Finite Volume Analysis of Swirl Flow Diffuser at Variable Swirl Angle and Different Wind Velocity

Rahul Pandey[1] Prof. Anil Kumar Rao[2] Prof. Vinay Yadav[3]
[1]PG Student (Thermal Engineering) [2]Professor [3]Head and Professor
[1,2,3]Department of Mechanical Engineering
[1,2,3]AISECT University Bhopal,(M.P) India

Abstract— Floor swirl diffusers used in air-conditioning system would create good air mixing to create indoor air comfort conditions and help in achieving human comfort. The variation in temperature in air conditioning system depends strongly on the flow characteristics produced by the diffuser outlet that vary considerably between different modeling set ups. In corporate sector it is very important to calculate the effect of variation in temperature of diffused air from floor swirl diffuser with and without heat load.The analysis has been performed inside a wooden room of size 4ft x 4ft x 5ft with swirl diffuser models installed at the roof. The variation in temperature of diffused air form floor swirl diffuser at different height and the effect of heat load on temperature variation is determined. This analysis has been performed on three different models of floor swirl diffuser having different slot angles of 7^0, 8^0 and $9^0$and at different wind velocities i.e. 2, 3, 4,5m/s.

Key words: Floor swirl diffusers, CFD, HVAC

I. INTRODUCTION

A. *Air Conditioning:*

Air conditioning is the procedure of exchanging the properties of air to provide satisfactory and relaxation conditions. Most commonly, air conditioning refer to cooling, heating, ventilation, or disinfection that changes the state of air.

An air conditioner is a major home appliance system, planned to change the air hotness and moisture within an area The cooling is usually done by using simple cooling, but occasionally evaporation is used, usually for cooling in buildings and motor vehicles to deliver relaxed environment. In construction, a complete system of warming, ventilation and air conditioning to deliver thermal comfort is mentioned to as "HVAC". Air conditioning is delivered by a simple cooling course which uses pumps to mix a coolant from a cold source, which in turn acts as a heat sink for the energy which is removed from the cooled space. Free cooling systems can have efficiencies very high and are sometimes combined with seasonal thermal energy storage (STES) so that the cold in winter can be used for summer air conditioning. Common storage mediums are deep aquifers or natural underground rock mass accessed via a cluster of small-diameter, heat exchanger equipped boreholes etc. Some systems with small storages are hybrids, using free cooling early in the cooling season, and later used as a heat pump to chill the circulation coming out from the storage. The heat pump is added because the temperature of the storage gradually increases during the cooling season, there by declining in efficiency. Free cooling and hybrid systems are mature technology for cooling.

B. *The Past of Air Conditioning:*

The air conditioning thought is came from an prehistoric Egypt where reeds were hung in windows had water trickle down, departure (evaporation) cooled the air though ended it more moist. In prehistoric Rome aqueduct water was spread through the walls of some houses to cool them down through evaporation process. The other technique which is used in medieval Persia involved the utilize of cisterns and wind towers to cool building during the hot season. Modern air conditioning emerges during the 19th century, and first electrical air conditioning was invented and used in 1911 by Willis Haviland Carrier.

C. *Air Diffuser:*

Air diffusers are device that undergo as the ending point for HVAC unit. Diffusers circulate ventilated air into rooms and are found in both residential and commercial buildings. Diffuser comes in many shapes and size are naturally found in floors and ceiling. Diffuser is also every now and then referred to register. According to Alantsupply.com .Diffusers can be made of metal or wood, though wood is less common but are usually found in the home.

D. *The Past of Air Diffuser:*

Air diffusers are used most commonly in air-conditioning systems and the air diffusion is usually very much influenced by the characteristics of different diffuser designs. Swirl diffusers are most popular for ceiling level air supply system. The method of modeling has an important impact on the accuracy of the predicted air flow pattern in the room so it is very critical. Computational Fluid Dynamics (CFD) simulation is one of the most useful techniques to predict the air distribution inside the air-conditioned room. Some researchers (Emvinand and Davison 1996; Chen and Jiang 1996; Srebric and Chen 2001) investigated systematically many simplified modeling methods for complex air diffusers. They have recognized two simplify methods, the box and momentum methods, to be most correct for use in CFD simulations of indoor airflows. When the box method is used in the CFD simulation, it needs the distributions of velocity, temperature of air and contaminant concentration around the diffuser. Air velocity, The method on how to find out the box size has been given by some researchers (Srebric and Chen, 2001a). Similarly, the momentum method requires the airflow rate, discharge jet velocity or efficient diffuser area, supply air turbulence properties, supply air temperature, and contaminant concentrations. Regrettably, the box method is not suitable for flows that have low Reynolds number, such as Ceiling-level air supply system. For this system, the buoyancy force powerfully influences the jet progress from its discharge. Like the displacement diffuser system, the jet changes its profile shape and position very speedily in front of the diffuser (Jacobsen and Nielsen 1993). The other disadvantage about the box method is that it needs measured data, which may cost extended time and may need some costly equipment. The momentum method is another simplify way to inflict boundary conditions for diffusers in CFD simulations. For floor-level air circular ceiling diffusers are almost certainly the most general types of air terminal devices used for air distribution in commercial buildings.

E. Air Distribution System:

Five different air distribution systems are as follows:

1) Mixing ventilation with a wall- mounted diffuser
2) Displacement ventilation with a wall-mounted low velocity diffuser
3) Vertical ventilation with a ceiling-mounted textile terminal
4) Mixing ventilation with a ceiling-mounted radial diffuser
5) Mixing ventilation with a ceiling-mounted swirl diffuser temperature gradient is also low because of the high level of room

II. PROBLEM FORMULATION

The study of various literatures we find the temperature distribution is higher as compared to present study. The purposes of this study reduce to reduce a hot ambient condition from wooden room and to measure temperature variation w.r.t height of locations and whole room at various wind velocity. Thus chosen swirl flow diffuser at a place of normal diffuser. In order to verify the present numerical models, the thermal under the conditions Uin= 2,3,4,5 m/s and Q = 1500W are compared with the available experimental results of Suraj, Dr. V.N. Bartaria. And the design of swirl flow diffuser is 7, 8 and 9 degree angles. In this study, the simulations of SFD at various wind velocity i.e., 2,3,4,5 m/s and the configurations of swirl angles are proposed. The results show that increasing wind velocity could reduce the hot ambient conditions and increase the comfort conditions simultaneously.

III. RESEARCH METHODOLOGY

In this section I am explaining the methodology that is used in the research is explained. In this research a simulation technique is used to find the air flow pattern and measure the variation of temperature with respect to height with different air velocity and various angel of swirl diffuser.

IV. SIMULATION ANALYSIS OF SET UP

A. Preprocessing:

CAD Model: Generation of 3D CAD model of set up using CREO/PARAMETRIC. Then import the CAD model into Ansys Design modeler in Para solid format (.xtl or .xt).

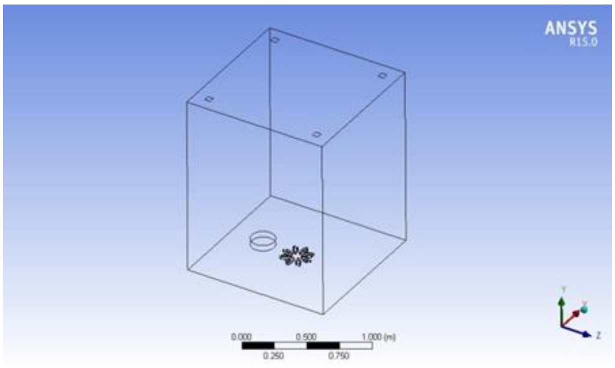

Fig. 4.1: CAD Model of the Set Up

1) Mesh:

Generate the mesh of ACC in the Ansys Mesh software .
Mesh Type: tetrahedral

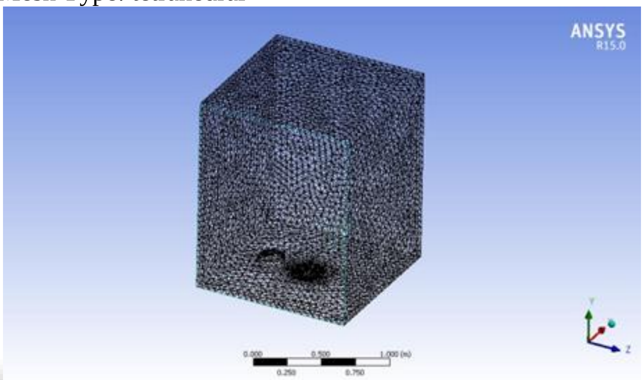

Fig. 4.2 Meshing of set up.

Element Edge Length =2.5 mm
No. of Nodes = 28125
No. of Element = 146404

Table 1:

2) Fluent setup:

After mesh generation define the following setup in the Ansys fluent.

- Problem Type : 3D
- Type of Solver: Pressure-based solver.
- Physical model: Viscous: K, e two equation turbulence model.

Density	1.225 kg/m^3
Viscosity	1.7894e-05

Table 2: Material Properties of Air

Density	700Kg/m^3
Specific Heat (C_p)	2310J/kg-k
Thermal Conductivity (K)	0.173W/m-k

Table 3: Material Properties of Wood

Density of air = 1.225 kg/m^3
Viscosity = 1.7894e-05
Boundary Condition:
Operating Condition:Pressure = 101325 Pa
Inlet: Velocity inlet– Velocity = 2 m/s
Turbulent intensity = 1%
Hydraulic Dia. = 280mm
Heat flux = 325 W/m^2
Outlet: Pressure outlet: Define the same outlet condition for all the vent outlet
Gauge pressure = 101325 Pa
Turbulent intensity = 1%
Hydraulic Length. = 50mm

B. *Solution:*

- Solution Method :
  Pressure- velocity coupling – Scheme -SIMPLE
  Pressure – Standard
  Momentum – Second order
  Turbulent Kinetic Energy (k) – First orde
  Turbulent Dissipation Rate (e) - First order
- Solution Initialization:
  Initialized the solution to get the initial solution for the problem.
- Run Solution:
  Run the solution by giving 2000 no of iteration for solution to converge.

V. RESULT ANALYSIS AND DISCUSSION

I have done the same analysis but with a simulation technique and compare the results with the experimental reading by taking the reference. The nature and behavior of air diffused by three different types of swirl diffuser having slots with draft angle of 7^0, 8^0, and 9^0. The graphs are plotted between temperature of diffused air inside the room and vertical height from the floor level. Pressure, Temperature, Velocity distribution inside the room and the graphs are plotted at six different locations inside the room, which shows the comparison between Experimental and CFD technique. The results are described in tabulation and graphical form at all six locations and at different slot angle of the diffuser

A. *5.1Post processing:*

1) *Post Processing:*

For viewing and interpretation of Result. The result can be viewed in various formats: graph, value, animation etc.

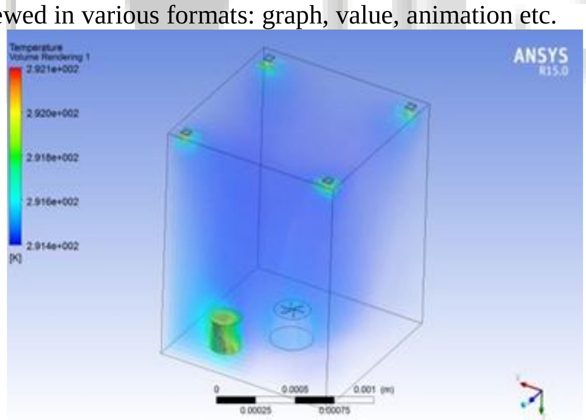

Fig. 5.1: Temperature Rendering At 7^0 Swirl Angle

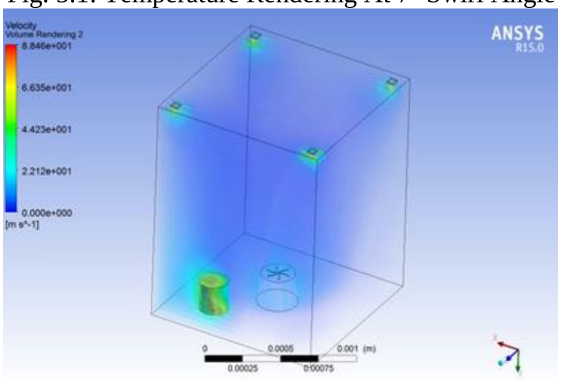

Fig. 5.2: Velocity rendering At 7^0 Swirl Angle

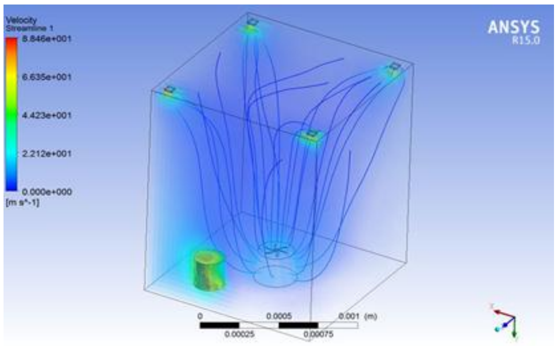

Fig. 5.3: Velocity Streamline flow At 7^0 Swirl Angle

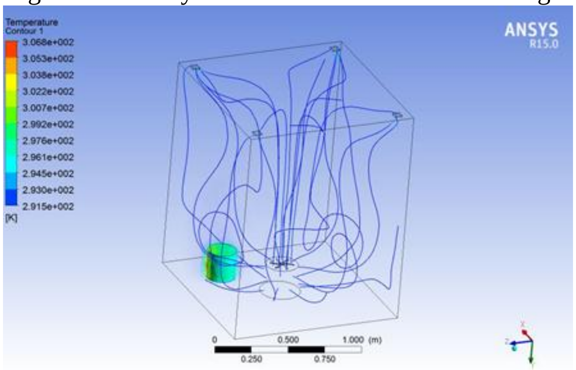

Fig. 5.4: Temperature & Velocity streamline At 8^0 Swirl Angle

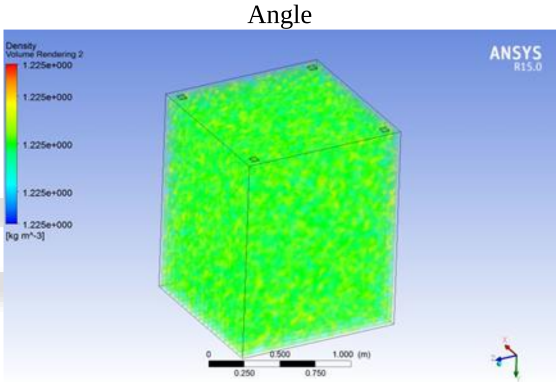

Fig. 5.5: Density variation At 8^0 Swirl Angle

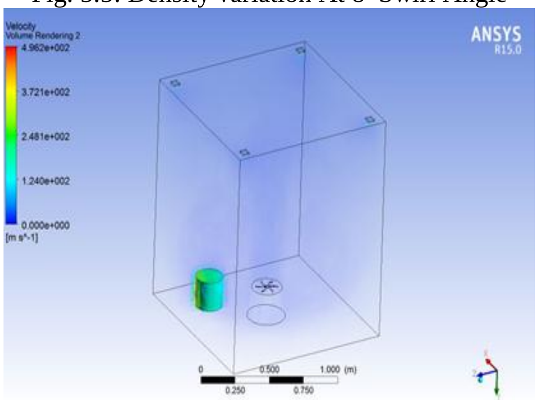

Fig. 5.6: Velocity At 8^0 Swirl Angle

S.NO	HEIGHT IN FT	TEMPERATURE (C)	
		EXPERIMENTAL	SIMULATION RESULT
1	0.7	23	22
2	1.4	22	21
3	2.1	21	23

4	2.8	24	22

Table 4:

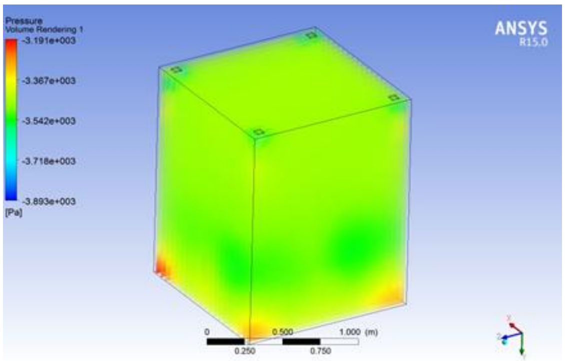

Fig. 5.7: Pressure Domain At 9^0 Swirl Angle

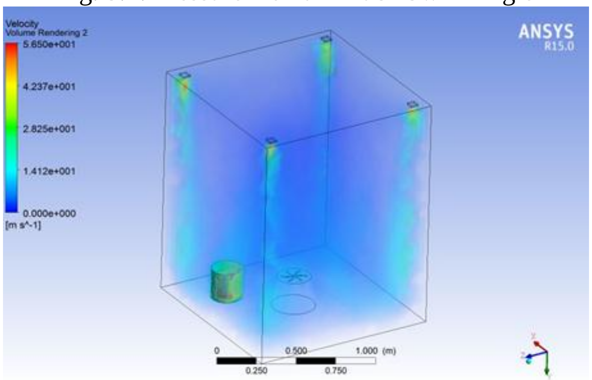

Fig. 5.8: Velocity At 9^0 Swirl Angle

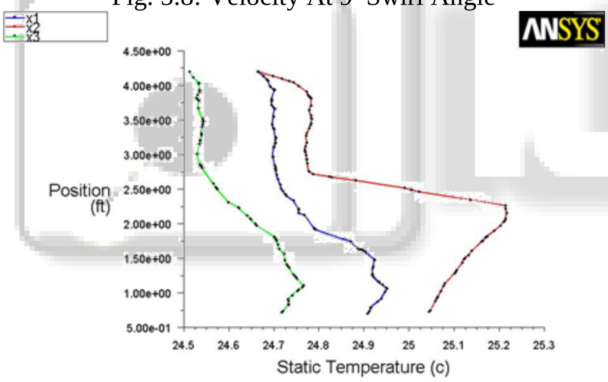

Fig. 5.9: Variation Of Temperature With Respect To Height At X1, X2, X3 (7^0 Swirl Angle)

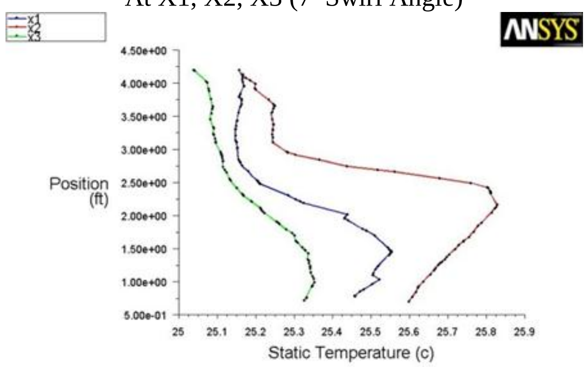

Fig. 5.10: Variation of Temperature With Respect To Height At X1, X2, X3 (8^0 Swirl Angle)

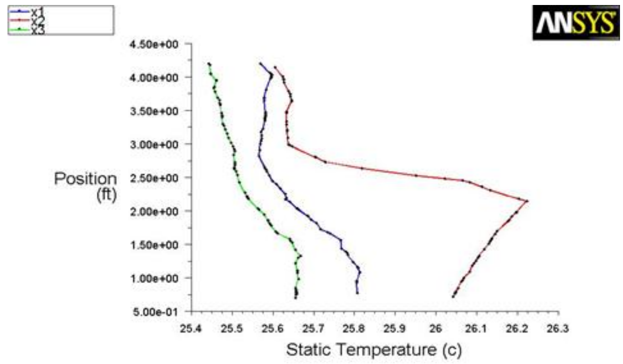

Fig. 5.11: Variation Of Temperature With Respect To Height At X1, X2, X3 (9^0 Swirl Angle)

S.NO	**HEIGHT IN FT**	**TEMPERATURE**	
		EXPERIMENTAL	**SIMULATION RESULT**
1	0.7	24	22
2	1.4	24	26
3	2.1	23	25
4	2.8	23	23

Table: 5.1: Variation of Temperature And Height At Location X1 At 7^0 Swirl Angle (Experimental And CFD)

S.NO	**HEIGHT IN FT**	**TEMPERATURE (^{0}C)**	
		EXPERIMENTAL	**SIMULATION RESULT**
1	0.7	22	25
2	1.4	20	25
3	2.1	21	22
4	2.8	24	24

Table 5.2: Variation of temperature and height at location X2 at 7^0 swirl angle (Experimental and CFD)

Above table shows the variation of temperature with respect to height at location X1 and at 70 swirl angle. This table also shows the comparison of the experimental and CFD readings at six different heights. Below also shows the comparison in graphical form.

S.NO	**HEIGHT IN FT**	**TEMPERATURE**	
		EXPERIMENTAL	SIMULATION RESULT
1	0.7	22	26
2	1.4	21	22
3	2.1	20	24
4	2.8	22	24

Table 5.4: Variation of temperature and height at location X1 at 8^0 swirl angle (Experimental and CFD)

Above table shows the variation of temperature with respect to height at location X1 and at 8^0 swirl angle. This table also shows the comparison of the experimental and CFD readings at six different heights. Below also shows the comparison in graphical form.

S.NO	**HEIGHT IN FT**	**TEMPERATURE**	
		EXPERIMENTAL	SIMULATION RESULT
1	0.7	22	21

2	1.4	20	22
3	2.1	20	26
4	2.8	21	23
5	2.8	21	23

Table 5.5: Variation of temperature and height at location X2 at 8^0swirl angle (Experimental and CFD)

Above table shows the variation of temperature with respect to height at location X2 and at 80 swirl angle. This table also shows the comparison of the experimental and CFD readings at six different heights. Below also shows the comparison in graphical form

Table 5.6: Variation of temperature and height at location X3 at 8^0 swirl angle (Experimental and CFD)

Above table shows the variation of temperature with respect to height at location X3 and at 80 swirl angle. This table also shows the comparison of the experimental and CFD readings at six different heights. Below also shows the comparison in graphical form.

Table 5.7 Variation of temperature and height at location X1 at 9^0 swirl angle (Experimental and CFD)

Above table shows the variation of temperature with respect to height at location X1 and at 9^0 swirl angle.

S.NO	HEIGHT IN FT	TEMPERATURE	
		EXPERIMENTAL	SIMULATION RESULT
1	0.7	22	23
2	1.4	20	22
3	2.1	20	22
4	2.8	22	20

S.NO	HEIGHT IN FT	TEMPERATURE	
		EXPERIMENTAL	SIMULATION RESULT
1	0.7	21	22
2	1.4	20	23
3	2.1	20	28
4	2.8	22	26

This table also shows the comparison of the experimental and CFD readings at six different heights. Below also shows the comparison in graphical form.

Table 5.8 Variation of temperature and height at location X2 at 90swirl angle (Experimental and CFD)

Table 5.9 Variation of temperature and height at location X3 at 9^0 Swirl angle (Experimental and CFD)

Above table shows the variation of temperature with respect to height at location X2 and at 9^0 swirl angle. This table also shows the comparison of the experimental and CFD readings at six different heights. Below also shows the comparison in graphical form.

S.NO	HEIGHT IN FT	TEMPERATURE	
		EXPERIMENTAL	SIMULATION RESULT
1	0.7	22	24
2	1.4	21	23
3	2.1	20	22
4	2.8	22	21

Above table shows the variation of temperature with respect to height at location X2 and at 9^0 swirl angle. This table also shows the comparison of the experimental and CFD readings at six different heights. Below also shows the comparison in graphical form.

Table 5.9 Variation of temperature and height at location X3 at 9^0 Swirl angle (Experimental and CFD)

Above table shows the variation of temperature with respect to height at location X2 and at 9^0 swirl angle. This table also shows the comparison of the experimental and CFD readings at six different heights. Below also shows the comparison in graphical form

Angle in Degrees	Velocity (m/s)	Temperature
7	2	26
7	3	23
7	4	22
7	5	21

Table 5.10: variation at different wind velocities inside a wooden room at 7^0 swirl angle

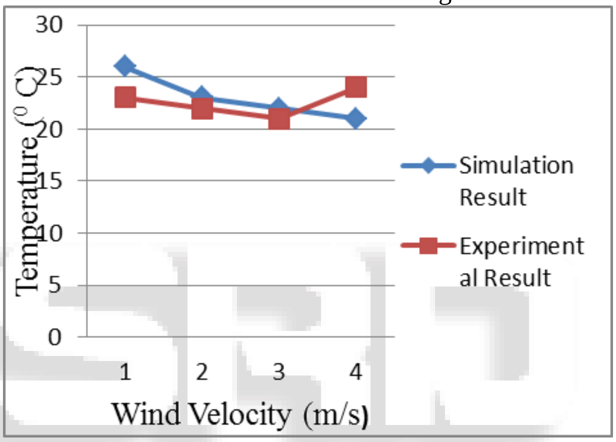

Fig. 5.11: temperature variation at different wind velocities inside a wooden room at 7^0 swirl angle

Angle in Degrees	Velocity (m/s)	Temperature
8	2	24
8	3	23
8	4	20
8	5	18

Table 5.11: temperature variation at different wind velocities inside a wooden room at 8degree swirl angle

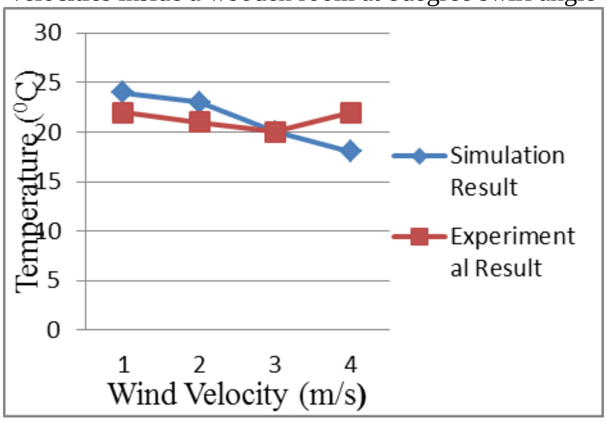

Fig. 5.12: temperature variation at different wind velocities inside a wooden room at 8^0 swirl angle

Angle in Degrees	Velocity (m/s)	Temperature
9	2	25
9	3	22
9	4	20
9	5	19

Table 5.12: temperature variation at different wind velocities inside a wooden room at 9^0 swirl angle

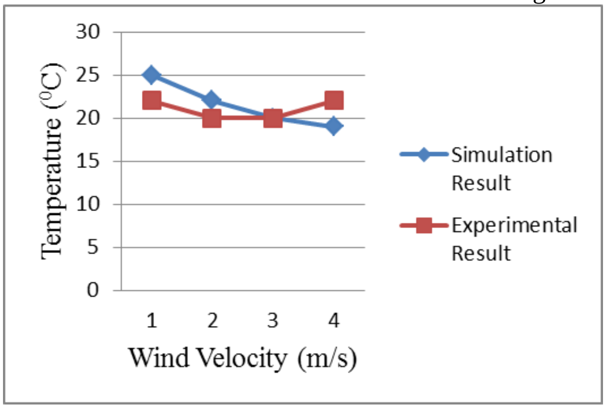

Fig. 5.13: temperature variation at different wind velocities inside a wooden room at 9^0 swirl angle

VI. CONCLUSION

As we have discussed in results above the temperature variation for comfort conditions in wooden room

1) Also we have seen with Maximum wind velocity we would easily achieve normal conditions
2) Also one of our concentrations in a measurement of thermal variation w.r.t different locations
3) Similarly Max. value of temperature variation is observed at high wind velocities.
4) This discussion directs us to understand the comfort condition and temperature variation at different wind velocities by analyzing it by CFD.
5) Thelast and best angle for comfort condition is 8^0 degrees for human comfort and temperature maintenance inside a wooden room.

VII. FUTURE SCOPE OF STUDY

In these analyses there are certain limitations and assumptions which are as follows:

1) ANSYS FLUENT software are very costly so the initial cost of the simulation technique is very high.
2) In simulation technique the environmental effect which comes in picture in case of experimental technique does not have any effect because it is a computer based simulation technique.
3) A heater is used in experimental technique which is of 1500W but in our analyses we can't use heater in simulation technique in place of that we consider heat flux.

REFERENCES

[1] B.F. Yu, Z.B. Hu, M. Liu, H.L. Yang, Q.X. Kong, Y.H. Liu, Review of Research on air conditioning system and indoor air quality control for human health, May 2008, ELSEVIER, Science Direct.

[2] Sami A, AL-Sanea, M.F Zedan, M.B. Al Harbi, Heat transfer characterstics in air conditioned room using mixing air distribution system under mixing convection system, May 2012, ELSEVIER, Science Direct.

[3] Amer Abduladheem, K. S. M. Sahari, H. Hasini, Wisam Ahmed, Raed Abed Mahdi, Ventilation Air Distribution in Hospital Operating Room-Review, November 2013, International Journal Of Science and Research.

[4] Tengfei (Tim) Zhang, Kisup Lee, Qingyan Chen, A simplified approach to describe complex diffusers in displacement ventilation for CFD simulation, 2009 School of Civil and Hydraulic Engineering Dalian University of Technology, Dalian, China

[5] Mohammed A. Aziz, Ibrahim A. M. Gad, El Shahat F. A. Mohammed, and Ramy H. Mohammed, Experimental and Numerical Study of A/C Outlets and Its Impact on Room Airflow Characteristics, November 2012, World Academy Of Science, Engineering and Technology.

[6] Josephine Lau and Qingyan Chen, Floor Supply Displacement ventilation for workshop, January 2006, ELSEVIER, Science Direct..

[7] Eunsu Lim, Kazunobu Sagara, Toshio Yamanaka, Hisashi Kotani, Noriaki Mishima, Susumu Horikawa, and Tomoaki Ushio, CFD analysis of air flow charactersties in office room with task air conditioning and natural ventilation, Department of Architectural Engineering, Osaka University, Japan, The Kansai Electric Power CO. INC., Japan

[8] C.J. Wu,, D.P. Liu , J. Pan, A study of the aerodynamic and acoustic performance of an indoor unit of a DC-inverter split air-conditioner, November 2011, ELSEVEIR, Science Direct.

[9] Vivian Chanteloup, Pierre-Sylvain Mirade, Computational fluid dynamics (CFD) modelling of local mean age of air distribution in forced-ventilation food plants, June 2008, ELSEVEIR, Science Direct.

[10] Dilek Kumlutas¸ Ziya Haktan Karadeniz, Investigation of flow and heat transfer for a split air conditioner indoor unit, September 2012, ELSEVEIR, Science Direct.

[11] Jichao Hu, Junye Shi, Yuanyuan Liang, Zijiang Yang, Jiangping Chen, Numerical and Experimental Investigation on Nozzle Parameters for R410A Ejector Air Conditioning System, Institute of refrigeration and cryogenics, Shanghai Jiao Tong University, No.800 Dongchuan Road, Shanghai, 200240, China, December 2013.

[12] G. Grazzini, A. Milazzo, D. Paganini, Design of an ejector cycle refrigeration system, November 2011, ELSEVEIR, Science Direct.

[13] Mayurkumar S. Gandhi, Arijit A. Ganguli, Jyeshtharaj B. Joshi, Pallippattu K. Vijayan, CFD simulation for steam distribution in header and tube assemblies, 2012, ELSEVEIR, Science Direct.

[14] Kwang-Chul Noh, Jae-Soo Jang, Myung-Do Oh, Thermal comfort and indoor air quality in the lecture room with 4-way cassette air-conditioner and mixing ventilation system, October 2005, ELSEVIER, Science Direct.

[15] Qiong Li, Hiroshi Yoshino, Akashi Mochida, Bo Lei, Qinglin Meng, Lihua Zhao, CFD study of the thermal

environment in an air-conditioned train station building, August 2008, ELSEVEIR, Science Direct.
[16] Ghassem Heidarinejad, Vahid Khalajzadeh, Shahram Delfani, Performance analysis of a ground-assisted direct evaporative cooling air conditioner, May 2010, ELSEVEIR, Science Direct.
[17] Ryan K. Dygert, Thong Q. Dang, Experimental validation of local exhaust strategies for improved IAQ in aircraft cabins, April 2011, ELSEVEIR, Science Direct.
[18] T.T Chow, Z.Lin, J.P. Liu, Effect of condensing unit layout at building re-entrants on split type air conditioner performance, July 2001, ELSEVEIR, Science Direct.
[19] K.C. Ng, K. Kadirgama, E.Y.K. Ng, Response surface models for CFD predictions of air diffusion performance index in a displacement ventilated office, April 2007, ELSEVEIR, Science Direct.
[20] Qi Jie Kwong, Nor Mariah Adam, B.B. Sahari, Thermal comfort assessment and potential for energy efficiency enhancement in modern tropical buildings, September 2013, ELSEVEIR, Science Direct.
[21] ZiyaHaktanKaradeniz, DilekKumlutas, Experimental visualization of the flow characteristics of the outflow of a split air conditioner indoor unit by meshed infrared thermography and stereo particle image velocimetry, July 2012, ELSEVEIR, Science Direct.
[22] E. Rusly, Lu Aye, W.W.S Characters, A.Ooi, CFD analysis of ejector in a combined ejector cooling system, May 2005, ELSEVEIR, Science Direct.
[23] C.F. Gao, W.L. Lee *, Chen Hua, Locating room air-conditioners at floor level for energy saving in residential buildings, May 2009, ELSEVEIR, Science Direct.
[24] JitendraRaghuwanshi, Dr V.N Bartaria, Performance and Flow characterstics of Ceiling Swirl Diffuser under different operating and flow parameters.
[25] Jia Yan, WenjianCai, Yanzhong Li, Geometry parameters effect for air-cooled ejector cooling systems with R134a Refrigerant, April 2012, ELSEVEIR, Science Direct.
[26] Jahar Sarkar, Ejector enhanced vapour compression refrigeration and heat pump systems—A review, October 2012, ELSEVEIR, Science Direct.
[27] Xiangjie Chen, SiddigOmer, MarkWorall, SaffaRiffat, Recent developments in ejector refrigeration technologies, December 2012, ELSEVEIR, Science Direct.
[28] Cuimin Li, Jianing Zhao, Study on Indoor Air Temperature Distribution of Gravity Air-Conditioning for Cooling, 2012, ELSEVEIR, Science Direct.

