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Evaluation of the Impact of Fan Coil Airflow Velocity on the Micron Particles Distribution in the Human Breathing Zone

M. Taheri[1], S. A. Zolfaghari[1]*, H. Hassanzadeh[1], M. Salmanzadeh[2]

[1] Department of Mechanical Engineering, University of Birjand, Birjand, Iran.
[2] Department of Mechanical Engineering, Shahid Bahonar University of Kerman, Kerman, Iran

ABSTRACT: Nowadays, most people spend their time in the interior spaces. Therefore, particulate pollutants in these spaces are serious threat to the human health. Hence, the investigation on distribution and deposition of particle pollutants in indoor spaces is important for assessing the indoor air quality. Due to the wide use of heating/cooling fan coils in the buildings, the effect of fan coil airflow velocity on the concentration of micron particles of 1, 10 and 100 microns in the breathing zone of seating (0.9 to 1.1 m) and standing (1.5 to 1.7 m) people has been studied in this article. For this purpose, by using the computational fluid dynamics and a developed code by the authors in OpenFOAM, the particle concentration is investigated in a room with a fan coil airflow velocity at 1.5 and 3 m/s. The results show that the large particles (100 microns) have not a significant effect on air quality and they settle down after about 10 seconds. In the other hand, the smaller particles (10 and 1 micron) have a major impact on ventilation conditions and they settle down after about 800 seconds. The results indicate that the fan coil velocity increases, also the results show that more particles are filtered by the filter in the fan coil by increasing fan coil velocity and the percentage of particles deposited on the floor reduced. For example, for 10 microns particles, by increasing fan coil velocity from 1.5 to 3 m/s, the percentage of deposited particles on the floor is reduced from 26% to 17%.

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1- Introduction

Nowadays, people spend the most of their time in buildings. Therefore, improving the air quality level has a great effect on the health and efficiency of individuals. Also, it is important to evaluate the amount of air pollutants to control the desirable air quality in the breathing zone [1].

On the other hand, although the fan coil heating/cooling systems are widely used all over the world, the effect of above system on the indoor air quality has not been investigated in the previous studies; Therefore, it is necessary to examine the indoor air quality and especially the distribution of particulate pollutants in ventilated space. Therefore, in the present study, the effect of fan coil outlet air flow rate has been investigated on the concentration of micrometer particles (1, 10 and 100 micrometers) and indoor air quality.

2- Model Space

The geometry of the present study is considered on the basis of reference [2]. So, the sample room is an office with 4 meters length, 3 meters width and 2.8 meters height. Also, a fan coil with the following dimensions is used for cooling the room: 1.2 meters length, 0.2 meter width and 0.4 meter height. The schematic of the room and fan coil location is presented in Fig. 1. The fan coil outlet air velocity is assumed to be 1.5 m/s and 3 m/s. In order to model the particulate pollutants, it is assumed that static particles are uniformly distributed at the initial time. Then, the particles dispersion and deposition are studied under the conditions of utilizing the mentioned fan coil cooling system.

3- Research Method and Governing Equations

In this study, an Eulerian–Lagrangian method is used to evaluate the concentration of indoor pollutant particles. In this method, airflow equations are initially solved in Eulerian approach. Then the particle transport equations are solved by using the Lagrangian approach on the basis of predicted airflow field. The mentioned equations are solved by pimpleFoam

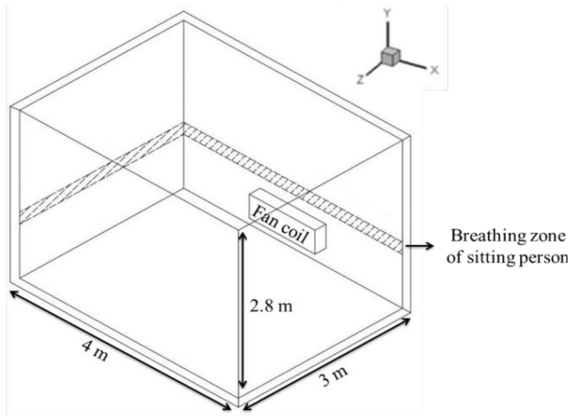
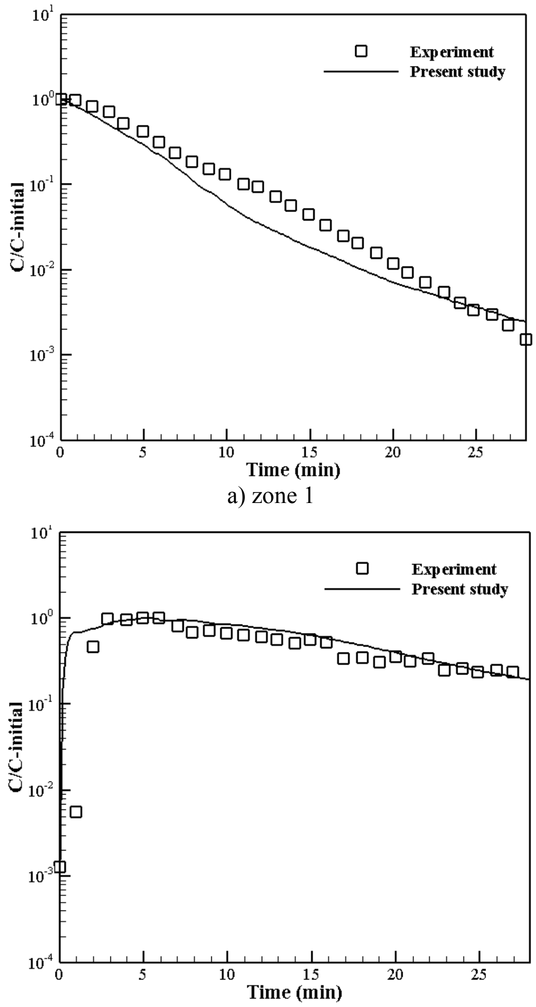


Fig. 1. Schematic of the sample room

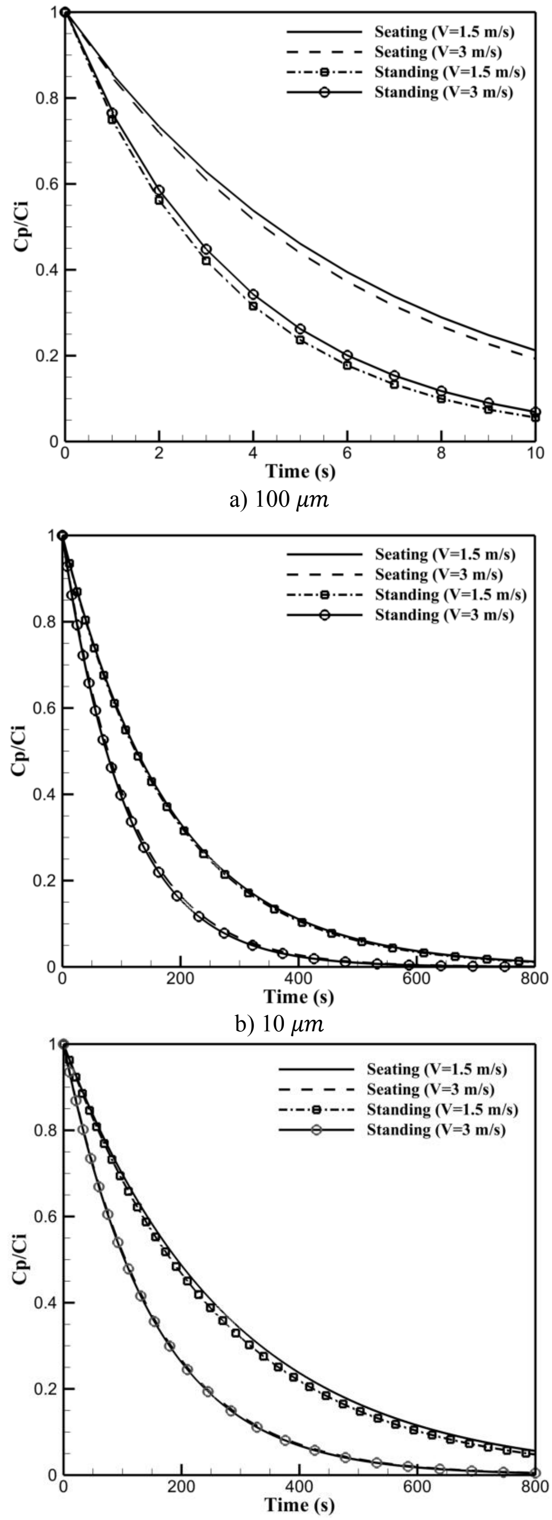
*Corresponding author's email: nozar@ssau.ac.ir



a) zone 1

b) zone 2

Fig. 2. Model validation against the result of Lu et al. [4, 5]



a) 100 μm

b) 10 μm

c) 1 μm

Fig. 3. The ratio of particles concentration to initial concentration in the sitting person breathing zone for (a) 100μm particles, (b) 10μm particles, (c) 1μm particles.

Computational Fluid Dynamics (CFD) code that developed by the authors in OpenFOAM.

For incompressible and steady flow with constant properties, the governing equations are as follows:

Mass conservation:

$$\nabla \vec{V} = 0 \tag{1}$$

Momentum conservation:

$$\rho\left(\vec{V}.\nabla\vec{V}\right) = -\nabla P + \mu_{\text{eff}}\nabla^2\vec{V} + \vec{s} \tag{2}$$

Energy conservation:

$$\vec{V}.\nabla T = \alpha\nabla^2 T + s_{\text{T}} \tag{3}$$

Also, Newton's second law is used to obtain the location and velocity of particles in space.

$$\frac{dx_P}{dt} = u_P \quad (4)$$

$$m_P \frac{du_P}{dt} = \sum F_i \quad (5)$$

That x_p, u_p and m_p are considered to be location, velocity and mass of each particle, respectively. Also,

$$\sum F_i = F_D + F_B + F_G \quad (6)$$

Which F_D is drag force F_B is buoyancy force, and F_G is gravity force [3].

4- Validation

In order to validate the developed CFD code, the concentration of particles is investigated in a two zone chamber. This experimental study is carried out by Lu et al. [4, 5]. The results of the present model is compared with experimental results of Lu et al. [4, 5] in Fig. 2. As it can be seen, the results show a good agreement with the experimental data.

5- Results and Discussion

The Fig. 3 shows the ratio of particles concentration to initial concentration in the sitting person breathing zone for particles with 1, 10 and 100 µm diameter. The mentioned figure indicates that the deposition of particles over the time follows an exponential function. The results show that large particles (100 microns) have not significantly affect the indoor air quality and they settle down after about 10 seconds. In the other hand, the smaller particles (10 and 1 micron) have a major impact on ventilation conditions and they settle down after more time (about 800 seconds). Also, the results indicate that by increasing the fan coil velocity, more particles have been filtered by the fan coil and the percentage of deposited particles on the floor has been reduced. For example, for 10 microns particles, by increasing fan coil velocity from 1.5 to 3 m/s, the percentage of particles deposited on the floor is reduced from 26% to 17%.

6- Conclusions

In the present study, the effect of fan coil outlet air flow rate was investigated on the concentration of micrometer particles (1, 10 and 100 micrometers) and indoor air quality. The results indicated that the particles settling time can be significantly affected by the particle size. Also, the results showed that increasing the outlet velocity of fan coil can lead to increase the number of filtered particle by fan coil system. Also, by increasing the fan coil velocity, the percentage of deposited particles on the floor reduced.

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