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NUMERICAL PREDICTION AND MODEL EXPERIMENT OF DOUBLE SIDE SUPPLY AIR FLOW IN A LARGE SPACE AIR CONDITIONING WORKSHOP

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SUMMARY

Double side air supply is widely used in large space air conditioning buildings such as large workshops. It is proved that this kind of air distribution can save about 30% or so of the cooling load compared with the full—room air conditioning in large spaces.

A three—dimentional turbulent K—ε model , P—V dependent variables, finite difference and SIMPLE method have been introduced, by means of which we have made the numerical prediction and characteristic analysis of the flow motion and temperature distribution about te double side supply air flow in a large space air conditioning workshop.

A model experiment on the double side air supply has been made , a comparison between the numerical and the model experiment results shows that they are basically consistent, which proves that the method used here and the disposition on the complex boundary are satisfactory and the results are correct.

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INTRODUCTION

Double side air supply is one kind of methods of air supply used in large space air conditioning buildings. It can seperated the large space into two parts , only the lower space (working zone) is air conditioned and the upper space is ventilated to dispose heat so as to get the goal of energy saving.

The series limited paralled air jets are often used in this kind of air supply. Because the goals of energy saving and designing are mainly realized by the special air distribution , almost all the research topics are on the study about the double side air supply especialy the series limited paralled air jets in the large space.

In this paper, the numerical prediction about the double side supply air flow in a largge space air conditioning workshop has been made with the three—di-

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mensional turbulent K—ε model, A comparison between the numerical and model experiment results shows that they are basically consistent. with two—component regression , some mathematical formulas of the series limited parallel air jets nave been got .

K—ε TWO—EQUATION MODEL

The mathematic model used in this study is the K—ε two—equation turbulence model developed by Launder and Spalding (1972) [1] . This model has been widely applied in predicting many types of turbulent flow phenomena. The simulation of room air flow with the K—ε The basic equations of K—ε model was first conducted by Nielsen(1974) two—dimensionally.

DISCRETIZATION AND MODEL ROOM

The control volume method is adopted to discretize the K—ε equations . The Power—Law Scheme (S. V Patanker 1979) is used in the U. V. W. K. ε equations , and the Up—Wind Scheme (Wolf shtein 1969) is used in the energy equation to avoid divergence of iterations. A stagged mesh system is taken and the grids spacing is 38×25×23. The definition points of variables are the same as those in the usual Marker—And—Cell(MAC) method (Harlow and Welch 1965). Velocity components are defined at the center of the cell surfaces. and scalar quantities are set in the center of the cell [2]

The model room for simulation and experiment is the main engine workshop of Nanjing Steam Turbine Factory of China . Three are 2×7—ply paralled chilled air jets in it as shown in Figure 1.

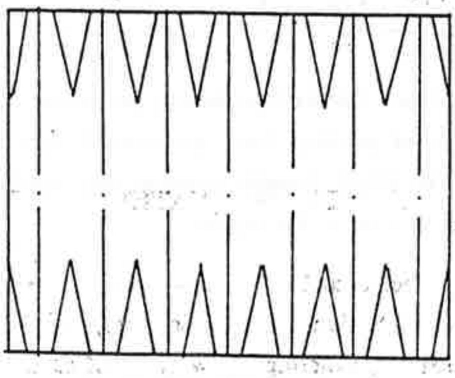

Fig. 1. Series Limited Parallel Chilled air jets on XOY plan

BOUNDARY CONDITIONS

(1) Jets´ Supply Outlet:

$Ut=\pm 1.0;\ V=W=0,\ K=0.04;\ \varepsilon=0.08;\ T=-1.0$

(2) Lower Exhaust Inlet:

$$V=W=0;\quad \frac{\partial U}{\partial x}=0;\quad \frac{\partial k}{\partial x}=\frac{\partial \varepsilon}{\partial x}=\frac{\partial T}{\partial x}=0$$

(3) Upper Ventilation Supply Outlet:

$$U=\pm\frac{U_{in}}{V_0};\quad V=W=0;\quad K=0.04;\quad \varepsilon=0.08;\quad T=0.4074$$

(4) Upper Exhaust Inlet:

$$U=V=0;\quad \frac{\partial W}{\partial Z}=\frac{\partial K}{\partial Z}=\frac{\partial \varepsilon}{\partial Z}=\frac{\partial T}{\partial Z}=0$$

(5) Wall Boundary:

$$\left(\frac{\partial U}{\partial n}\right)_{n=0}=m(V_t)_{n=h}/h;\quad U_n=0;\quad \frac{\partial K}{\partial n}=0;\quad \varepsilon_{n=h}=(C_D K^{\frac{3}{2}}h)/(C_D^{\frac{1}{4}}kh)$$

According to [3], the wall boundary of energy equation is given in table 1.

Table 1

Ground	Walls of Working Zone	Walls of Non—working Zone	Ceiling
−0. 125	0. 00	−1. 0+1. 625×Z/H	0. 625

here, h: Length from the wall surface to the center of the adjacent ceil; m: 1/7, Power Law of profile, U∝Z is assumed here; K: 0. 4. Von Karman Constant; C_D = 0. 09; Z: Length from te wall surface to the ground ; H: Length from the ground to the ceiling.

COMPUTATION

The SIMPLE (Simc—Implicit—Mcthod for Pressure Linked Equations) (S. V. Patankcr 1975) and undcr—relaxation technics are adopted to solve the equatios. All prcdictions are conducted by the SIEMES 7, 570C computer of Hunan Univcrsity, China. The predictions precision is 10^{-3}, and it takes 20, 000 seconds (five hours) CPU time to obtain a stationary solution every time . In order to study the scrics limited parallel chilled air jets further , We have made more than 60 times simulations under the all kinds of conditions . It takes us two years to accomplish that. Figure 2 showes the velocity vector of the double side air supply on XOZ plan and the figure 3 showes the temperature distribution on XOY plan.

COMPARISON BETWEEN NUMERICAL PREDICTION AND MODEL EXPERIMENTAL RESULTS.

With the computer programm "HOPE1" advanced by us . the numerical results about the series limited paralled chilled jets are made . Compared with the model experiment results about the jets . We find that they are basically consistent. The best error of the locuses of the jets between numerical and experiment results is 9. 8%. The best error of the attenuation of flow velocity

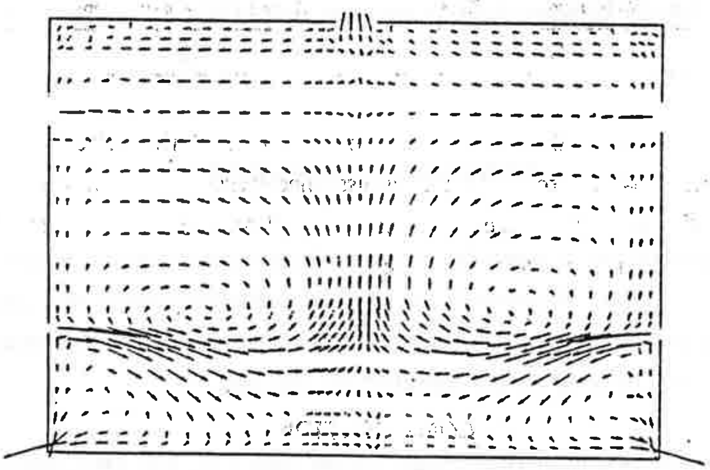

Fig. 2 . Velocity vector of the jets on XOZ plan ,Ar=0. 0032

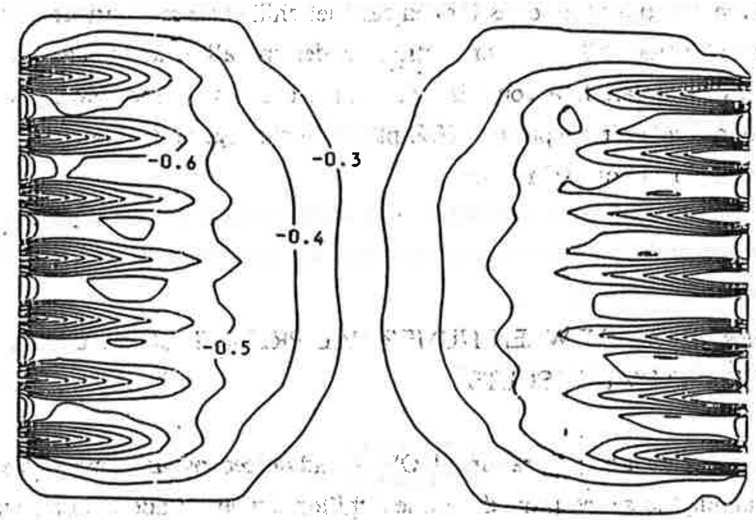

Fig. 3 . Temperature distribution of the jets on XOY plan, Ar=0. 0016

along the jets′ flow axis between them is 7. 3% and the best error of temperature distribution between them is no more than 4%.

NUMERICAL RESEARCH

The correspondence between the mumerical prediction and the model experiment is rather close. Numerical prediction of turbulent flow is thus proved to be a fairly promising tool for analyzing turbulent airflow of the double side air supply in a large space air conditioning building.

By ananize the rich numerical results (more than 200,000 datas could be got every time), we find that the jets′ locuses have mainly something to do with Ar number and approximate to parabolas. The attenuation regulations of the flow veiocity and the temperature along the jets′ flow axis approximate to hyperbalas. The variation regulation of flow veiocity along the center curve between two mear jets′ flow axies approximates to X2 distribution. and the variation regulation of flow velocity along the Y coordinate axis approximates to sine wave .

Flgure 4,5,6 show the above charateristics.

With two—component regression, the mathematical formulas of the locuses of the jets and the flow velocity on whole air flow camber (see Figure 4) are presented as foilows:

$$\overline{Y}=0.6317Ar^{1.11}(\overline{X})^{2.47} \qquad (1)$$

$$\overline{U}x=[4.027Ar^{-0.15}\overline{X}^{-1.121}-\frac{14.785Ar^{-0.147}}{2^{2l+1}\Gamma(2l+1)}\cdot{}^{2l}e^{-\frac{x}{2}}]\cdot|Sin(\frac{\pi\overline{Y}}{l}+\frac{\pi}{2})| \qquad (2)$$

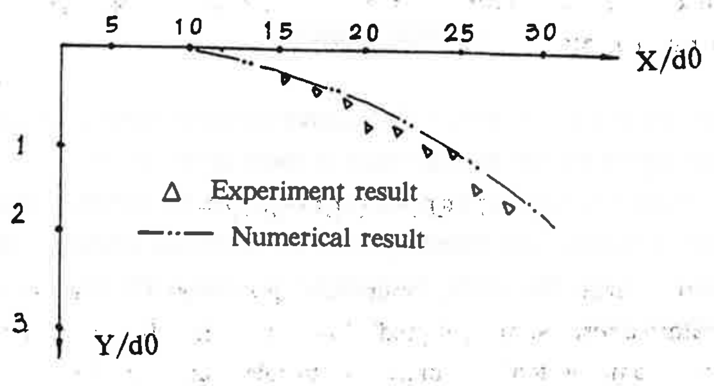

Fig. 4 . Locuse of jets

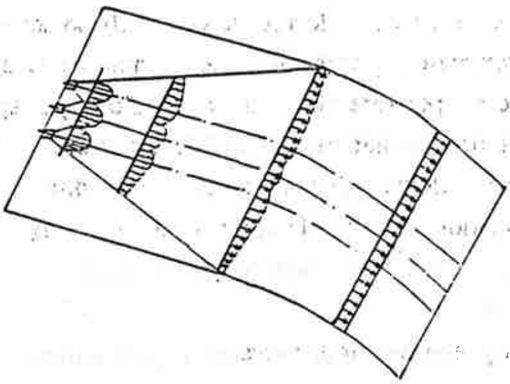

Fig. 5 . Flow regulation of the jets on flow camber

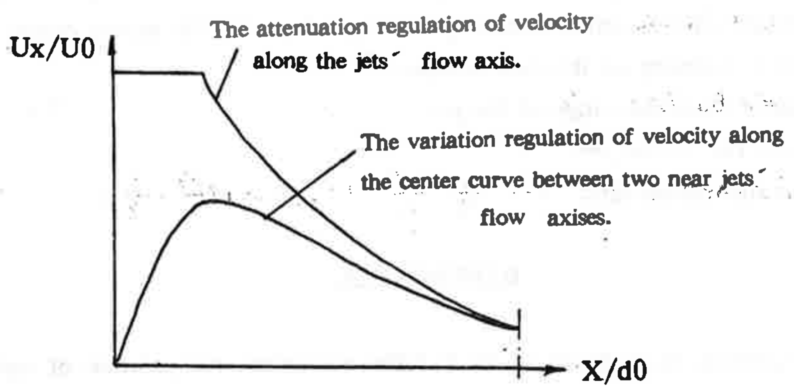

Fig. 6 . Variation Curve of Velocity of the jets

CONCLUSIONS

Numerical research of the three—dimensional turbulent airflow of series limited parallled chilled air jets in large space is made by means of k—ε turbulent model. Comparison with the experiments shows that the turbulent model, the dispositions of complicated boundaries and the numerical prediction presented in this paper are correct. Some mathematical formulas are conducted by further numerical research.

Thus the numerical simulation used in this paper is proven to be a very promising technique to study complicated flow phenomena in large air conditioning space .

NOMENCALATURE

Ar : Archimedes number
d_0 : representative length defined by width of supply outlet
k : turbuience kinetic energy
l : relative lengh between the center of two near supply outlets
T : relative temperature of air flow
T_0 : temperature of air jets in supply outlet
U, V, W : X, Y, Z components veiocity vector
U_0 : representative length definded by veiocity of air flow in supply outlet.
U_X : relative veiocity on the flow camber.
X, $\bar{X}$: range, relative range of the jets.
$\bar{Y}$: drop of the chilled jets.
ε : kinetic dissipation rate.

REFERENCES.

[1] Launder. B. E, Spalding. D. B, "The numerical computation of turbu-

lent flows" ,Compter Methods in Applied Mechanics and Engineering ,1974 , vol 19.

[2] Suhas V. Patanker," Numerical Heat Transfer and Fluid Flow ", McGraw—Hill, 1980.

[3] Guan Qing, Tang Guanfa, "Numerical study of three dimension turbulence air flow for stratified air conditioning in high—large space", HV&AC, 1991,4