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Number Simulation and Optimization of Air Distribution in a Data Room

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Abstract. With the rapid development of communication industry, many kinds of severs are displayed in the data center today. Their different power consumptions lead to different heat diffusion. The decorate position of air conditioning units have sever effects on the air distribution and the operation of all kinds of facilities [1, 2]. As a background of this kind of area, three different positions of air conditioning units had been used to analyze how they affected the data center's thermal environment by means of combining field measurements with computational fluid dynamics. Thus we got a suitable decorate position which can provide better air distribution. Based on these, this work made a further analysis of two kinds of air conditioning modes of bottom income and top outcome. The scheme had been optimized again and the server performance had also been improved. This work had presented proof for the design of air distribution and the retrofit of existing data center.

Introduction

With the need of high density and multitasking calculation, more and more high performance data centers had been built.Uneven air distribution causes local temperature too high or too low. It is a common problem in modern data center, which is harmful to facilities. Precursors[3,4] had researched a lot to explain the reason causing the phenomenon, but for the data room of servers with different power consumption and arranged in rows, few people had studied the influence of air conditioner units' different arrangements on the environment. This paper used the method of combining experiment with CFD simulation to analyze a relatively better air distribution scheme, it can improve the facility running environment and increase the operation life.

Numerical simulation process

Model establishment

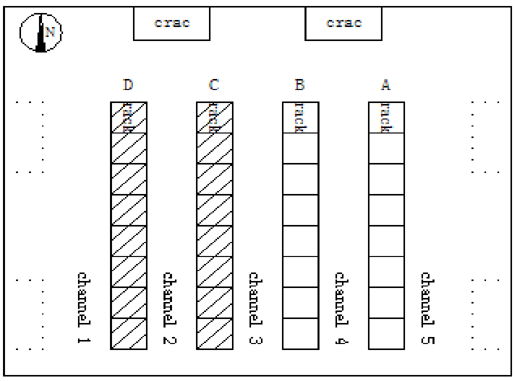


Fig.1 Simplified plan.

This paper takes a data center in Harbin for simulation example, the simplified plan is shown in Fig.1. The room has an area of $113.28m^2$ and $3.2m$ in height. There are four rack rows in it, and each row has 8 racks, each rack offers a working section of $0.8m\times0.8m$ in area and $2.0m$ in height. The power consumption of each server (work in the rack) in row A, B, C and D is $3KW$, $3KW$, $7KW$ and $7KW$. Servers in each row are displayed in the form of face to face and back to back, forming cooling channels (channel 2 and channel 4) and hot channels (channel 1, channel 3 and channel 5).The data room is equipped with two sets of special air conditioning. Cooling channels has been laid perforated floors whose perforation rate is 0.5, the width accounts for one-third of the channel width. Return air inlets are set over thermal channels, and each size is $0.5\text{m}\times1.4m$. The air flows from perforated floors to return air outlets above. Usually the door is closed, personnel stay time is short and lights are rarely opened. So the room can be approximately seen as a closed system, and the heat load of human bodies and lights can be ignored.

Control equation

This paper adopts k-ε double equation model, simulation process are presented in the following hypothesis:

1) The air meets internal friction Newton's law, and can be seen as Newton's fluid;
2) Indoor air flow is steady-state turbulent flow;
3) The wall is thermal insulation;
4) Ignoring the effects of radiation between the various heat transfer surfaces;
5) Without considering the influence of air leakage.

Thus to determine the general control equations[5]as follows:

$$\frac{\partial}{\partial x}(\rho_u \Phi)+\frac{\partial}{\partial y}(\rho_v \Phi)+\frac{\partial}{\partial z}(\rho_w \Phi)=\frac{\partial}{\partial x}(\Gamma_\Phi \frac{\partial \Phi}{\partial x})+\frac{\partial}{\partial y}(\Gamma_\Phi \frac{\partial \Phi}{\partial y})+\frac{\partial}{\partial z}(\Gamma_\Phi \frac{\partial \Phi}{\partial z})+S_\Phi \qquad (1)$$

Where Φ is the velocity component of u,v,w and temperature T respectively,Γ_Φ is the diffusion coefficient of Φ,S_Φ is the Source term of Φ.

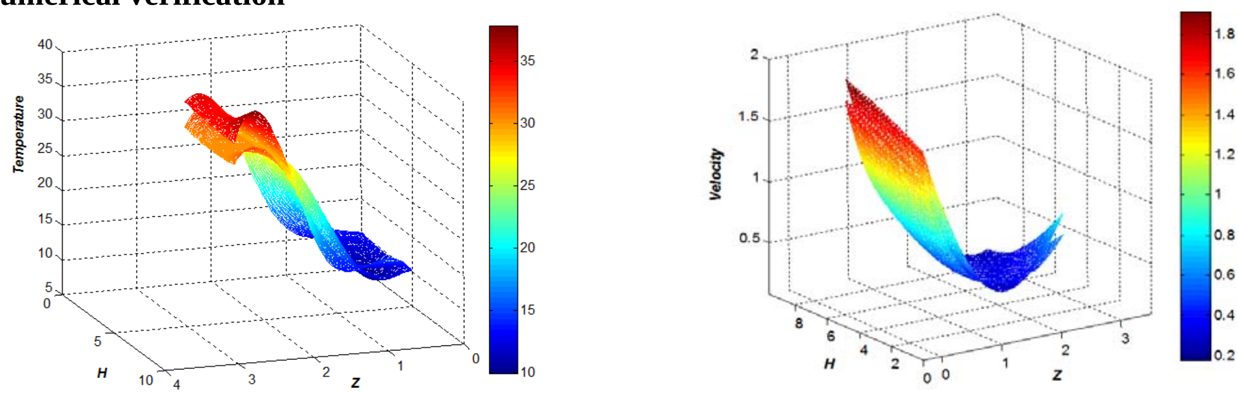
Boundary conditions and grid partition

The boundary conditions setting are based on the measured data. Inlets and outlets are set to be speed boundary; racks set heat flux boundary, the value is equal to the ratio of the total heat and the surface area of heat loss. The structure of the data room is seen as insulation.

Division of grid compute: unstructured grid can avoid the grid nodes' structural constraints of the structured grid and it can better deal with the boundary. Therefore this work use unstructured meshing method to mesh.Conduct mesh refinement towards the air supply outlets, return air inlets and surroundings of racks.

Simulation results and analysis

Numerical verification



a. Temperature contrast. b. Velocity contrast.

Fig.2 Contrast between measurement and simulation.

12 different points in channel 2(most serious region of causing super-cooling phenomenon) were selected in different height (Z) of 0.3m, 0.9m, 1.5m, 2.1m, 2.7m and different horizontal distance from the air conditioning(H) of 2.4m, 5m, 7.2m to measure the temperature and velocity. The results of measurement and simulation were compared as shown in Fig.2. In the figures, the upper surfaces represent the simulation values and beneath them are measured values. Observing these two figures, it is not difficult to find that the simulated and measured values of temperature and velocity are almost of the same tendency. The maximum error are 3.9°C and $0.23\text{m}/\text{s}$ respectively, and the relative errors are both less than 10% .The main reason of having errors is the racks and floor have been simplified in the simulation, while for the whole space these simplified treatments have limited effect on the air distribution. So this established model can be used to analyze the thermal environment in the room.

The impact and optimization of air conditioning units with different arrangements on the air distribution

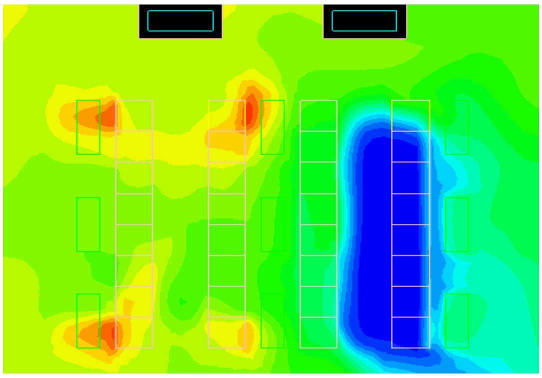


Fig.3 Temperature distribution at 2.25m .

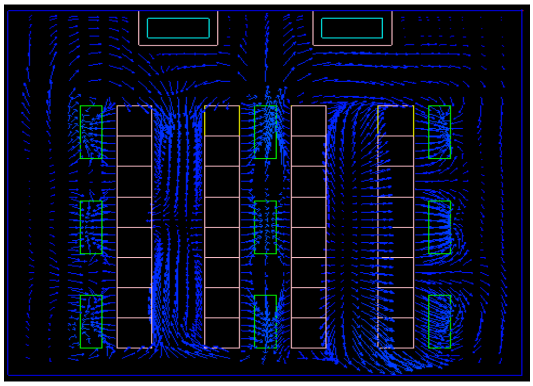


Fig.4 Velocity distribution at 2.25m .

Temperature and velocity distribution affect the thermal environment seriously, and then affect the running status of servers. In this room cold air is supplied through the perforated floors under the cold channels and exhausted through inlets above thermal channels. Fig.3 shows the temperature distribution at 2.25m (top level of the rack) in height, Fig.4 shows the velocity distribution at the same height. To observe these two figures, hot spot (highest temperature) is located at two ends of row C and D, the temperature is $39.5^{o}C$. It is under $67^{o}C$ which is the maximum design temperature for server cooling surfaces[6]. Velocity in channel 4 is fast, large number of cold air flows to row A whose right side has broader space. It leads row A to stay at super-cooling state ($12.8^{o}C$), which shows the arrangement of the room is not reasonable.

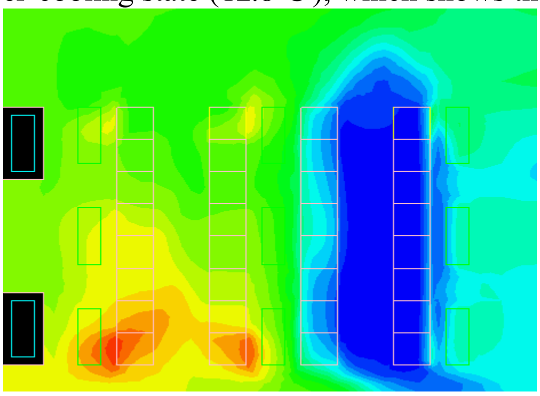


Fig.5 Simulated result of Scheme One.

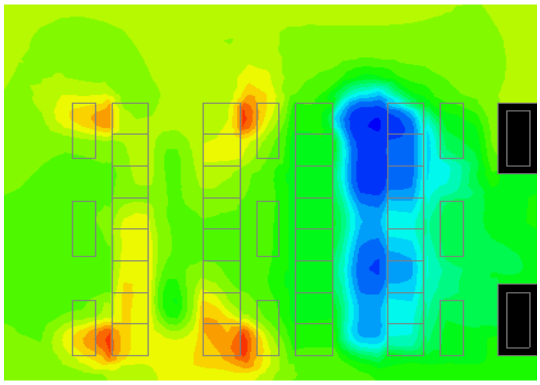


Fig.6 Simulated result of Scheme Two.

In order to improve the thermal environment, two improved schemes have been put forward to simulate. Moving air conditioning units to dotted line positions as shown in Fig.1.Scheme One: shift air conditioning units at the west wall; Scheme Two: shift air conditioning units at the east wall. The simulated temperature distribution of the two schemes at 2.25m are shown in Fig.5 and Fig.6 respectively. Now compare them with the results of the original arrangement.

As shown in Fig.5, air conditioning units are placed at the west wall near high power consumption severs. Free space at the northern end of row C and D has been enlarged, which is convenient to exhaust heat air. Thus hot point is shifted to the south end, when the highest temperature is $40.1^{o}C$ which can meet the design requirements. But the supper-cooling phenomenon of low power consumption row A and B is not improved. If move the air conditioning units to the east wall near the low power consumption rows as shown in Fig.6, hot spot is located at two ends of row C and D, the highest temperature is $38.3^{o}C$ which can meet the design requirements. The original supper-cooling phenomenon of row A has significantly reduced. May be it is due to hot air after cooling directly discharged from the upper return air outlets over the hot channels, there is no obvious retention phenomenon, thus easing the super-cooling phenomenon. Through the comparative analysis above, Scheme Two will not only reduce the age of the air, but also will weaken the super-cooling phenomenon of low-power racks, therefore it will significantly improve the thermal environment.

The impact and optimization of different form of underfloor air supply on the air distribution

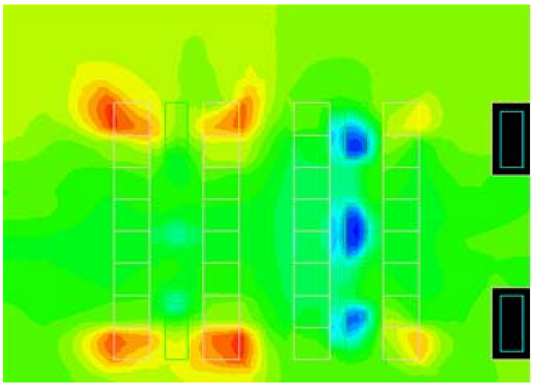


Fig.7 Newly temperature distribution.

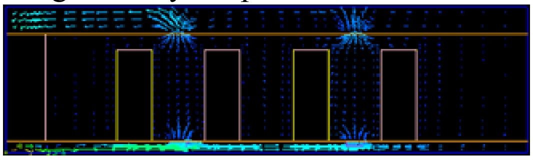


Fig.8 Newly velocity distribution.

The following studies another kind of air conditioning mode of bottom income and top outcome. Keep the position of perforated floors unchanged and transfer the return air outlets over the cooling channels. On the foundation of Scheme Two and use this air conditioning modes to simulate again. Fig.7 is the temperature distribution of the room at 2.25m and Fig.8 is the velocity distribution of its longitudinal section. Although the hot spot is still located at two ends of row C and D, the temperature is 37.2°C which not only meet the design requirements, but also is lower than above schemes. Super-cooling phenomenon of row A and B is resolved, and at the same time, the inlet and outlet temperature (27.5°C) of the racks tend to be approximately same.It is due to the hot air flows to the low pressure return air outlets quickly and then reduce airflow disorders between the racks.As a result the heat sources have been effectively cooled. Above all, the newly scheme can further enhance the thermal environment than Scheme Two.

Conclusion

In this paper, existing thermal problems of the center had been analyzed,and some schemes had also been put forward to solve these problems. Studies show that:

1) Hot spot of the original data room is located at two ends of the high power consumption rows. The surface temperature of the servers has met the design requirements, but low power consumption row A and B exist super-cooling phenomenon.

2) Adjusting the arrangement by placing air conditioning units at the east wall near low power consumption rows can weaken the super-cooling phenomenon.

3) Based on the above method, changing air exhausting mode by shifting the return air outlets over the cooling channels can further improve the thermal environment.

References

[1] Y.C.Tung,et al:Building and Environment Vol.44(2) (2009):p.271-279.

[2] J,K,Cho,et al: Journal of the Architectural Institute of Korea Vol.24(12) (2008):p.313-320.

[3] Ping Yang,et al:Journal of South China University of Technology(Natural Science Edition) Vol.37(11) (2009):p.107-111.

[4] Jian Chen, et al: Journal of Shenyang Normal University(Natural science) Vol.29(4) (2011): p.526-529.

[5] Wencuo Tao:*Computational Fluid Mechanics and Heat Transfer*(Chinese Building Industry Publications, China1991).

[6] GB 50174-2008:Code for Design of Electronic Information System.