VOL. 11, NO. 10, MAY 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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AIRFLOW BEHAVIOR IN PARTICLE TRANSMISSION IN AN OFFICE BUILDING

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ABSTRACT

The utilization of energy in office building is mostly for create comfort and health for employee to work. However, it always consume energy excessively which is caused from the utilization of air-conditioning. The high demand of energy adopted from air-conditioning is to dilute indoor air particle. This article is about a parametric study of inlet air supply position for identifying the effectiveness of airflow behaviour of a room to dilute indoor air particle. It was carried out using COMSOL Multiphysics software of modelling and simulation approach. In simulation stage, the first process was to simulate the airflow behavior and the second was to assess its behaviour to dilute indoor air particle. Results from the simulation indicated that effectiveness of airflow behaviour in diluting indoor air particle are affected by inlet air supply position, outlet position and barrier condition in the room. Thus, these indicate that to improve IAQ of a room it needs to properly understand the airflow behaviour.

Keywords: airflow, COMSOL multiphysics, parametric study, barrier condition, simulation.

INTRODUCTION

In response to protect the global environment due to excessive energy use, the green office buiding design has been adopted in many office buildings (Ravindu *et al.* 2015). One of consideration in designing green office building is the effectiveness of airflow either room or space of building to dilute indoor air pollutants (Abanto *et al.* 2004). Generally, to reduce the concentration level of indoor air pollutants it can be achieved by increasing the ventilation rate of air-conditioning. However, this approach often conflicts with building energy efficiency requirement due to consume energy (Posner and Buchanan, 2003). Thus, an alternate solution is carried out by identifying the proper location of inlet air supply in order to generate airflow behaviour to dilute indoor air pollutants effectively rather than solely to the mechanical performance of the ventilation system.

In order to identify the proper location of inlet air supply, an approach of parametric study has been widely adopted as a consideration in building design prior to construction for cost saving. According to various researchers (Abanto *et al.* 2004)(Posner and Buchanan, 2003)(Chung and Dunn-Rankin, 1998)(Chung and Hsu, 2001)(Daoud and Galanis, 2008)(Wurtz *et al.* 1999)(Guerfala *et al.* 2012)(Kolesnikov, 2006)(Asmi *et al.* 2014), numerical simulation is a valuable tool that can be used for room ventilation design. However, since the model of room or space of building is need to be constructed in three dimension space prior to simulate, then it is contribute to the computational time for solving the model. Subsequently, this constraint can be handled by using an approach of COMSOL Multiphysics software. This software is interactive environment software for modelling and solving all kinds of scientific and engineering problems based on Partial Differential Equation (PDE) (Asmi *et al.* 2014). The software solves the PDE by using Finite Element Method (FEM) (Asmi *et al.* 2014). It runs the FEM analysis together with the adaptive meshing and error control using a variety of numerical solvers. Modelling work in COMSOL is able to interrelate with different kinds of physics phenomena into a single model. Hence, this flexibility is simplifying the modelling and also decreasing computational time.

METHODOLOGY

The dimension of model being investigated is depicted as in Figure-1.

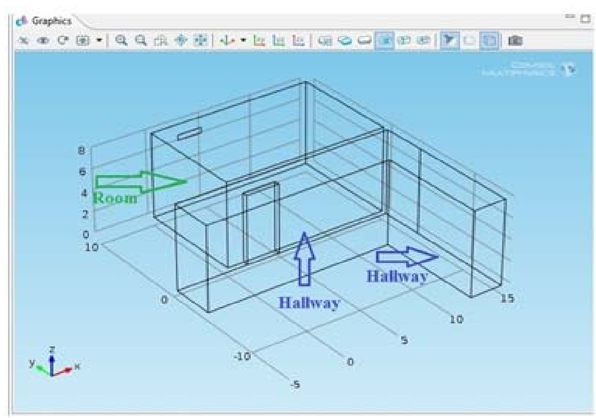

Figure-1. Model of building investigated.

The dimension of room as shown in Figure 1 is with the direction of x = 15 ft, y = 10 ft and z = 8 ft. While, the dimension of Hallway is consisted of 2 parts where hallway 1 with the direction of x = 20 ft, y = 4 ft and z = 8 ft. Whereas for hallway 2 with the direction of x = 3 ft, y = 10 ft and z = 8 ft. Additionally, for input the air supply velocity the dimension of inlet is made with the direction of x = 2.2 ft and z = 0.5 ft. In order to transmit the indoor air particle to hallway area, the dimension of

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door assigned as outlet is constructed with the direction of x = 2.5 ft and z = 6.5 ft.

Subsequently, this parametric study was carried out by perturbing the location of inlet air supply of the room model as in Figure-2 in the direction of x, y and z.

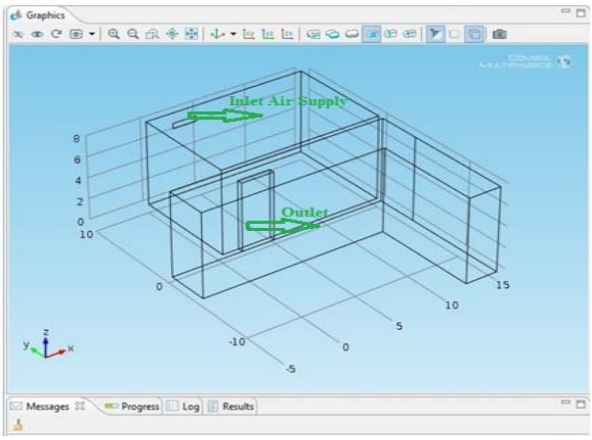

Figure-2. Room and its hallway model.

The x direction is the distance of inlet air supply from the left corner, y direction is the distance of inlet air supply from the door and z direction is the distance from the floor to the inlet air supply. For this study, the perturbation for x direction from 2.5 ft to 10.5 ft and z direction varies from 6.5 ft to 7 ft. While, y direction remains at 10 ft from the door. The setting up from these perturbations are as in Table-1.

Table-1. Perturbation values.

No. of Parametric Model	Inlet Air Supply Position (ft)			Inlet Air Supply Inputs (m/s)	Particulate Matter ≥ 0.3 µm
	x	y	z		
1	2.5	10	6.5	1	5000
2	2.5	10	7	1	5000
3	5.5	10	6.5	1	5000
4	5.5	10	7	1	5000
5	10.5	10	6.5	1	5000

From the Table-1 it shows that the inlet air supply inputs (m/s) and PM ≥ 0.3 µm are set up to 1 m/s and 5000 µm. This is aimed for generalize the air velocity of inlet air supply in order to obtain the significant effect from the perturbation of inlet location. Furthermore, the number of PM ≥ 0.3 µm is set up to 5000 for minimize the computational process of simulation.

RESULTS AND DISCUSSION

Once the input data for each perturbation was completed, the simulation of that model was carried out to visualise the airflow behaviour. The simulation results from each perturbation are illustrated as in Figures-3 to 7.

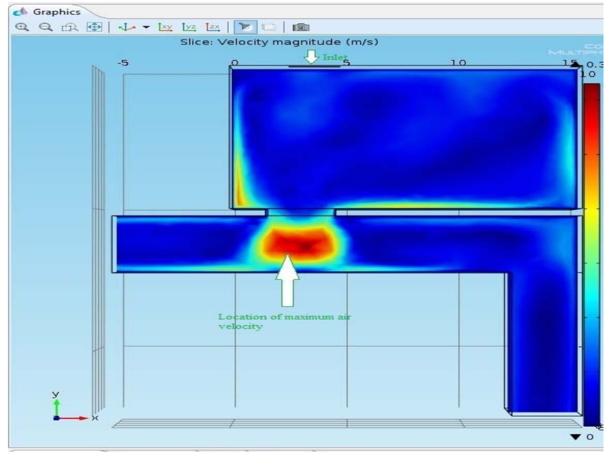

Figure-3. x = 2.5 ft, y = 10 ft, z = 6.5 ft.

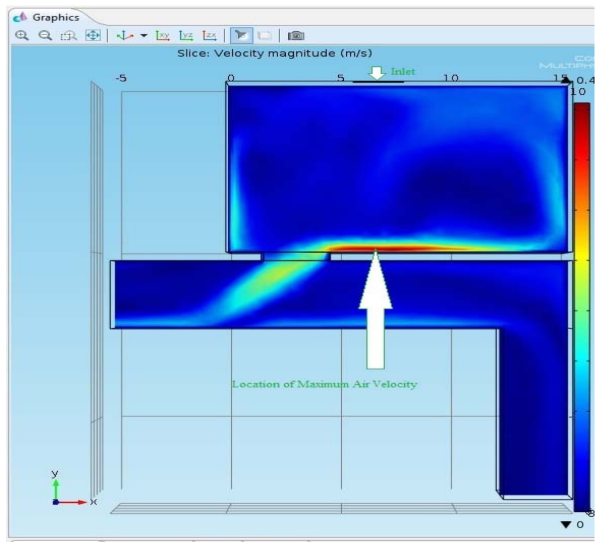

Figure-4. x = 2.5 ft, y = 10 ft, z = 7 ft.

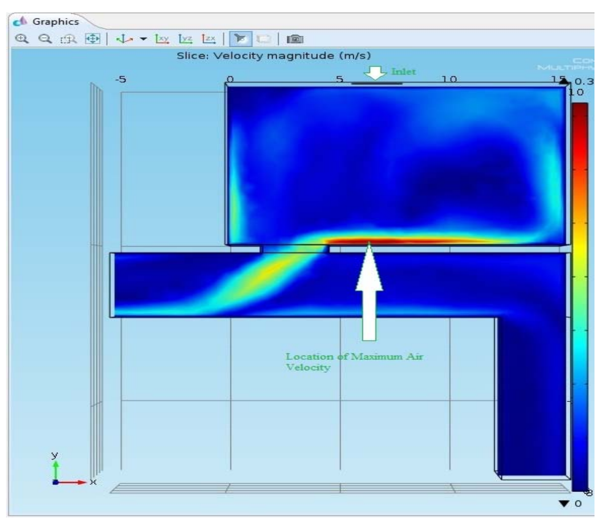

Figure-5. x = 5.5 ft, y = 10 ft, z = 6.5 ft.

VOL. 11, NO. 10, MAY 2016 ISSN 1819-6608
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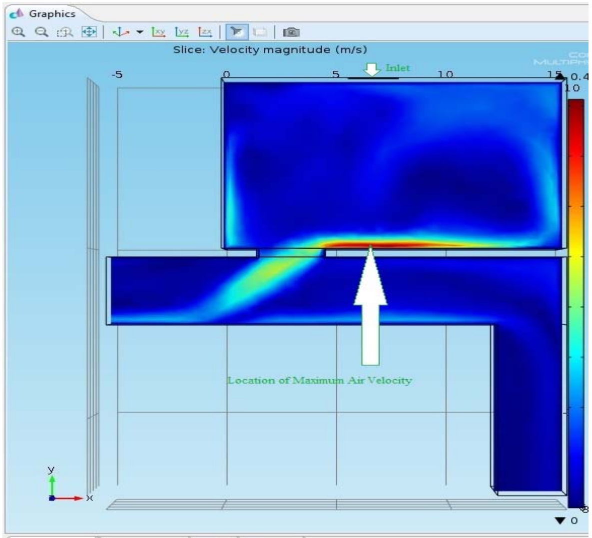

Figure-6. x = 5.5 ft, y = 10 ft, z = 7 ft.

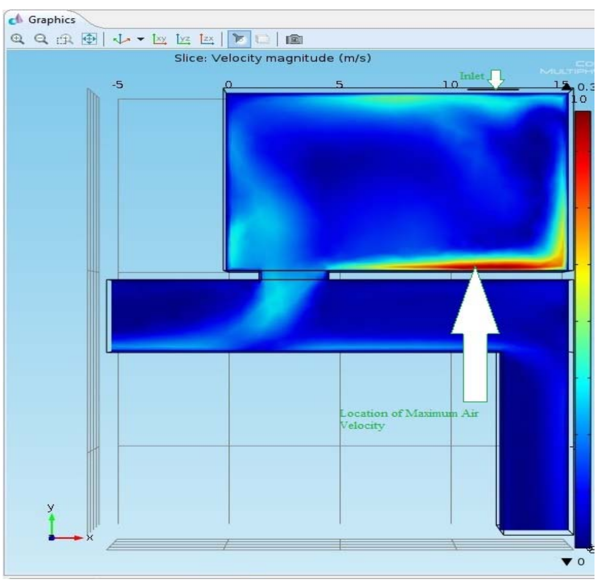

Figure-7. x = 10.5 ft, y = 10 ft, z = 6.5 ft.

From these figures, it shows that the displacement of inlet air supply position affects to the location of maximum value of air velocity distributed. The simulated air velocity of each simulation model was extracted and tabulated as detailed in Table-2.

Table-2. Simulated air velocity.

No. of Parametric Model	Simulated Air Velocity (m/s)
1	0.3147
2	0.3029
3	0.3614
4	0.4059
5	0.3847

The highest simulated air velocity is achieved through model 4 with the value of 0.4059 m/s. Furthermore, to assess the effectiveness of airflow behaviour and air velocity to dilute particles it is accomplished by using transmission probability function in COMSOL Multiphysics and the results are tabulated as in Table-3.

Table-3. Simulated particle transmission.

No. of Parametric Model	Transmission Probability (%)	
	Room	Hallway
1	40.48	59.52
2	56.12	43.88
3	55.72	44.28
4	61.06	38.94
5	57.44	42.56

Table-3 shows the transmission probability of each indoor air particle which is distributed both at room and at hallway. Transmission probability is defined as a possibility of a substance distributed from one place to another place (COMSOL Version 4.3, 2012). Subsequently, the table shows that model 1 performs better in transmitting particle as compared to other models. However, simulated air velocity for this model is lower as compared to model 4 as in Table-2. Since the position of inlet air supply of model 1 is in line with the door position which acts as discharge outlet, thus this position will facilitate the transmission of particles through the door to the hallway. This means that the effectiveness of inlet air supply is its position and barrier condition of a room. Since particle mass concentration is generally smaller in indoor environment, this approach is better than increasing ventilation rate (Brightman *et al.* 1996) (Jamriska and Morawska, 1996).

Additionally, to calculate the influence from the location displacement of inlet air supply towards the number of indoor air pollutants transmitted to the hallway it can be achieved by using the Equation 1.

Difference Values = [% Transmission probability of particle at hallway in Table 3 - % Transmission probability of particle at room in Table 3] (1)

Once the calculation is done, the results are tabulated as in Table-4.

Table-4. Influence of inlet air supply towards indoor air pollutants.

No. of Model	Inlet Air Supply Position			Difference values
	x	y	z	
1	2.5	10	6.5	+ 19.04 %
2	2.5	10	7	-12.24 %
3	5.5	10	6.5	-11.44 %
4	5.5	10	7	-22.12 %
5	10.5	10	6.5	- 14.88 %

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From the Table-4, it shows that the proper location designed for dilute indoor air particle effectively is achieved with position of x = 2.5 ft, y = 10 ft and z = 6.5 ft. Subsequently, to obtain the pattern of airflow performance in diluting indoor air particle is illustrated as in Figure-8.

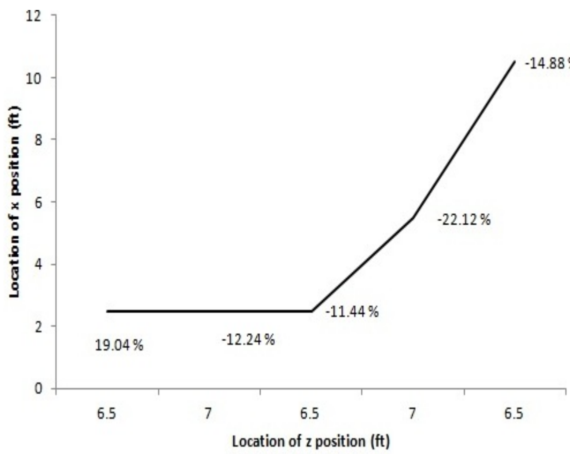

Figure-8. Variation of inlet location towards transmitted indoor air particle.

The Figure-8 shows the displacement of z position influenced to the performance of inlet air supply become more decrease to dilute indoor air particle as compared to the displacement of x position. This is because the displacement of z direction is inline with the direction of mass gravity. That means each of particle which is located at lower level is more easier to transmit to the hallway. This is due to each of particle has potential energy which is confine to the altitude of the object and it is proposed by equation 2.

$$EP = m.g.h \tag{2}$$

Where:

EP = Potential Energy (J)
m = Mass of the object (kg)
g = Acceleration due to gravity (m/s^2)
h = Altitude of the object (m)

CONCLUSIONS

The parametric study has successfully shown particle transmission solution by perturbing the location of inlet air supply. The study found that the selection of inlet air supply position and the barrier condition in the room are important elements to generate airflow behaviour for diluting the indoor air particles effectively.

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