Indoor particle dispersion motion simulation

Shuo Zhao

School of Mathematics and Statistics, Hebei University of Economics and Business, Shijiazhuang, 050051, China

Abstract

Based on the more realistic situation, the simulated dispersion motion calculation model suitable for indoor particulate matter is re-derived. The basic parameters and force analysis of solid particles and droplet aerosol particles are used to simulate the motion of the particles. The velocity of these two kinds of particles at the same height is compared by the process of cell automata output simulation. The results show that the movement of micro-solid particles is more active and distributed at the same height, and the distribution of aerosol particles is mainly concentrated. In the lower part of the space.

Keywords

Indoor pollution particle diffusion numerical simulation cellular automaton.

1. Introduction

Indoor air pollution is actually not lower than smog. It is mainly divided into eight categories, including dust pollution, inhalable particulate matter pollution, nicotine pollution, kitchen fume pollution, indoor odor, bacteria, viruses and chemical pollution caused by decoration and decoration. For modern people, more than 70% of the time is indoors every day, especially for vulnerable groups such as infants and the elderly, the elderly, the weak and the sick, and the like, and the pollution of particulate matter is the most serious. We have studied the movement of suspended matter in indoor air as an example.

Therefore, we mainly focus on the study of respirable particles with a particle size of fewer than 50 microns, because these small-sized particles can float in the air for a long time, it is difficult to settle to the ground, and it is easy to be inhaled into the human respiratory tract, thus infecting various respiratory diseases. Or deposited in the lower respiratory tract (the smaller the particle size, the greater the hazard)

2. Particle motion calculation model

The free-falling particles and the droplet aerosol particles were separately modeled.

1. Analysis of free falling solid particles

(1) Force analysis in the air In the process of free fall of particles, the force received is very complicated, but in the case of the same particle size, the magnitude of the additional mass force, pressure gradient force, Magnus force, Saffman force and it's small, negligible relative to gravity and Basset force.

In the case where only the Basset force is considered in the falling process, that is, other forces are negligible, the drag force can be expressed as：

$$F_t = \frac{1}{8}\pi C_t d^2 \rho \left|u - u_p\right| \left(u - u_p\right)$$

Where d is expressed as the particle size of the encouraging particle, u is the velocity of the air, and C_t is the drag coefficient of the particle, which is expressed as：

$$C_t = \frac{24}{\mathrm{Re}} f\left(\mathrm{Re}_p\right)$$

Where Re_p is the particle Reynolds number and the expression is：

$$\mathrm{Re}_p = \frac{\rho d \left| u - u_p \right|}{\mu}$$

(2) Basic parameters Particle size, particle shape, and particle density are the basic parameters in the calculation of particle diffusion model.

①Particle size: Particles in the air are generally not standard spheres, so for the definition of general shape particle size, we generally Both are represented by the equal volume of the standard particles, i.e.

$$D_V = \left(\frac{6V}{\pi} \right)^{\frac{1}{3}}$$

②Shape: By looking up the relevant literature, in the process of studying particle motion, the research object is generally assumed to be spherical particles.

③The higher the density of the particles in the same volume, the direct influence on the sedimentation velocity of the particles, so the density of the particle flow is expressed as：

$$\rho_p = \frac{M_P}{V_P}$$

(3) The calculation method for the free settling velocity of the particles can be calculated as follows

The value of the Reynolds number $Ar = \frac{d_p^3(\rho_p - \rho_g)\mathrm{g}}{\mu^2}$ of the particle is calculated by Re_p, and the value of the velocity is calculated by the formula $v_t = \frac{\mu \mathrm{Re}_p}{d_p \rho_g}$.

3. Analysis of droplet aerosol particles

(1) Classical force model aerosol particles and free-falling particles are significantly different, mainly including their own gravity, drag force, Basset force, Saffman force, Brown force, thermophoretic force and so on.

Gravity

$$G = mg = \frac{\pi}{6} d_p^3 \rho_p g$$

Drag force

$$F_T = \frac{18\mu}{\rho_p d_p^2 C}\left(u - u_p\right)$$

Basset force

$$F_{Bt} = \frac{3}{2} d_p^2 \sqrt{\rho \mu \pi} \int_{-\infty}^{t} \frac{d\left(u - u_p\right) \big/ dt}{\sqrt{t - \tau}} d\tau$$

Saffman force

$$F_s = 3.084 \frac{\rho v^{\frac{1}{2}}}{\rho_p d_p} \sqrt{\left| \frac{du}{dy} \right|} \left(u - u_p\right)$$

Brown force

$$S = \frac{216 v \sigma T}{\pi^2 \rho d_p^5 \left(\frac{\rho_p}{\rho}\right)^2 C}$$

Thermophoresis force

$$F_{Th} = -\frac{6\pi d_p \mu^2 C (K + CKn)}{\rho (1+3CKn)(1+2K+2CKn)} \frac{1}{m_p T} \frac{\partial T}{\partial x}$$

(2) Characteristics of aerosol particles

① Droplet size distribution and its corresponding initial velocity: the data obtained by the experimental method test, about 45% to 80% of the droplet size is below 100 microns, about 25% to 45% of the particle size is Under 50 microns, the droplets of different particle sizes were observed and tested.

② Particle concentration: Some studies have used the interference imager to test the particle concentration of the droplets, coughing 2.4~5.2 microns, speaking 0.004~0.223 microns.

Table 1. The finalized different snout behaviors

Type of mouth and nose behavior	Aerosol particle size range (μm)	Initial velocity (m/s)
Talking	1~20	2~20
Coughing	1~20	10~28
Sneezing	1~50	25~45

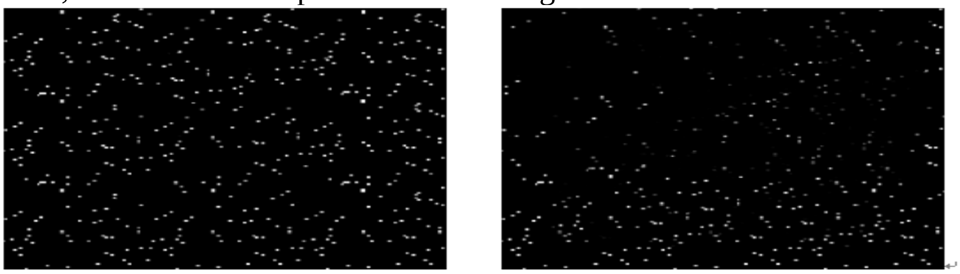
(3) Simulation of the motion diffusion model of aerosol particles The velocity calculation formula for aerosol particles at any time is $v = \sqrt{\frac{KTC}{6\pi\eta d_p t}}$, and v0 is obtained.

4. Cellular automaton simulates scattered motion

By initializing the mass point, the basic parameters of the particle motion are substituted into the model. During the simulation process, the energy of the aerosol particle at the initial moment is calculated, and the energy conservation is combined with the force analysis, and then the next moment is moved to all directions. Probability, the formula is as follows:

$$\exp\left(\frac{-\Delta E}{kT}\right) \Big/ e$$

When the force on the particles gradually becomes smaller, then update the position of the particle points, repeat the above steps, output the dynamic simulation process animation and the total energy of each time node, and obtain a comparison chart during the movement:



(a) (b)

Fig. 1 (a) Free falling solid particle motion simulation; (b) Motion simulation of aerosol particles

It can be seen from the above figure that the free-falling solid particles are more widely distributed in the same height range.

5. Conclusion

In this paper, indoor solid particles and droplet aerosol particles are taken as the main research objects, and the motion simulation models of these two kinds of particles are respectively established. Finally, the diffusion results are compared by the process of cellular automata output simulation. The results show that microscopic heights are the same. The movement of solid particles is more active and more widely distributed, while the distribution of aerosol particles is mainly concentrated in the lower part of the space.

Based on a large number of mathematical physics models, numerical simulations and research status at home and abroad, this paper establishes the force and motion model of free-falling solid particles and final aerosol particles. The model can be applied to air-conditioned rooms and can be inhaled in the treatment room. Application in the particulate matter has a good control effect on indoor environmental pollution.

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