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Research on particle penetrate through single crack based on CFD

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Abstract: *Particle pollutant is the prime pollutant of most cities in china, the tiny particle accumulated lots of harmful substance, and it is the carrier of bacteria, revealing the Mechanism of particle transport has an important meaning on controlling the indoor particle pollutant and disease prevention. This article sets up the model of particle penetrating the building envelope based on mathematics modeling, this model takes the pressure difference between indoor and outdoor(air change rate in rooms), crack depth, crack height and particle size as the input parameters and using the CFD to do the simulation analysis , drawing a conclusion.*

Keywords: *particle; crack; penetration rate; CFD*

1. Introduction

In recent years, many research conclude that indoor environmental pollution caused by particle have unknown damage in residential buildings [1-3], public welfare buildings, commercial buildings with central air-conditioning system. The tiny particle not only supply the condition for air pollution growing ,but also carry lots of Bacteria and moulds due to its strong surface activity, so the IAQ condition have an important effect on human health. The research show that if people stay in particle long [4], it will have a big effect on human heath. In order to changing the IAQ, we need to deeply understand the mechanism of particle transporting indoor and outdoor, master the regular characteristics through testing and theory, so we can get the specific control measures and wiping out or relieving the damage caused by particle indoor.

2. Setting up Model

2.1 Basic model

As the FIGURE 1 shows, the crack length(W) is the longest, and crack height is the least. the crack whose direction is keeping with airflow direction is deemed to crack depth(Z).

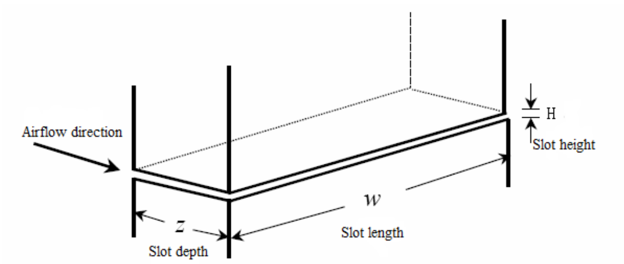

Figure 1: Three-dimensional display picture of crack.

The effect of particle penetrating the building envelope is expressed by penetration rate P, which is defined as the particle density before penetrating the building envelope to the particle density after penetrating the building envelope ratio. When the air penetrating the building envelope, due to the

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effect of gravity sedimentation, Brownian diffusion, inertial impaction, the particle in air will subside on the slot surface, so the quantity of particle which getting into indoor will reduce, namely the penetration rate will change litter.

The process of particle penetrating building envelope is effected by three mechanism: gravity sedimentation, Brownian diffusion, inertial impaction. When the error is not big, we think the subsiding mechanism is mutual independence. When the three mechanism work on the particle, the penetration rate is [5]:

$$P = P_g P_d P_i \tag{1}$$

P_g —the penetration rate by gravity sedimentation; P_d —the penetration rate by Brownian diffusion; P_i —the penetration rate by inertial impaction.

As to the crack, the difference of pressure between both sides of crack is litter than 10Pa, the condition of fluid is laminar flow, and the particle which subsides by inertial impaction also can subside by gravity sedimentation, so the above formula is also writing as:

$$P = P_g P_d \tag{2}$$

The penetration rate by alone mechanism is formulated specifically, so when the radius of particle is confirmed, we can know which mechanism plays a leading role ,this will have a big help to research.

2.2 Initia conditions and boundary conditions

The density of particle in this article is 1000kg/m3, the radius of particle is 0.01μm to 10μm, due to the software limitation, we simulate by divide the particle size into many parts: 0.01μm, 0.02μm, …, 0.09μm; 0.1μm, 0.2μm, …, 0.9μm; 1μm, 1.2μm, 1.4μm, …, 10μm. The penetration rate is the inlet particle quantity to the outlet particle quantity ratio, so we can get the rule of penetration rate changing with radius of particle.

The simulation in this article uses the following assumption [6]:

The effect of force to particle except the air flow force is ignored. Ignoring the effect of particle to the laminar flow, this is because the particle volume fraction in the building environment is little enough, so the effect of subsiding velocity to the laminar flow is little enough;

The heat transfer between air and particle is ignored;

The air indoor is incompressible;

When the particle meets the wall, it will be captured by wall;

There is no collision, condensation, chemical reaction between particle , the particle size is invariable;

All the particle is spherical, slippy particle.

The boundary condition is as following:

Inlet: first kind boundary condition, the inlet pressure and temperature will introduce in following article;

Outlet: pressure outlet;

Wall: no slip, when the particle meet the wall, it will be captured by wall;

All the flowing kind boundaries (velocity inlet) are escape boundary condition.

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3. The Result of Simulation and Analysis

3.1 The effect of pressure difference to the penetration rate

When the inlet temperature T=303K, z=3cm, W=20cm, the crack height is same, we simulate the rule of penetration rate changing with particle size in different pressure difference.

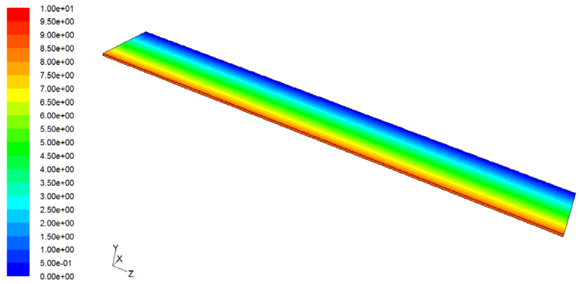

Figure 2: H=1mm, ΔP=10PA, air pressure figure of crack.

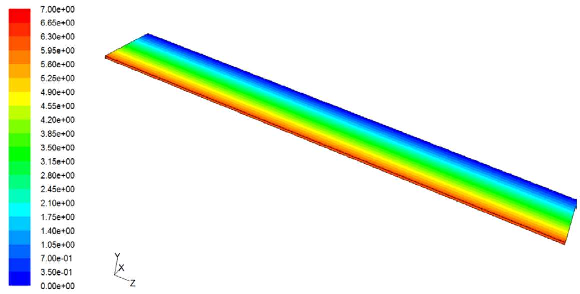

Figure 3: H=1mm, ΔP=7Pa, air pressure figure of crack.

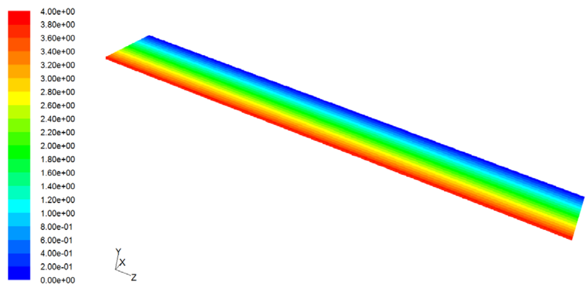

Figure 4: H=1mm, ΔP=4Pa, air pressure figure of crack.

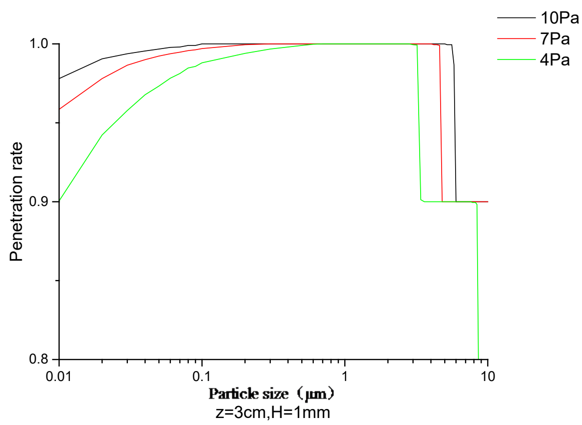

Figure 5: H=1mm, the rule of penetration rate changing with particle size in different pressure difference

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As the FIGURE 5 shows, the different pressure difference have a big effect on the penetration rate, the particle penetration rate is above 0.8 in all particle size. When the H=1mm, and the radius is 0.1μm to 3.2μm, the particle penetration rate is nearly 1. When ΔP=4Pa, d＞8.6μm, the penetration rate is litter than 0.8. The different pressure differences have a big effect on the penetration rate of big particle size particle. When the pressure difference is changing litter, the big particle size particle is effected by gravity sedimentation easily, so the penetration rate changes litter.

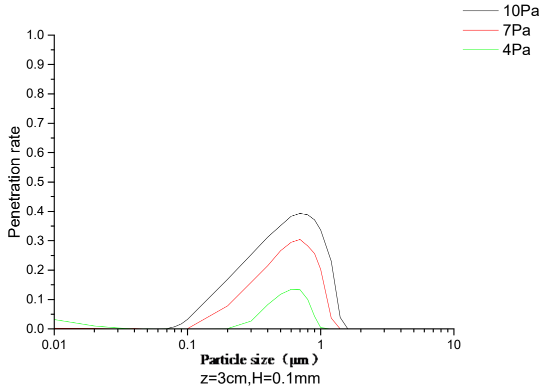

Figure 6: H=0.1mm, the rule of penetration rate changing with particle size in different pressure difference

As the FIGURE 7 shows, when H =0.1mm, ΔP＝4Pa, the penetration rate is nearly litter 0.1 in all range of particle size. When ΔP＝7Pa, the biggest penetration rate is litter than 0.3. As the figure 2 to figure6 show we can get the bigger slot height and the bigger pressure difference between both sides of crack, the bigger penetration rate. When the H is litter than 0.1mm, the ΔP is litter than 4 Pa; the particle can not penetrate the crack nearly.

3.2 The effect of crack depth to the penetration rate

When pressure difference ΔP is 10 Pa, the inlet air flow temperature T=303K, H=1mm, W=20cm, the crack depth is different, we simulate the rule of penetration rate changing with particle size. The pressure contour of each air flow is shown in FIGURE 7 to FIGURE 8. The FIGURE 9 shows the rule of penetration rate changing with particle size in different crack depth.

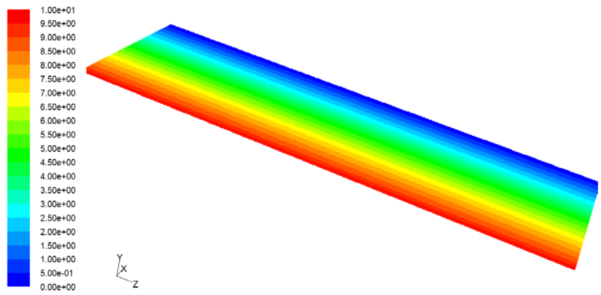

Figure 7: Z=6cm, ΔP=10Pa, Air pressure figure of crack

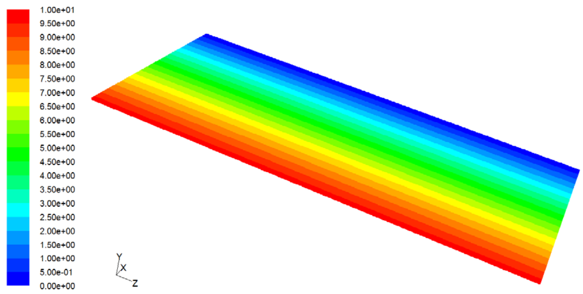

Figure 8: Z=9cm, ΔP=10Pa, air pressure figure of crack

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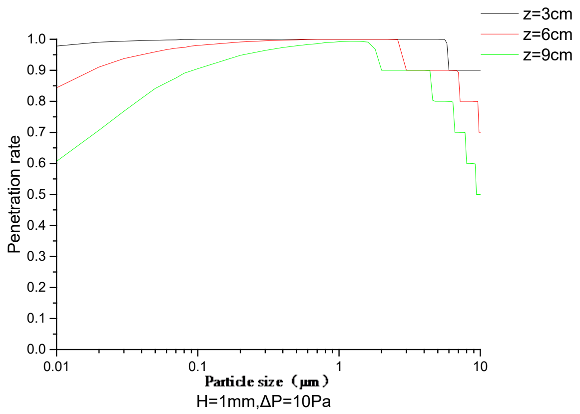

Figure 9: Z=1mm, ΔP=10Pa, air pressure figure of crack

As the FIGURE 9 shows, we can get the bigger crack depth, the litter penetration rate. When the radius is 0.4 to 1.6μm, the penetration rate is nearly 1 in different crack depth. When the particle size is bigger than 3μm, the penetration rate difference of different crack depth is obvious, the bigger crack depth, the litter penetration rate. This is because the gravity sedimentation has a big effect on the big radius particle, so the particles subside on the wall before getting the outlet. When z=9cm, the particle size is bigger than 10μm, only half particle can penetrate the crack.

3.3 The effect of crack height to the penetration rate

When pressure difference ΔP is 10 Pa, the inlet air flow temperature T=303K, z=3cm, W=20cm, the crack height is different, we simulate the rule of penetration rate changing with crack height. The rule of penetration rate changing with crack height is shown in FIGURE 10.

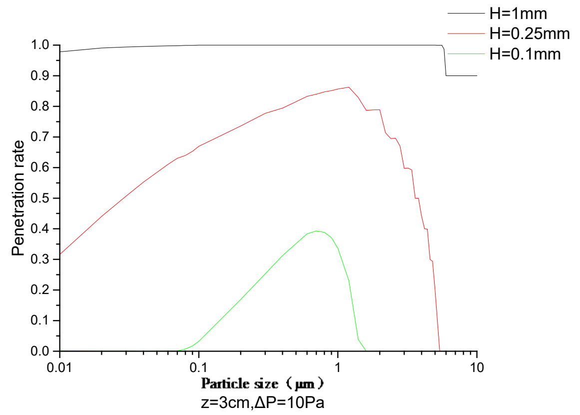

Figure 10: Z=1mm, ΔP=10Pa, air pressure figure of crack

As the FIGURE 10 shows we can get the penetration rate of particle whose radius is 0.5 to 1μm is biggest in all range of particle size, this is because the bigger and litter radius particle is effected by gravity sedimentation, Brownian diffusion and subside on the slot surface. When the crack height is bigger than 1mm, the penetration rate is nearly 1. When the crack height is 1mm, the penetration rate of particle whose radius is 0.01 to 10μm is bigger than 0.9, the crack height have a big effect on the penetration rate. As the figure shows, when H=0.25mm, the penetration rate of particle whose radius is 0.4to 1.4μm is bigger than 0.8; when H=0.1mm, the penetration rate of particle whose radius is 0.7 μ m is about 0.4.

4. Conclusion

The different pressure differences have a big effect on the penetration rate, and have a bigger effect on bigger radius particle. When the pressure difference changes litter, the bigger radius particle is effected by gravity sedimentation so the penetration rate changes litter. The litter pressure difference, the litter penetration

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rate. When H =0.1mm, ΔP＝4Pa, the penetration rate is nearly litter 0.1 in all range of particle size. When the H is litter than 0.1mm, ΔP is litter than 4Pa; the particle can not penetrate the crack nearly.

The bigger crack depth, the litter penetration rate. When the radius is bigger than 3μm, the effect of different crack depth that affect penetration rate is obvious, the bigger crack depth, the litter penetration rate. This is because the gravity sedimentation has a big effect on the big radius particle, so the particles subside on the wall before getting the outlet.

The penetration rate of particle whose radius is 0.5 to 1μm is biggest in all range of particle size, this is because the bigger and litter radius particle is effected by gravity sedimentation. Brownian diffusion and subside on the slot surface. When the crack height is bigger than 1mm, the penetration rate is nearly 1. The crack height has a big effect on the penetration rate in all range of particle size.

Acknowledgment

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