Large Size Static Pressure Box Airflow Distribution

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***Abstract*—This paper mainly studies at the different way of ventilation to the influence of air distribution in the large size plenum. The model is a grand theatre stalls. To model the plenum which under the grand theatre stalls,and took out the size of large mutations alone modeling and studying it. the six different way of ventilation: small plenum with four directions supply air; Take a duct with four tuyere on supply air; Single tuyere withside air supply; Tuyere parallel supply air; Single tuyere with air supply under; Take a duct with four draught under supply air have influence of air distribution.And combined with the well of heat insulation in the large size plenum.It can use the standard RNG turbulence model, and the pressure interpolation adopt standard discrete format, the convection item of the momentum equations, k equation, ε equation adopt with second order the format. the pressure speed coupling adopt Simple algorithm. Finally through the FLUENT software were used. It can use the air balance coefficient wich is one evaluation index to analyz Simulation results of the Six air distribution mode . Through the analysis and comparison with a wind that four tuyere air supply under** Static pressure box**air supply the best effect, the static pressure air distribution most evenly**

Keywords- Large size static pressure box; floor air supply systems; the way of ventilation; turbulent model;

I. PREFACE

In the tall space building air conditioning system design,floor air supply systems because of its energy conservation in practical projects to get more and more extensive application. At present, the research of floor air supply systems more concentrated in the upper area of static pressure box, the application of static pressure layer is commonly floor overhead form, and the structure form is relatively simple[1] .In the stadium, theater and other places often make use of the audience under floor architectural space as a static pressure box. The static pressure box shape is irregular, profile often with a ladder shape, and its beam distribution is more, so air duct layout difficult, often based on relief set air duct and air supply outlet. Static pressure box space size bigger, civil structure is complex, leading to the gas flow distribution in the complex, if processing is bad to can affect the uniformity of air supply[2].

The air distribution air conditioning system, using complex structure punching plenum ventilation engineering case is not much, at present there is no Uniform design codes and standards, and static pressure box airflow organization quality will directly affect the audience area ambient air quality and comfort, so if you can grasp accurately the static pressure and velocity distribution situation, will be to improve the air quality audience and comfort play an important role. So it is necessary to use modern computational fluid dynamics method for large space static pressure box airflow organization for simulation and optimization, in order to design and construction of static pressure box for certain theoretical guidance .

This paper is the application of the CFD technology on a grand theatre of the supply air static pressure box flow uniformity simulation, and the analysis of the large space, structure irregular static pressure tank of air supply characteristics，And analysis of air supply characteristics of the large space structure irregular static pressure tank . Because of air supply outlet arrangement position and the influence of building structure， the velocity distribution non-uniform in static pressure box inside .If take traditional tuyere regulation approach, that is, by adjusting the air out of the size of the area, to adjust the volume, the actual operations found that the regulation measures are effectively; But for this project, due to the theater seat diffuser quantity, if these measures are taken to tuyere air adjusted, huge workload, unfavorable take, so by changing the supply air form method, to adjust the wind speed, to achieve the purpose of air distribution uniform distribution.

II. MODELING

A. Model introduction

The actual model size bigger,so take more typical regional modeling for simulation study. The regional static pressure box area 52.5 ㎡, volume of about 112 m3, the calculation area has air duct air supply outlet 1, the audience area a total of 7 row seat, seat diffuser has 66 . The regional total air output 5650 m3/h, the air supply outlet area of air duct is 0.75 ㎡, Figure 1 for the theatre auditorium, static pressure box located in the below. Figure 2 for static pressure box model profile.

Figure 1. Theatre auditorium

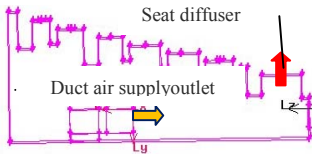
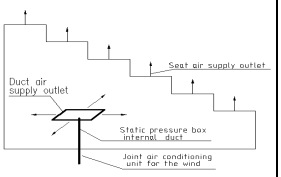
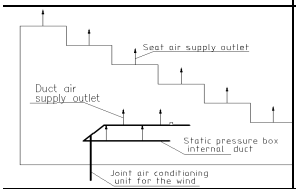
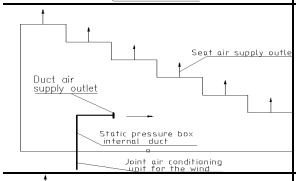
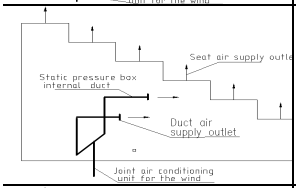
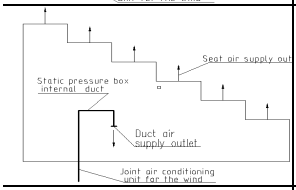
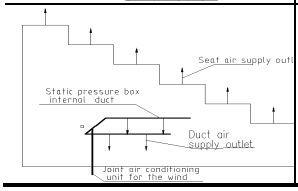


Figure 2. Static pressure box model profile

Published by Atlantis Press, Paris, France.

According to the field condition, this paper puts forward six feasible way of ventilation, respectively study the static pressure air distribution situation, and determined the optimal program; Table 1 below for different air supply mode diagram:

TABLE I. DIFFERENT AIR SUPPLY MODE DIAGRAM

The way of ventilation schematic diagram	Air supply mode name	Air supply mode introduction
	static pressure boxair supplyoutlet schematic diagram	Air supply, through the static effect sent to the seat diffuser, air supply outlet size for 500 x 500 mm.
	Take a duct upward air supply plan	In the static pressure box set up inside a duct, air supply outlet arrangement in the upper air duct, Air supply outlet size for 350 x 350 mm.
	Single tuyere side air supply plan	Air supply by side air supply outlet into static pressure box, Air supply outlet size for 1250 x 600 mm.
	Tuyere parallel air supply plan	In the same section set two air supply outlet; Air through the side air supply outlet into static pressure box , air supply outlet size for 1250 x 600 mm.
	Single tuyere downward air supply plan	Air supply outlet arrangement in the down side, the wind send to the ground first. Air supply outlet size for 1250 x 600 mm.
	Take a duct downward air supply plan	In the static pressure box set up inside a duct, air supply outlet arrangement in the air duct underside, air supply outlet size for 350 x 350 mm.

B. *Mathematical model*

Air conditioning system to send, return air duct package have heat preservation rock wool , In the static pressure box at the air quantity of heat loss is very small. The small temperature difference between air supply outlet in static pressure box and seat diffuser can be ignored. So in this simulation calculation does not consider the energy loss. Use RNGk - e turbulence model, the differential pressure value using standard discrete format, momentum equation, k equation, e equation of convection item using second order windward format, pressure velocity coupling using simple algorithm[3][4][5].

The general form of mathematical equations for:

$$\frac{\partial(\rho\phi)}{\partial t} + div(\rho v\phi - \Gamma_\phi grad\ \phi) = S\phi \tag{1}$$

The formula of $\frac{\partial(\rho\phi)}{\partial t}$ is unsteady items, $div(\rho v\phi)$ is convection item, $div(\Gamma_\phi grad\ \phi)$ is diffusion term, Γ_ϕ is generalized diffusion coefficient, $S\phi$ is source term.

C. *Grid generation*

For each small body of grid division, in the space is larger, simple structure place division size for 150, in diffuser part division mesh sizes 50. Finally in these areas divided mesh, using Tet/Hybird element of TGrid type, obtained the tetrahedron unstructured grid. The grid division as follows figure 3 shows:

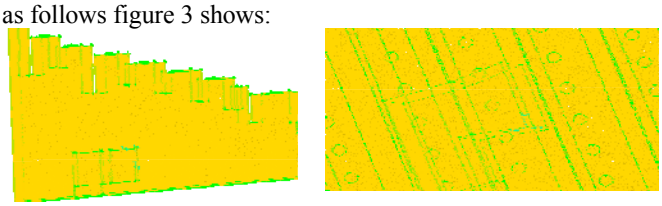


Figure 3. Grid division

D. *Boundary conditions*

Upon completion of the model and the grid division after, the need to install boundary conditions.When we set the boundary condition in the fluent, we need to pay attention to each model due to the size of the diffuser is not the same, so the wind speed and k, ε value is not the same.

TABLE II. BOUNDARY CONDITIONS SET

Name	Velocity (m/s)	K value	ε value
With a small static pressure box	1.57	0.006195	0.002289
Take a duct four tuyere upward air supply	3.2	0.02359	0.024301
Single tuyere side air supply	2.11	0.000931	0.0026
Tuyere parallel air supply	1.04	0.0027	0.00041
Single tuyere downward air supply	2.11	0.000931	0.0026
Take a duct four tuyere downward air supply	1.57	0.006195	0.002289

III. SIMULATION RESULTS ANALYSIS

A. *Velocity field distribution*

Static pressure box at the velocity distribution as shown in figure 4 shows, with speed flow diagram to show air flow line, the velocity distribution for six different condition as flow diagram.

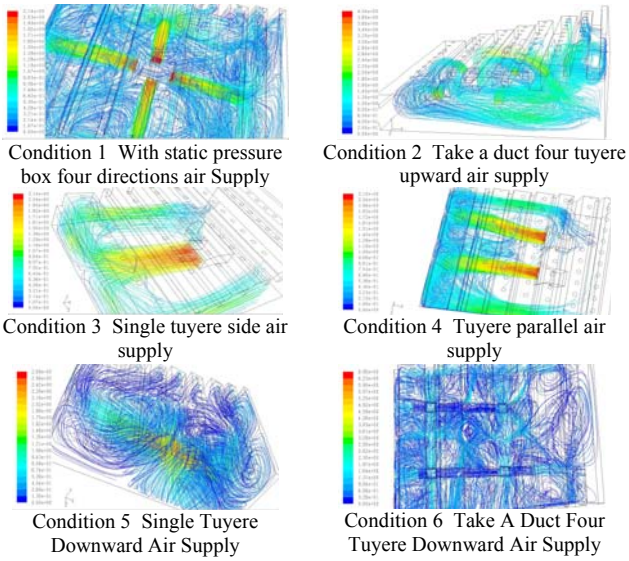


Figure 4. Velocity distribution flow diagram

Figure 4 is speed flow diagram to describe the flow of air route and the size of the speed. Condition 2, 3 and condition 5, 6 speed streamline phase comparison, Can see air supply outlet down the way of ventilation air flow path is to reach the ground, Air as a result of the ground of the barrierpeed decrease , then send to the seat diffuser.

B. *Static pressure distribution*

Figure 5 for static pressure box at the static pressure distribution, different color said static pressure vary in size, color distribution more uniform, the static pressure distribution more uniform.

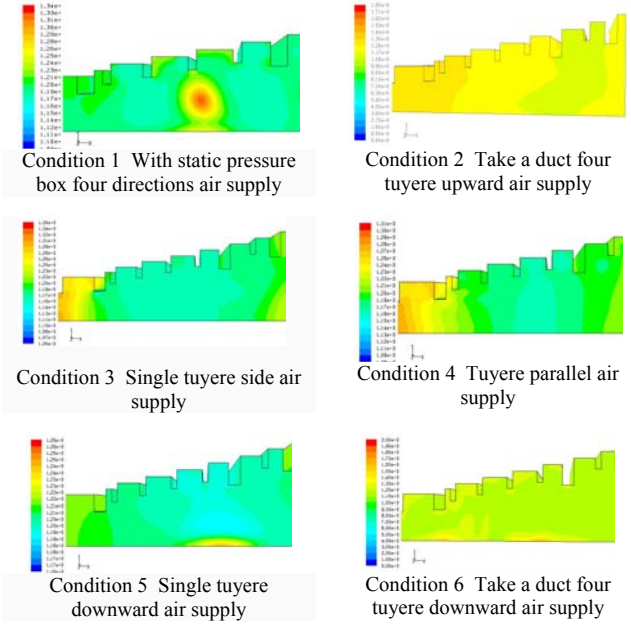


Figure 5. Pressure distribution nephogram

In the static pressure box air supply, the size of the static pressure directly with the flow uniformity related, static pressure distribution more uniform, the velocity distribution more uniform. Figure 5 May safely draw the condition and static pressure distribution is the most evenly, seat outlet pressure fluctuations of smaller. Air supply forms can also found that air downward than to side supply air pressure distribution is uniform. Side supply air pressure distribution was from back to front is roughly stepped distribution, and then influence the speed distribution.

C. *Tuyere air uniformity analysis*

Due to the seat diffuser amount is more, if only from the air to compare the gas flow distribution in the case to compare a trouble, so here we use air uneven factor the and air distribution closely related parameters to say; Air not uniformity coefficient can be more image showed air distribution. At the same time to six air supply model is simulated and analyzed, and the simulation data processing, the air that uneven coefficient as the chart shows. And study different model corresponding to the different simulation results, a conclusion, determine the optimum design.

TABLE III. 6 KINDS OF AIR SUPPLY MODE OF AIR VOLUME UNEVEN COEFFICIENT

Name	Air Uneven Coefficient
Condition 1	0.02
Condition2	0.25
Condition 3	0.05
Condition 4	0.04
Condition 5	0.03
Condition 6	0.01

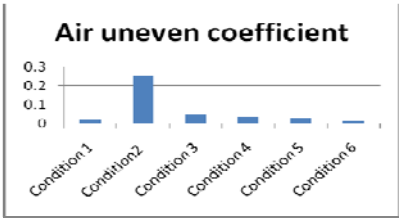


Figure 6. Air Uneven Coefficient Distribution Histogram

Table 3 and figure 6 can analysis, for different air supply form air non-uniform coefficient is different. From the following four aspects:

- The influence of air direction: downward air supply than side air supply, up air supply air supply effect is good, air uneven coefficient were 0.03, 0.05 and 0.25. This is because air supply is air to send to the ground, the upper space in reflux area, make air distribution more uniform.
- Air supply outlet amount of influence: multiple air supply outlet than single air supplyoutlet air supply

effect is good, not uniformity coefficient 0.04 and 0.05, respectively. This is because many air supply outlet than single air supply outlet of air supply velocity is small (total air volume in certain cases), in the static pressure box internal dynamic pressure is small, the static pressure is big , static pressure box relies mainly on the static pressure supply air, the air distribution more uniform.

- Small static pressure box connection mode influence: take static pressure box four air supply outlet of air supply form effect is good, non-uniform coefficient is 0.02, the effect is very good; This is because the wind speed in the small static pressure box will reduce a lot of, can enter the decompression in the air more uniform distribution, this kind of situation of static pressure box a highly restricted, and static pressure box height change is big, beam distribution more condition is not applicable.
- Set a duct influence: and single tuyere air supply under compared, uneven coefficient were 0.01 and 0.03, with side air duct air supply under the obvious effect, this is due to the air in a duct inside, dynamic pressure reduce , outlet wind speeddown, static pressure increases, the static pressure box into the air uniform distribution. uneven coefficient are respectively 0.01 and 0.25, the difference is big, this is due to a supply air duct is upward flow, from diffuser nearer area, wind speed is bigger, and far away from the outlet area, wind speed is smaller, the wind speed distribution and air uneven coefficient is bigger.

IV. CONCLUSION

Through the static pressure box internal different air supply mode flow uniformity simulation studies, different air supply way of air distribution uniformity have influence. In the static pressure box internal static pressure distribution influence the velocity distribution. From figure 4 and figure 5 speed, pressure distribution analysis, air supply mode of wind effect than other air supply way; Condition 5, 6 than other modes of the velocity, pressure distribution is uniform. Seat diffuser velocity distribution in not uniformity coefficient evaluation, condition and take a duct four hole under the way of ventilation effect best, uneven coefficient is

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