Study on Influence factors of Purification efficiency of wall absorbing haze automatically

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Abstract. A new type of wall absorbing haze automatically was presented based on industrial architecture. The purification efficiency of wall absorbing haze automatically was simulated and analyzed by Fluent. A particle trajectory analysis model based on Lagrange method was established. RNG k-ε turbulence eddy viscosity model was used to analyzing air flow. The momentum and turbulence equations were dispersed by the two order upwind scheme. SIMPLE algorithm was used to calculate the coupling solution of pressure and velocity. The variation of particle concentration and air pressure in wall absorbing haze automatically were simulated. The results show that the concentration change of particles in wall absorbing haze automatically is mainly affected by the adsorption of the adsorbents. The resistance that wall absorbing haze automatically acts on the air is affected by the change of air pressure. And then it affects the volume of induced ventilation of the wall. So, it has an important effect on the effect of air purification of wall absorbing haze automatically.

1. Introduction

Because of haze weather, people's quality of life and health are seriously threatened [1]. As a new way to remove haze, wall absorbing haze automatically has the characteristics of energy saving, convenient operation and good economy. And it has a good prospect in improving the indoor air quality of buildings. When air flows through the wall, some of particles deposited in the airflow channel, and some are captured by the adsorbents. Therefore, the indoor air affected by haze can be greatly purified. Its diagrammatic sketch is shown in the Fig. 1.

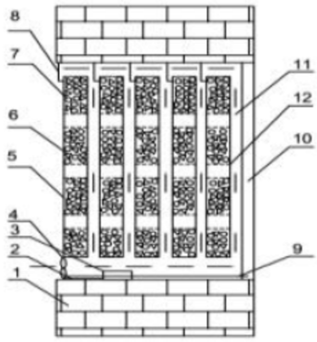

Figure 1. Diagrammatic sketch of structure of wall absorbing haze automatically
1—Wall, 2—Wire, 3—Battery, 4—Fan, 5—Metal mesh, 6—Adsorption material, 7—Phase Change material, 8—Bracket, 9—Wire, 10—Solar panel, 11—Airflow channel, 12—Hardware cloth.

During the day, the power generated by solar panels is provided to the fan, and the fan rotates to extract indoor air into the device. When air flows through the air passage, the particles in the air are absorbed by the adsorbent and the air is purified. At the same time, the phase change material in the wall is heated by radiation and convection, and the solar energy is stored in the phase change material, because the temperature of the solar panels rises in the sunlight.

At night, the fan stops working. Because the phase change material in the wall contains heat, it can heat the air in the air passage. The natural convection of the air in the device can be realized, and the function of purifying the air of the wall can still be realized, and there is no noise, no influence on people's rest.

When the weather is sunny, solar panels can store battery power. Under the weather of insufficient solar energy, the battery can provide power to the fan, so as to realize the function of purifying air by the device.

At present, indoor air purification is mostly based on air conditioning and air supply system, or the equipment removing haze is placed directly in the building. It is rare to use building envelope to remove haze [2]. Some scholars put forward the breathing wall is to directly intercept particles in the direction of air flow through the filter materials filled in air passage [3]. Wall absorbing haze automatically does not directly intercept particles passing through the air passage. The adsorption heat storage modules are arranged on both sides of the channel of the wall. The wall captures particles through the adsorbents, so as to achieve the purpose of purifying air. This paper studies the purification efficiency of Wall absorbing haze automatically when only placing the adsorption modules.

2. Differential equation of simulation of airflow

In the process of simulation, the flow area is divided into one small control units. We assume that the air state in each units is the same, and the air in each unit is affected by its surrounding elements. The motion characteristics of each unit satisfy the continuity equation, momentum equation and other related physical quantities transport equations. These equations satisfy the law of conservation of energy, which can be expressed as equation (1) [4].

$$\frac{\partial(\rho\varphi)}{\partial t}+\frac{\partial(\rho\varphi u_i)}{\partial x_i}=\frac{\partial^2(\Gamma_\varphi\varphi)}{\partial x_i\partial x_i}+S_\varphi \tag{1}$$

In the formula, ρ is the density of the airflow, μ_i is the velocity component of the airflow, Φ is the air quantity controlled by transport equation, and Γ is the diffusivity of the corresponding air. The first item on the left is the unsteady state term of the transport equation, and it represents the amount of air volume that the transport equation controls in a unit time. S_φ is the endogenous term, and it represents the change rate of air volume increased or reduced that is controlled by transport equation.

On the left is convection, and it represents the total volume of air passing in and out the units under relative force. $\partial^2(\Gamma\phi)$ is the diffusion term, and it represents the total volume of air at the control boundary passing in and out the units [5].

In this paper, RNG k-ε turbulent eddy viscosity model based on Lagrange method (RANS) is applied to simulate the air flow in wall absorbing haze automatically. Using the Lagrange method based on mass points tracking, we decompose the physical quantity studied (airflow) into a time mean and a pulsation. Its expression is equation (2) [6].

$$\Phi(t)=\frac{\int_{\Delta t}\Phi(t)dt}{\Delta t}+\varphi^{`}=\langle\Phi\rangle+\varphi^{`} \tag{2}$$

In the formula, $[\Phi]$ is the average air volume during the time, $\Phi^{`}$ is the pulsation quantity of the instantaneous value of air volume deviating from the mean at any time.

3. The process of air percolation in adsorbents

Because the internal structure of the adsorbents is more complex than that of the air passages, the air flows very slowly after penetrating the adsorbents. In this case, we can use volume averaging method to solve the average velocity of air infiltrated into the adsorbents. The volume averaging method assumes that there is no turbulent flow in the adsorbents, and the volume average velocity of the air is solved by regarding the interior of the adsorbents as a pure fluid space. Compared with the pure fluid, the control equation of volume averaging method has more than one resistance source of the adsorbents to air flow [7].

$$S_{porous,i}=-\left(\frac{\mu}{C_1}\mu_i+\frac{C_2\rho}{2}|u|u_i\right) \tag{3}$$

In the formula, μ is the air motion viscosity, C_1 is the viscous drag coefficient. C_2 is the inertia drag coefficient, D_b is the average particle size of filling materials of the adsorbents, and α is the porosity of the adsorbents[8].

The formula for calculating viscous drag coefficient and inertia drag coefficient is equation (4).

$$\frac{1}{C_1}=\frac{150}{D_b^2}\frac{(1-\alpha)^2}{\alpha^3}\quad,\quad C_2=\frac{3.5}{D_b}\frac{(1-\alpha)}{\alpha^3} \tag{4}$$

4. Establishment and simulation of wall absorbing haze automatically

4.1 The model of wall absorbing haze automatically

In this paper, a three-dimensional wall model is established by Fluent. Reference to the dimensions of the load-bearing wall [9], the size parameters of the model are selected as: the height of the wall is 1.8m, the width of the wall is 1m, the thickness of the wall is 0.19m. The height of the adsorption module is 1.7m, the width is 1m, the thickness is 0.025m. The size of the air inlet and outlet are the same, the length is 1m, the height is 0.05m, the width is 0.05m.

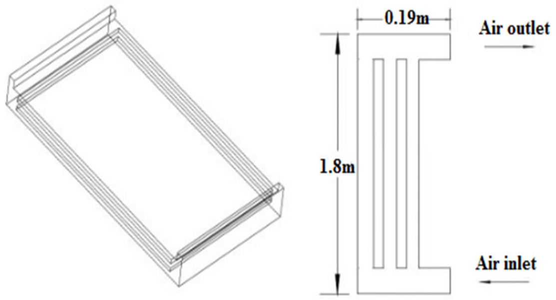

Figure 2. Diagrammatic sketch of the model of wall absorbing haze automatically

On the left of the Figure 2 is a three-dimensional effect map of wall absorbing haze automatically, and the right side is the wall side view. There are three airflow channels in the wall, whose width is 30mm. The left and right sides of the adsorption module are adhered to the wall surfaces, and the top and bottom surfaces are all 50mm from the wall surfaces. The air inlet and outlet are respectively installed on the upper and lower ends of wall absorbing haze automatically. When air enters the wall, it flows through three airflow channels. Particles mixed in air deposit in the channels or are captured by the adsorbents, so as to achieve the effect of air purification.

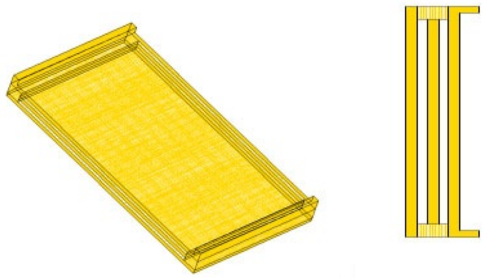

Figure 3. Grid partition schematic diagram of the model of wall absorbing haze automatically

The computing area (the airflow passages) of wall absorbing haze automatically is meshed in the form of Hex-Map. We set the entrance boundary condition of the wall for velocity inlet and set the export boundary for outflow. The wall model after division is shown in Figure 3.

4.2 Simulation and analysis of the change of particles concentration

In the haze weather, the average concentration of particles in the air is at 150μg·m^{-3} to 260μg·m^{-3}. Most of the particles concentration is around 200μg·m^{-3}, and a very small fraction of the particles concentration is higher than 300μg·m^{-3} or lower than 150μg·m^{-3} [10]. In the simulation, we set the particles concentration for 200μg·m^{-3} and set the velocity of movement of the particles for 0.05m·s^{-1}. The influence factors of gravity are selected. The pressure is a standard atmospheric pressure, and it is dispersed by the two order upwind way.

As can be seen from Figure 4, most of the particles that are purified in the air are mainly captured by the adsorbents. Only a small part of particles deposited in the airflow passages. The concentration of particles changed immediately after entering the wall. The change is most obvious, especially at the bend of two adsorption modules. In the first airflow passage on the right side of the wall, the particles concentration changed more evenly, decreasing gradually. In the airflow passage of the wall middle, the particles concentration decreased from about 190μg·m^{-3} directly down to about 170μg·m^{-3}.The reason for this large decline is that the two sides of the particles are both adsorption modules. During the collision between two parts, quite a few particles are captured by the adsorbents.

In the airflow passage on the left side of the wall, the change of particles concentration was not obvious. Basically, it flowed directly through the passage along with the airflow. This is because that the particles gradually diverted into three strands and its velocity was gradually decreasing. The velocity of particles flowing to the left passage of the wall is far lower than that in the other two airflow passages. So, there are fewer collisions between the particles and the wall surfaces. Both the deposition efficiency and the capture efficiency are relatively low. Therefore, the change of the particles concentration in this passage was not obvious on the whole.

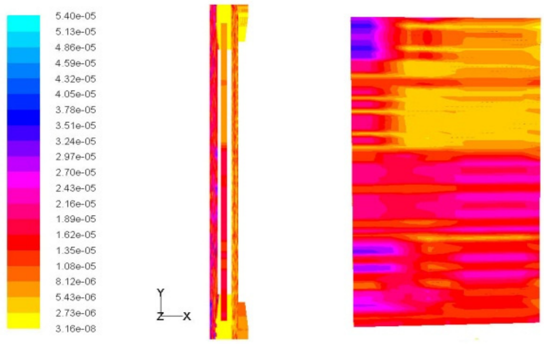

Figure 4. The change of the particles concentration in wall absorbing haze automatically

4.3 Simulation and analysis of the change of the airflow pressure

The air pressure has an important influence on the effect of removing haze of wall absorbing haze automatically. In the simulation, we set the pressure at the entrance of wall absorbing haze automatically for a standard atmospheric pressure. The results are shown in Figure 5. After the airflow entered the wall, its pressure value must change. The pressure loss is mainly composed of the local resistance loss of air in the wall entrance and the passage bend, the pressure drop of air flowing through the adsorbents and the drag loss of air in the passages.

From Figure 5, we can see that the change of the airflow pressure was more obvious near the entry and exit of the wall. The change in the vertical passages was not remarkable. The change of airflow pressure affected the resistance of the wall to the air entering into it, and it prompted the airflow velocity to produce a corresponding change. And further it affected the volume of ventilation induced by the wall. Moreover, the change of airflow pressure directly affected the percolation process of airflow in the adsorbents. As a result, the capture efficiency of the adsorbents was changed. Consequently, the pressure change of airflow in t wall absorbing haze automatically has an important influence on the effect of air purification.

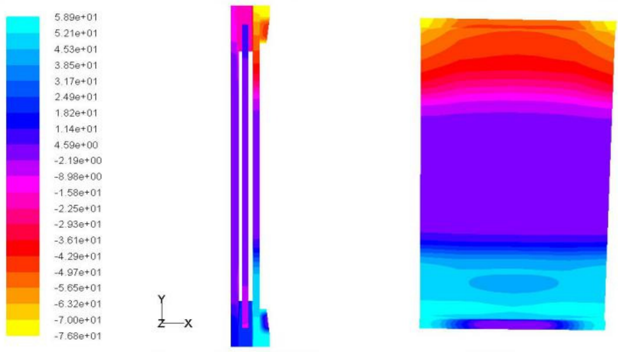

Figure 5. The change of the airflow pressure in wall absorbing haze automatically

5. Conclusions

(1)The concentration change of particles in wall absorbing haze automatically is mainly affected by the adsorption of the adsorbents. Only a small part of the particles deposit in the airflow passages.

(2)The adsorption amount of the adsorbents on particles increases with the increase of particles concentration. When the particle concentration is large, the adsorption amount begins to decrease.

(3)The change of airflow pressure affects the volume of ventilation induced by wall absorbing haze automatically. Meanwhile, it affects the percolation process of airflow in the adsorbents. Therefore, the pressure of airflow in t wall absorbing haze automatically has an important influence on the effect of air purification.

Acknowledgments
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