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Comparison of Air Flow Distribution in the Building for Different Position of Air Return

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ABSTRACT

A modern building has requirements need to consider increasing the quality of the building. In design the building, fresh air, cooling, and heating is the important role to consider. The Heating, Ventilation and Air conditioning (HVAC) is most important part in building. Centralized system is the common use especially in large building. Usually, the system is using diffuser for air inlet and grille for air return. Therefore, the aim of this study is to determine the effectiveness of grilles position to distribute the cool air into building. The aims of this papers are to simulate three types of location grilles for a building. In addition, the number of diffusers and grilles are same for each type. RNG K-ε model was used as the turbulence model. The result show that different position will affect the air flow pattern due the different position of grille.

1. Introduction

HVAC system is an important part of system that can increase the performances and quality of the building. A HVAC system provides is to meet the requirement of comfort, cost, efficiency, and aesthetic appeal [1]. The cooling in building is important and need to improve day by day to provide comfortable indoor environment. The absence of comfort condition will disturb people and effect to health. According to ASHRAE Standard, thermal comforts are state of mind of the fulfilment of the thermal condition [2].

The two important factors for indoor environment comfortable are indoor air quality (IAQ) and thermal comfort. In thermal comfort, the basically consist of air humidity, air temperatures, mean radiant temperature, air velocity and activity of occupant. Based on ASHRAE standard the temperature and humidity ranges are comfortable to most people in large sedentary activity. In addition, air indoor quality and thermal comfort have significant impact to the occupant output productivity. The thermal comfort achieves by varying the condition of air supply. Based on the ASHRAE standard section, the design of thermal environment condition which required is to satisfy a

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specific percentage of the tenant of the space. Air indoor quality (AIQ) is state as cleanness of air in room with regard human health [3].

Air velocity is an important parameter in contributing thermal comfort. Without air velocity or stagnant air in indoor environments that are artificially heated may cause people to feel stuffy [4-6]. However, high air velocity in cool or cold environments may be perceived as a draught as people are particularly sensitive to these movements. ASHRAE standards recommend that air velocity should greater than 0.2 m/s [7]. Meanwhile, according to industry code of practice on indoor air quality 2010, air velocity should between 0.15 m/s until 0.50 m/s [8].

Therefore, in this paper present simulation of three of location of diffusers and grilles by using CFD. The simulation of each location is simulated by using ANSYS-FLUENT software. Grid independency test was carried out to ensure the best size of meshing and the accuracy of simulation result.

2. Methodology

2.1 Case Description

There are three cases with different location of grille for return air as shown in Figure 1. For the case 1, the grille location at the side, case 2 the grille at behind and case 3 at the frond and middle. The number of diffuser and grille are same for all three with diffuser are 24 and grille are 5.

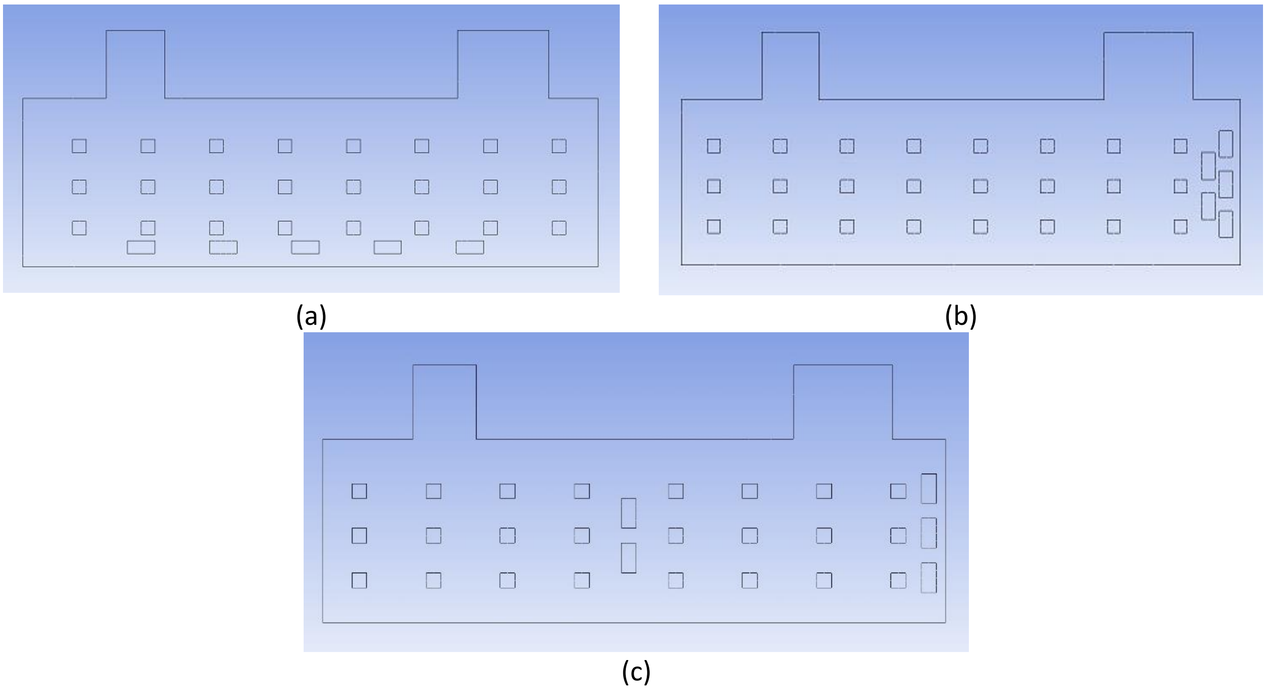

Fig. 1. (a) side, (b) behind and (c) front & middle

2.2 Modelling and Setup

Selected turbulence model was RNG K-ε model. The RNG K-ε model widely used for building simulation such in Ref. [9-11]. Numerical approach by using Finite volume method was applied to solve the governing equation as below:

In Eq. (1), the ρ, **V** and t represent the density of fluid, vector velocity and time respectively. The momentum equations in three components can be written as below,

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \boldsymbol{V}) = 0 \tag{1}$$

x-component

$$\frac{\partial}{\partial t}(\rho u) + \nabla \cdot (\rho u \boldsymbol{V}) = -\frac{\partial p}{\partial x} + \frac{\partial}{\partial x}\tau_{xx} + \frac{\partial}{\partial y}\tau_{yx} + \frac{\partial}{\partial z}\tau_{zx} + \rho f_x \tag{2}$$

y-component

$$\frac{\partial}{\partial t}(\rho v) + \nabla \cdot (\rho v \boldsymbol{V}) = -\frac{\partial p}{\partial y} + \frac{\partial}{\partial x}\tau_{xy} + \frac{\partial}{\partial y}\tau_{yy} + \frac{\partial}{\partial z}\tau_{zy} + \rho f_y \tag{3}$$

z-component

$$\frac{\partial}{\partial t}(\rho w) + \nabla \cdot (\rho w \boldsymbol{V}) = -\frac{\partial p}{\partial z} + \frac{\partial}{\partial x}\tau_{xz} + \frac{\partial}{\partial y}\tau_{yz} + \frac{\partial}{\partial z}\tau_{zz} + \rho f_z \tag{4}$$

In Eq. (2) to Eq.(3) p is static pressure, τ is shear stress and f is flux vector. Meanwhile, u, v, w are the x, y, z components of the velocity. The energy equation can be written as below:

$$\begin{aligned}\frac{\partial}{\partial t}\left[\rho\left(e + \frac{V^2}{2}\right)\right] + \nabla \cdot \left[\rho\left(e + \frac{V^2}{2}\right)\boldsymbol{V}\right] = \rho\dot{q} + \frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(k\frac{\partial T}{\partial y}\right) \\ + \frac{\partial}{\partial z}\left(k\frac{\partial T}{\partial z}\right) - \frac{\partial(up)}{\partial x} - \frac{\partial(vp)}{\partial y} - \frac{\partial(wp)}{\partial z} + \frac{\partial(u\tau_{xx})}{\partial x} \\ + \frac{\partial(u\tau_{yx})}{\partial y} + \frac{\partial(u\tau_{zx})}{\partial z} + \frac{\partial(v\tau_{xy})}{\partial x} + \frac{\partial(v\tau_{yy})}{\partial y} + \frac{\partial(v\tau_{zy})}{\partial z} \\ + \frac{\partial(w\tau_{xz})}{\partial x} + \frac{\partial(w\tau_{yz})}{\partial y} + \frac{\partial(w\tau_{zz})}{\partial z} + \rho\boldsymbol{f} \cdot \boldsymbol{V}\end{aligned} \tag{5}$$

where ∇ is vector operator, **V** is vector velocity, **f** is vector of body force per unit mass. It can be defined as below

$$\nabla \equiv \boldsymbol{i}\frac{\partial}{\partial x} + \boldsymbol{j}\frac{\partial}{\partial y} + \boldsymbol{k}\frac{\partial}{\partial z} \tag{6}$$

$$\boldsymbol{V} = u\boldsymbol{i} + v\boldsymbol{j} + w\boldsymbol{k} \tag{7}$$

$$\boldsymbol{f} = f_x\boldsymbol{i} + f_y\boldsymbol{j} + f_z\boldsymbol{k} \tag{8}$$

Namely, Eq. (1) to Eq. (5) are representing the governing equation for viscous flow which considers the transport phenomena of friction and thermal conduction. These equations are known as Navier-Stokes equation.

For grid generation, unstructured grid was applied to the model as shown in Figure 2. The boundary condition for diffuser is velocity inlet and outlet is pressure outlet. Summary of setup as shown in Table 1.

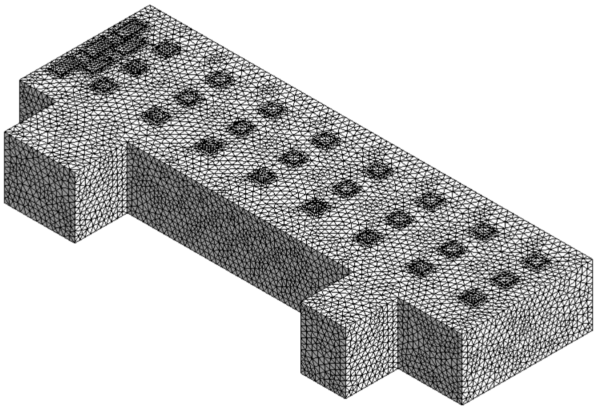

Fig. 2. Meshing for physical model

Table 1
Details setup

Items	Description	
Number of Meshing	Nodes	31811
	Elements	158266
Viscous Turbulence Flow	RNG K-ε model	
Boundary condition	Diffuser (supply air)	Velocity inlet
	Griller (outlet)	Pressure outlet
	Wall, ceiling, floor	adapted

2.3 Grid Independency Test

To ensure that the mesh used for the solver is independent of the size of the mesh, three size of mesh was tested. The Case 1 was selected for the testing. Details of meshing parameters as shown Table 2.

Table 2
Grid independency testing

Mesh	Number of nodes	Number or elements
1	50476	257416
2	35493	178409
3	20697	102749

The result of grid independency test for air velocity profile was plotted as shown in Figure 3. The result show that the Mesh 1 and Mesh 2 are close each other compared to Mesh 3. By comparing results from size of Mesh 1 and Mesh 2, Mesh 2 is more practical to use. Therefore, Mesh 2 will be for the other cases.

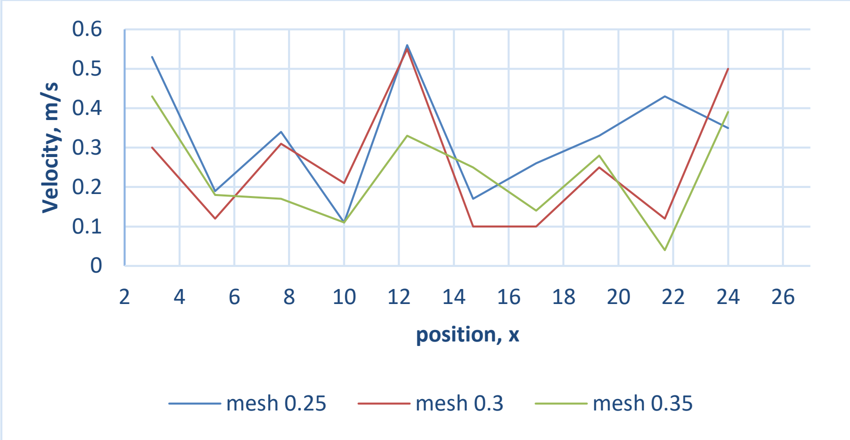

Fig. 3. Grid independency test for air velocity profile

3. Results

Figure 4, Figure 5, and Figure 6 show the air velocity distribution plotted from 1m height from the floor. Overall, most air velocity distributed more than 0.2m/s for the three cases. That means that air flow requirement for each case is satisfied as follow the ASHRAE Standard and Industry Code of Practice on Indoor Air Quality 2010 requirement. However, for Case 1, high velocity indicated at a few points (below diffuser) which is greater than 0.5m/s. That means is over the maximum Industry Code of Practice on Indoor Air Quality 2010.

In term of air flow pattern, Case 1 and Case 2 given more uniform distribution compared to Case 2. Position grille at behind for Case 3 indicate the air flow behaviour only higher at one part only which is near the grille. Comparing Case 1 and Case 2, air velocity more distributed well for case 3.

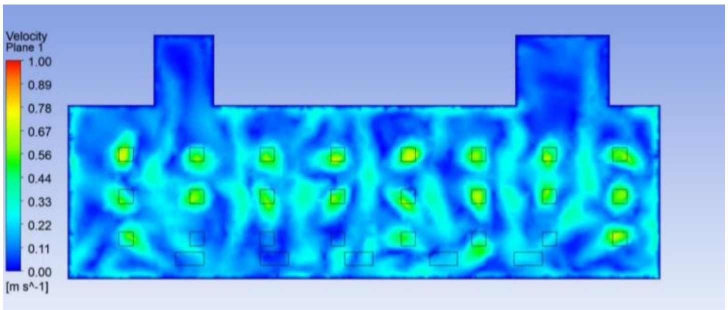

Fig. 4. Air velocity distribution for Case 1

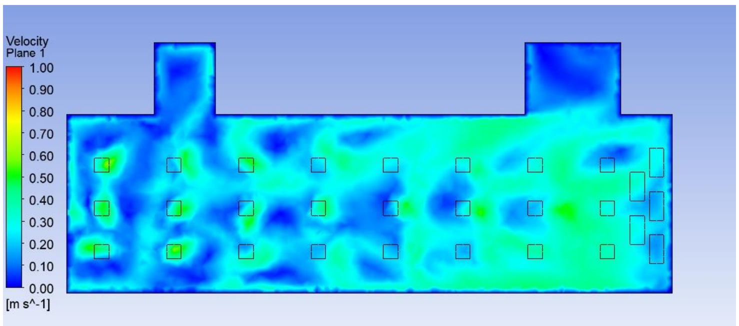

Fig. 5. Air velocity distribution for Case 2

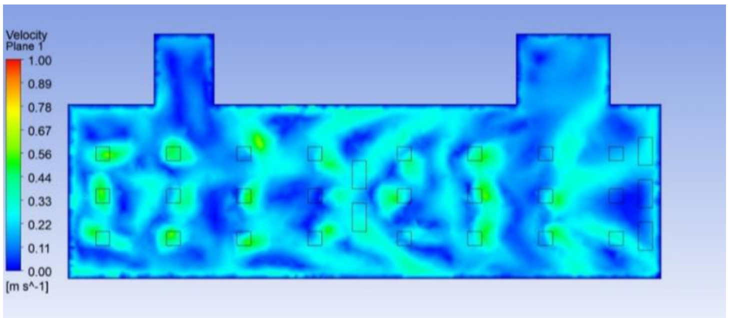

Fig. 6. Air velocity distribution for Case 3

4. Conclusions

Overall, from this study indicate the different position of diffuser and grille will affect air flow distribution for the area. For the large area, grille position required a few different points to get uniformly air flow distribution for the area. Therefore, Case 3 indicate the most effective air flow distribution compare Case 1 and Case 2.

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