bottom	$297^{O}K$
Temperature at the distance 1.8 meter from the bottom	$298^{O}K$

Case III: AC is 2.3 meter from the bottom of the ground:

(a) Distance from AC is 1.8 meter:

Temperature at the distance 0.6 meter from the bottom	$297^{O}K$
Temperature at the distance 1.2 meter from the bottom	$296.5^{O}K$
Temperature at the distance 1.8 meter from the bottom	$296^{O}K$

(b) Distance from Air conditioner is 2.7 meter:

Temperature at the distance 0.6 meter from the bottom	$297^{O}K$
Temperature at the distance 1.2 meter from the bottom	$296.5^{O}K$
Temperature at the distance 1.8 meter from the bottom	$296^{O}K$

(c) Distance from AC is 3.6 meter:

Temperature at the distance 0.6 meter from the bottom	$297^{O}K$
Temperature at the distance 1.2 meter from the bottom	$297^{O}K$
Temperature at the distance 1.8 meter from the bottom	$296^{O}K$

Table 3:

The Three Cases Are Summarized in the Following:

Case	Supply air Vent Location	Return air vent Location
I	0.8 meters above the floor	0.5 meter below the ceiling
II	1.0 meters above the floor	0.5 meter below the ceiling
III	2.3 meters above the floor	0.5 meter below the ceiling

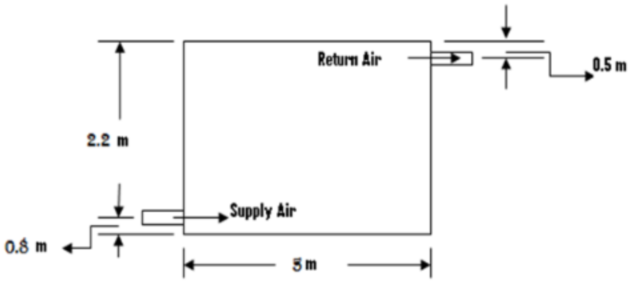


Fig. 4: Room Dimension

For the analysis of these cases, the numerical technique Computational Fluid Dynamics (CFD) has been used. The geometrical model for the three cases is prepared using GAMBIT 2.4.6 and numerical solution is obtained using ANSYS-FLUENT 6.3.26.

The Boundary Conditions Used Are Shown In The Following

Table 4:

Sr. No.	Boundary	Boundary Condition Used
1	Inlet	Velocity Inlet
2.	Outlet	Pressure outlet
3.	Room walls	Wall

In this simulation the different walls of the room are set at different temperatures and the values at the boundaries are tabulated in the following table.5:

Sr. No.	Boundary	Value
1.	Velocity of supply air	0.7 m/s
2.	Temperature of Supply air	297 K
3.	Temperature of Ceiling	304 K
4.	Temperature of side walls	297 K
5.	Temperature of floor	293 K

The results are shown below for the above mentioned three cases as under:

Case I: The supply air vent is at a position of 0.8 meter above the floor and return air vent is kept at 0.5 meter below the ceiling.

Case 2: The supply air vent is at a position of 1.0 meter above the floor and return air vent is kept at 0.5 meter below the ceiling.

Case3: The supply air vent is at a position of 2.3 meter above the floor and return air vent is kept at 0.5 meter below the ceiling.

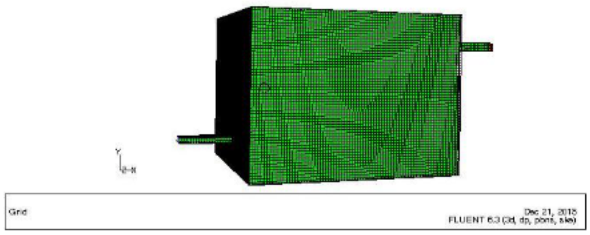
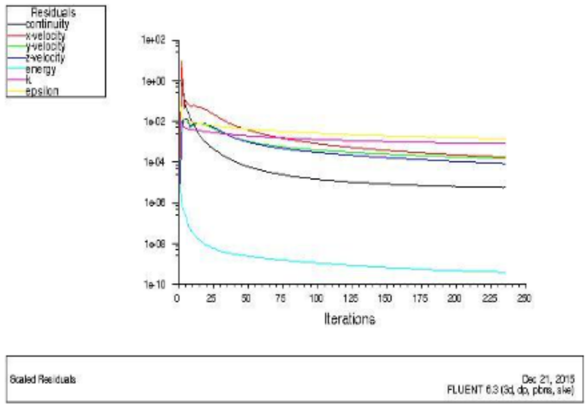
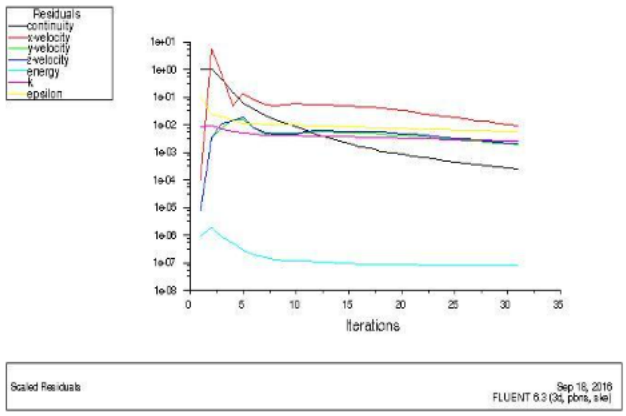


Fig. 5: Model



Graph: 1



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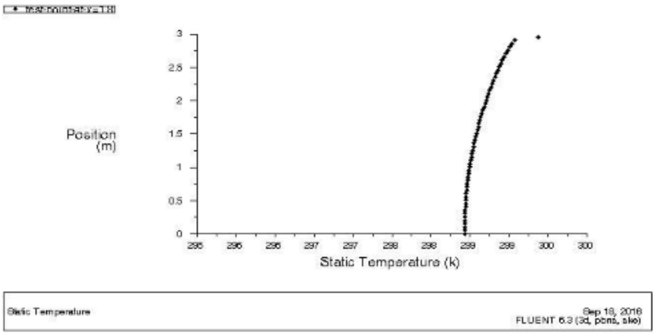

Graph: 3

IV. CONCLUSION

The results of the simulation obtained for the three cases in which air is supplied to the conditioned space through three different locations show the temperature and velocity variations. The results show that the indoor temperature and velocity is changing as the supply air diffuser location is changed. It is desired that the conditioned space should have uniform temperature and velocity for the better comfort in the conditioned space.

V. SCOPE FOR FUTURE WORK

It is hereby suggested by the authors that the following work may be performed in future:

(a) Experimental analysis may be performed for the above particular cases. Although the CFD methodology used in the present work is validated as the same numerical technique is found in the literature for providing results with best agreement with experimental results.

(b) Other locations of the supply air diffuser or vent may be taken into consideration for finding optimum location of the supply air vent.

(c) Supply air conditions may be optimised for the specific case of supply air vent location.

(d) The analysis may be performed for different return air vent location in future.

REFERENCES

Andrew Manning et. al. (2000). Analysis of Air Supply Type and Exhaust Location in Laboratory Animal Research Facilities Using CFD, ASHRAE.

D. Prakash et. al. (2012). Simulation of Indoor Air Flow for A Room With Windows at Their Adjacent Walls Under Various Wind Flow Direction Using Cfd, ARPN Journal of Engineering and Applied Sciences, Vol. 7, No. 11.

Eddy Rusly, Mirek Piechowski et. al. (2011). Cfd Modeling For Swirl Diffuser And Its Implications on Air Change Effectiveness Assessment To Green Star's IEQ-2, Proceedings of Building Simulation 2011:12th Conference of International Building Performance Simulation Association, Sydney.

John Swift, Emily Avis (2007). Air Distribution Strategy Impact on Operating Room Infection Control, Proceedings of Clima, Well Being Indoors.

John Swift, Emily Avis et. al. (2007). Air Distribution Strategy Impact on Operating Room Infection Control, Proceedings of Clima Well Being Indoors.

L. James Lo, Atila Novoselac (2010). Localized air-conditioning with occupancy control in an open office, www.elsevier.com, Energy and Buildings 42, pp. 1120–1128.

M. Taheri, M. Schuss et. al. (2014). Design Analysis of an Office Ventilation System Via Calibrated CFD Application, Fifth German-Austrian IBPSA Conference RWTH Aachen University in 2014.

Prabhat Kumar Pandey, Vipin Shrivastava (2014). Comparative Analysis of Under floor And Overhead Air Distribution of Air Conditioning of Room, International Journal of Advanced Technology & Engineering Research (IJATER), ISSN No: 2250-3536 Volume 4, Issue 2, March 2014.

Sarkar, Jahar and Mandal, Soumen (2008). "CFD Modeling and Validation of Temperature and Flow Distribution in Air-Conditioned Space". International Refrigeration and Air Conditioning 972.http://docs.lib.purdue.edu/iracc/972.

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