Key Factors in Displacement Ventilation Systems for Better IAQ[1]

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Abstract: This paper sets up a mathematical model of three-dimensional steady turbulence heat transfer in an air-conditioned room of multi-polluting heat sources. Numerical simulation helps identify key factors in displacement ventilation systems that affect air-quality in rooms of multi-polluting heat sources. Results show that it is very important to determine the suitable air-intemperature , air-inflow, and heat source quantity and dispersion, to obtain better displacement ventilation results.

Keywords: multi-polluting heat sourse displacement ventilation; air quality; heat lamination height; numerical simulation

1 INTRODUCTION

As a new fashion of ventilation, displacement ventilation has some new characters . such as higher in ventilation efficiency and better in air quality. It has a wide application foreground because admixture ventilation just can't match with it in comfort , energy consumption and it is coincident with the conception mode of new type air conditioning . Multi-polluting heat sources exist in most public building and industry building. Most scholars take their studies through experiments and computer simulations surrounding just one polluting source. But the further study is few now. Considering these, the emphasis of this paper is the factors of the air quality in the room of multi-polluting heat sources displacement ventilation, and set theorectical ground for the application of displacement ventilation.

According to the character of displacement ventilation[1], the distribution of the temperature likes layers. The bottom layer is the low temperature air area where people stay , and there gets the lowest residual heat and contamination concentrate, pollutant concent ration and the best air quality. The top layer is the high temperature air area where temperature is the highest and the concentration of the contamination is also the highest -near to the tempetature of vented air. The boundary of the two areas is heat lamination height. Therefore, the heat lamination height will affect the air-quality of the working area directly.

This paper just uses numerical result to analyse many factors which impact the heat lamination height in the room of multi-polluting heat sources displacement ventilation.

2 SETTING UP THE NUMERICAL SIMULATION OF THE DISPLACEMENT VENTILATION ROOM

2.1 Setting up the Physical Model

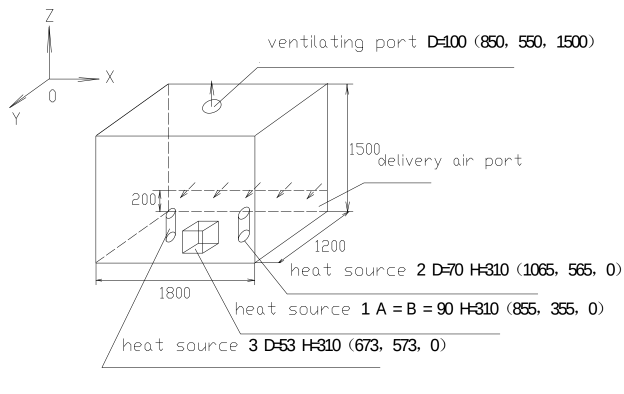

Fig. 1 Physical model of the displacement ventilation

Based on the experiment model ,this paper does the following supposition to set up the physical model of displacement ventilation numerical calculation.(Fig. 1).

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① Airflow in room is Newton liquid which cann't be compressed. Physical parameter: density ρ 、 specific heat C_p;

② Ignoring the exchanging heat of the radiation between the heat source object and the wall surface, also every wall surface ;

③ Due to the heat vented airflow of the heat source, considering the action of heat rising power ;

④ Supposing the working condition steady, $d\Phi/d\tau = 0$.

2.2 Setting up the Mathematical Models

2.2.1 Three-dimensional disorganized flow and the control equation of heat transfer[2]

Based on the physical models, to research the distribution law of temperature and velocity in the airflow field ,to set up the model of multi-polluting heat source three-dimensional steady flow and heat exchange, to adopt K/ε model ,to consider the action of the heat rising power in the energy equation, and to adopt the method of wall surface function in the glutinosity embranchment layer which is near to the surface are what need to do.

The extensive use form of the control equation wroten as:

$$\partial(\rho\Phi)/\partial t + div(\rho \vec{u}\, \Phi) = div(\Gamma grad\Phi) + S \qquad (1)$$

In the equation, Φ represents a random unknown variable; Γ represents the diffusion coefficient of random variables; S represents source item.

2.2.2 Condition of definite results of the control equation[2][3]

The entry temperature and velocity are transfered from outside. The value K of the entry section (the entry pulsant kinetic energy)and value ε are calculated according to the literature; Supposing the flow of the exit section turns to one direction. Solid surface can be calculated by surface function method.

2.2.3 Searching the result of the mathematics model

Adopting the unsymmetrical gridding, interlaced gridding, dense boundary gridding, and adopting the SIMPLEST method solve the control equation.

3 THE RESULT ANALYSIS OF THE NUMERICAL VALUE

3.1 The Impact of the Delivery Air Temperature on the Heat Lamination Ieight

In the multi-polluting heat source displacement ventilation system, the variance of delivery air temperature decides the variance of the temperature field directly in the ventilation room and brings great impact on the heat lamination height of the displacement ventilation room.

The writer chooses four different working conditions, according to different cases of the three heat sources and starts simulate. Tab.1, as follows

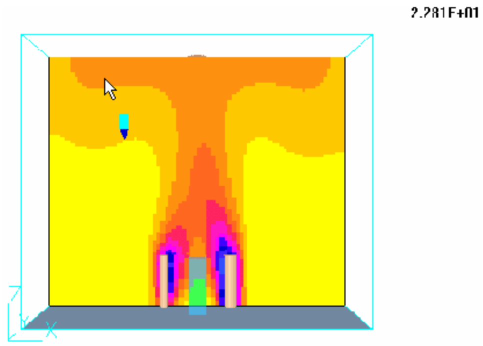
With the same heat source condition and delivery air velocity, when the delivery air temperature is 23℃the heat lamination height is higher than that case the delivery air temperature is 21℃.That is to say that debasing the delivery air temperature is disadvantageous in the improving of the heat lamination height. This is because that lower delivery air temperature forms great density difference with the heat airflow. In this case, the upper airflow of the heat source will enhance to engulf the surrounding air when it ascends. Then the quantity of the flux of the ascending airflow equal to the quantity of delivery air soon, reaching the heat lamination height, debasing the heat lamination height at the same time. Table 1 and Fig. 2 show this case. We also can find from Fig. 2 that when the delivery air temperature debases, the mix of the heat airflow and room air will be enhanced to make the room temperature increasing in the same point.

We can know from Fig.3 that the dispersion of room heat airflow is feebler in 23℃than in 21℃ and the polluting heat sources do smaller impact on the air quality, besides, the heat lamination height is higher.

Tab.1 Working conditions of different delivery air temperature and parameters

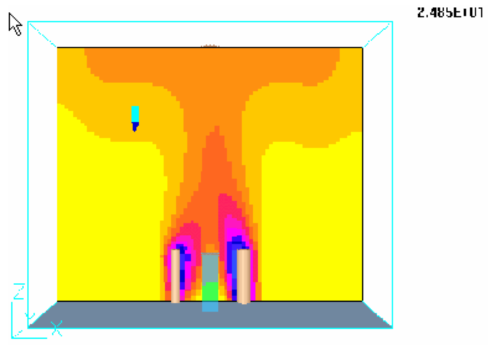
Working conditions	1	2	3	4
Delivery air temperature T_{in}（℃）	23	22	21	20
Heat lamination height Z_r（m）	0.9588	0.9388	0.9200	0.9188

Notice：The surface temperature of the heat sources is 50℃.The delivery air velocity is 0.15m/s



（a）delivery air temperature T_{in} = 23℃

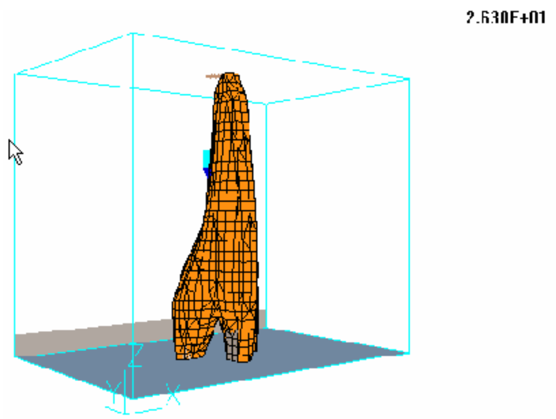
Z_r=0.9588m，t=22.81℃



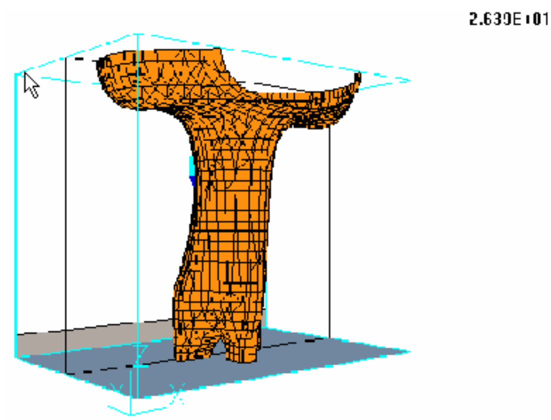
(b) delivery air temperature T_{in} = 21℃

Z_r=0.9200m, t=24.85℃

Fig. 2 X-Z plane temperature distribution under different delivery air temperature Y=0.6000m



（a）T_{in}=23℃， Z_r=0.9588m



（b）T_{in}=21℃， Z_r=0.9200m

Fig. 3 The three-dimensal equal potential ground of 26.30℃ room air temperature under different delivery air temperature

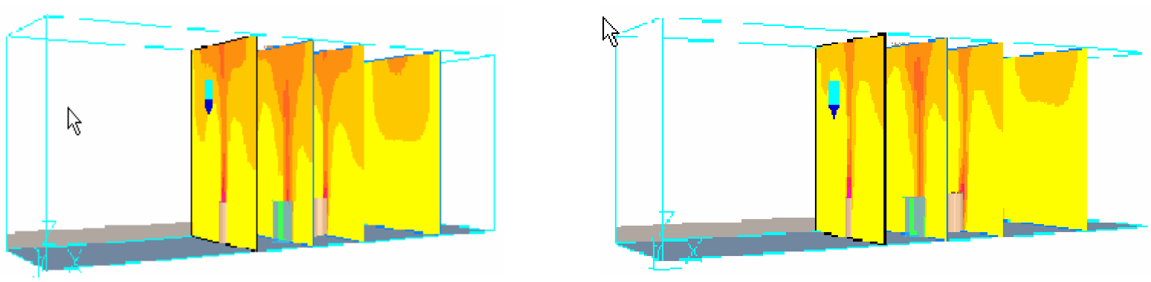
3.2 The Impact of Delivery Air Quantity on the Heat Lamination Height

Supposing 7 conditions for the simulation room, Tab. 2, as follows.

Tab.2 Working conditions of different delivery air quantity and parameters

Working conditions	1	2	3	4	5	6	7
Deliveryair quantity L_{in}（m^3/h）	64.8	129.6	194.4	259.2	324	388.8	453.6
Heat lamination height Z_r（m）	0.68	0.815	0.94	1.095	1.105	1.035	no lamination

notice：delivery air temperature 21℃. the heat flow quantity of the three heat sources ,each 200W.



(a) the delivery air quantity 129.6m^3/h **(b) the delivery air quantity 324m^3/h**

Fig. 4 Y-Z plane temperature distribution under different delivery air quantity

X_1=0.6800m, X_2=0.9000m, X_3=1.128m, X_4=1.500m

We can see from Fig. 4 that when the delivery air quantity goes up from 129.6m^3/h to 324m^3/h, the heat lamination height will go up from 0.815m to 1.105m.This shows if the area of the delivery air ports don't change, with the improvement of the delivery air quantity , so the delivery air velocity will increase within some extent and the effect of the floor airflow will be enhanced. At the same time, due to the increase of delivery air quantity , the heat jet stream above the heat source can engulf more surrounding air to make the quantity of the pinnate gas equal to the delivery air. It will make the heat lamination height improved and get better air-quality.

3.3 The Impact of the Heat Source Quantity on the Heat Lamination Height

Let's compare the impact of single heat source and multi heat sources on the airflow organization in the room, under the same heat flux （600W）. The designed working conditions and the major parameters are showed in Tab.3.

We can know from Fig. 5,Fig. 6 and Tab. 3 that although the total heat flux of erery room is 600W, the heat lamination height of the multi heat source rooms is lower,Z_2=0.935m than the single heat source room, Z_1=1.175m. This can explain that multi heat sources will make the heat lamination height going down obviously and make the air quality of the working area debasing. The major reason is that the diffusion of multi heat sources is much stronger than the single source, which weakens the astrict of the delivery air to the heat flux and engulfs much surrounding air too early.

In addition, in the same condition, the upper area and vented air temperature of the multi-polluting heat sources room debase（show in Tab. 3）. The reason is that the debasing of the heat lamination height makes the heat flux engulfing more surrounding air to debase the temperature.

3.4 The Impact of Heat Source Dispersion on the Heat Lamination Height

The supposed working conditions and major parameters are showed in Tab. 4.

Tab. 3 Working conditions of changed heat source quantity and the major parameters

Heat source and the heat flux（W）	Heat lamination height Z_r（m）	Temperature of vented air T_p（℃）
Single source600W×1	1.175	33.02
Multi heat sources200W×3	0.935	32.64

Notice ： the heat jet stream velocity 0.20m/s，delivery air temperature 21℃，delivery air velocity 0.10m/s.

Tab.4 Working conditions of different dispersion degree of the heat sources and the major parameters

Working conditions	1	2	3	4	5	6
Heat source dispersion	1	1	2	2	3	3
Heat lamination height（m）	0.695	0.725	0.665	0.695	0.615	0.635
Delivery air velocity（m/s）	0.15	0.25	0.15	0.25	0.15	0.25

Notice: Each of the three heat sources is 300W; the delivery air temperature is 20℃; the velocity of heat jet stream is 0.3m/s; the dispersion degree of the heat sources increase in turn.

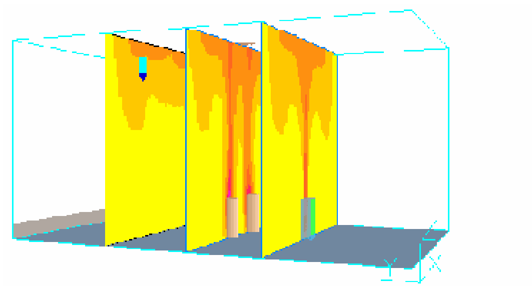


Fig. 5 X-Z plane temperature field of multi heat sources

Y_1=0.3800m，Y_2=0.6040m，Y_3=0.8600m

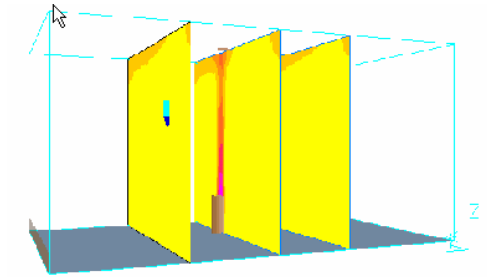
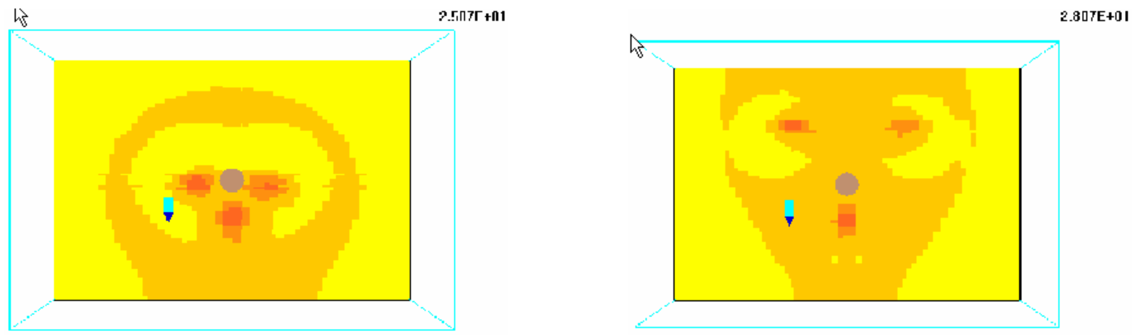


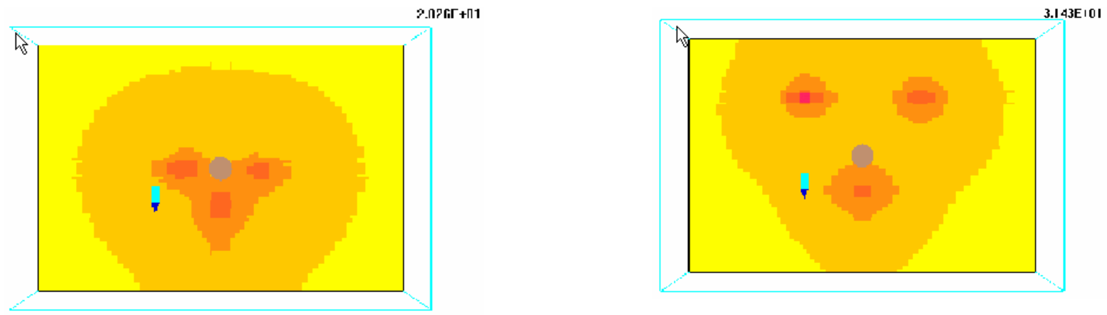
Fig. 6 X-Z surface temperature field of single heat source

Y_1=0.3800m，Y_2=0.6040m，Y_3=0.8600m



（a）heat source position 1 t=25.1℃ （b）heat source position 2 t=28.1℃

Fig. 7 Z=0.8600mX-Y plane temperature field



（a）heat source position 1 t=28.3℃ （b）heat source position 2 t=31.4℃

Fig. 8 Z=1.1000mX-Y plane temperature field

Under the same other condition, the general effect of multi heat sources is more obvious when the disposal of the heat sources is compact, which will make the heat rising power enhance and make the heat lamination height increasing. Contrarily, the heat lamination height will debase. We can see that going with the increasing of the dispersion, the heat lamination height goes down from 0.695m to 0.665m, 0.615m (the delivery air velocity 0.15m/s). At the same time, under different height, observing the temperature distribution Fig. 7, Fig. 8 can know the temperature of position 2 is higher than position 1. This explains that owning to the more dispersive distribution of the heat sources for position 2, the heat flux will diffuse faster. Therefore, the heat lamination height descends and the air quality debases.

4 CONCLUSIONS

4.1 The delivery air temperature does great impact on the effect of the displacement ventilation. When the delivery air temperature goes down, the heat lamination height debases correspondingly to impact the air quality in the working area. When the heat load is not too large in the room, Δt ,which is the difference of the temperature value of the displacement ventilation working area and the delivery air ,is suitable between 2～4℃ and it's better to choose the high value.

4.2 The delivery quantity does great impact on the airflow distribution in the displacement ventilation room. Going with the increase of the delivery air quantity ,the heat lamination height will increase to make the air quality of the working area become better. However, comfortable will be debased when the delivery air quantity is too big .When the intensity of the heat sources is under 280W/ m^2 , to control the delivery air velocity below 0.3m/s is suitable.

4.3 The dispersion of the heat sources is too large, the heat lamination height will debase, too. The compact distribution of the heat sources is very advantageous in improving the air quality of the working area in the displacement ventilation room.

4.4 Under the same heat flux of the heat sources, the heat lamination height of multi heat sources displacement ventilation will debase obviously and the upper area temperature of the heat lamination height and the vented air temperature will debase, too. Therefore, multi heat sources are more disadvantageous in improving air quality of the displacement ventilation working area compared with the single source.

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