小型家用中央空调气流组织数值模拟

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摘要: 本文用 FLUENT 软件对小型家用中央空调气流组织进行数值模拟, 以热线风速仪法测定流场辅助数值模拟验证。通过对原始模型数值模拟计算, 提出了改善与优化测试室气流组织的方法。

关键词: 空调; 气流组织; FLUENT; 流场测试; 优化改进
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1 引言

家用中央空调测试室在以往工程设计过程中, 常常忽略外部流场分布的不均匀性, 从而影响到空调器测试结果的稳定性和准确性。而大量实时流场测试周期长、操作复杂, 测试室气流速度通常很小, 即使微小扰动对测试结果都有很大影响, 而且缺乏对气流方向的预测, 即使排除人为因素也很难测出流场的真实速度, 不利于测试室气流分布的改进工作。对中央空调测试室气流组织进行数值模拟将有利于工程设计的检测、改进和优化, 节省大量的人力、财力和时间。计算机数值模拟与实验测试相结合的方法有助于工程设计的改进与优化[1~3]。研究如何形成合理的气流组织, 满足测试室负荷要求, 避免回流短路现象, 以达到良好的送风效果, 这具有十分重要的理论意义和实际价值。

2 控制方程和湍流模型

2. 1 模型简化

采用标准 $k－\varepsilon$ 两方程模型来求解湍流问题时, 控制方程包括连续性方程、能量方程及 $k－\varepsilon$ 方程。为了简化实际问题, 便于分析, 在建立数学模型前对室内气体的流动先作以下假设:

(1)室内气体满足牛顿内摩擦定律, 为牛顿流体;

(2)室内流体温度变化不大, 密度可视为常数;

(3)室内气体的流动形式为稳态紊流;

(4)在紊流中心区, 忽略能量方程中由于粘性作用而引起的能量耗散;

(5)室内空气在房间内壁面上满足无滑移边界条件。

本文计算所选择的求解器是 FLUENT5/6。对于在用 FLUENT 软件计算时所采用的有关数值计算方法, 说明如下:

(1)压力项、能量项、紊流动能和紊流耗散率项的离散都采用二阶迎风格式。二阶迎风格式也就是一阶导数具有二级截差的差分格式, 它可以克服迎风差分截差比较低的缺点而又能保持它的长处。

(2)压力与速度耦合关系的处理方法选用 SIMPLE 算法。

2. 2 控制方程

根据以上假设可建立其数学模型, 整场的流动应满足质量和动量方程[4~5]

(1)连续性方程

$$\frac{\partial \bar{u}_j}{\partial x_j} = 0 \tag{1}$$

(2)动量守恒方程

$$\frac{\partial \bar{u}_i}{\partial t} + \frac{\partial \bar{u}_j \bar{u}_i}{\partial x_i} = - \frac{1}{\rho} \frac{\partial p}{\partial x_i} + (v + v_t) \frac{\partial^2 \bar{u}_i}{\partial x_i \partial x_j} \tag{2}$$

2. 3 湍流模型

标准 $k－\varepsilon$ 两方程模型(Jones & Launder, 1972)

湍流动能 k 的方程, 其一般形式为

$$\rho \frac{\partial k}{\partial t} + \rho V_j \frac{\partial k}{\partial x_j} = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_T}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right] + S_k \tag{3}$$

这里 $S_k = P_k - D_k$, $P_k = \tau_{ij}^{(T)} \frac{\partial V_i}{\partial x_j}$ 为生成项, $D_k = \rho\varepsilon$ 为耗散项。

湍流耗散率 ε 的方程, 一般采用的形式为

$$\rho \frac{\partial \varepsilon}{\partial t} + \rho V_j \frac{\partial \varepsilon}{\partial x_j} = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_T}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}\right] + S_\varepsilon \tag{4}$$

这里 $S_\varepsilon = P_\varepsilon - D_\varepsilon$, $P_\varepsilon = C_{\varepsilon 1} \frac{\varepsilon}{k} \tau_{ij}^{(T)} \frac{\partial V_i}{\partial x_j}$ 为生成项, $D_\varepsilon = C_{\varepsilon 2} \rho \frac{\varepsilon^2}{k}$ 为耗散项。

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对于标准的 $k-\varepsilon$ 模型，有

$C_{\varepsilon 1}=1.44$，$C_{\varepsilon 2}=1.92$，$C_{\mu}=0.09$，$\sigma_k=1.0$，$\sigma_{\varepsilon}=1.3$

3 计算模型和边界条件

3.1 计算模型

测试室几何模型效果及布局结构如图 1、图 2 所示，测试室由工况机、送风管道、孔板及顶层静压室组成。

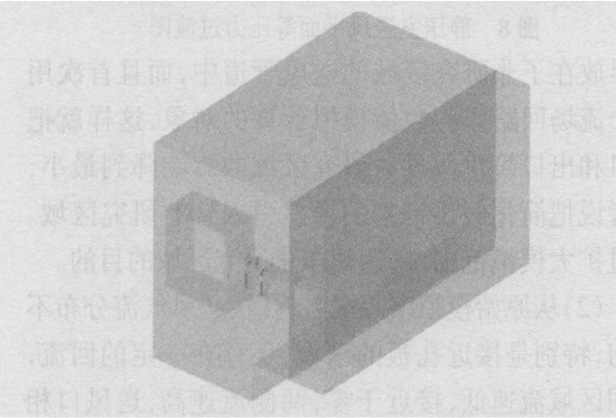

图 1　几何模型效果图

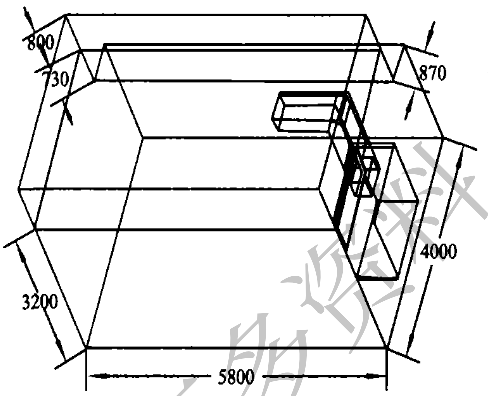

图 2　结构布局图（单位：mm）

3.2 边界条件

本文中的算例包括以下边界条件[6]：

(1)进口边界：给出入口速度边界，具体值由风机风量及送风管道尺寸计算给定。

(2)出口边界：给出出口压力边界，具体值由测试给定。

(3)固体边界：在固体边界上对速度取无滑移边界条件，即在固定边界上流体的速度等于固体表面的速度，当固体表面静止时，有 $u=v=w=0$。

4 数值计算结果及分析

图 3 为气流区域整体三维速度矢量图，可以看出送风管道内速度最大、变化最剧烈，静压调节室内速度次之，主流区域（孔板下方）速度很小且相对均匀，符合理论预测和测试结果。

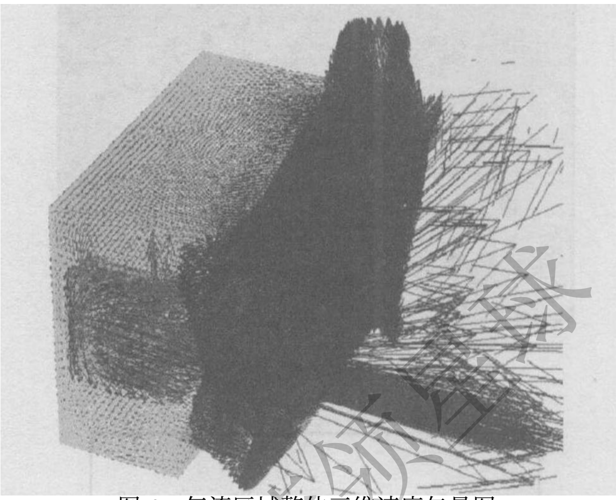

图 3　气流区域整体三维速度矢量图

图 4 为静压调节室内送风平面的速度矢量分布情况，可以看出送风射流区域两侧形成两个显著的涡流区域。

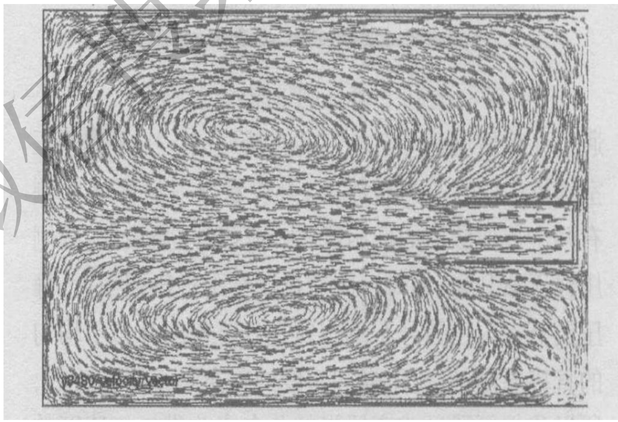

图 4　静压调节室送风平面速度矢量图

图 5 为距孔板 200mm 平面速度分布图，可以清楚看到该水平面上速度分布情况。送风伊始水平面内速度分布均匀，从左侧到右侧速度先减小后又增大，高速流动主要集中在送风相对一侧靠近墙壁区域，速度高达 0.23m/s 左右，而且送风初始平面中央位置两侧形成两个明显的涡流区域，涡流区域内速度非常小，部分区域送风速度接近 0.02m/s，这说明有气流死区存在。图 6 为横向垂直平面上的等速度分布图，工况机相对一侧的墙壁附近区域速度最大，从上到下速度逐渐变小，等速线呈扩散趋势。中间位置上方（靠近孔板）有一个低风速区域，速度从这个位置开始以环型增大的等速线向下方扩散，随着流动的发展，气流分布呈均匀趋势。

图 7 为横向垂直面上的压强分布图，可以看到中间区域低压区和墙壁附近高压区的存在，同时可以看出通过孔板后气压分布相对稳定，这也是空气

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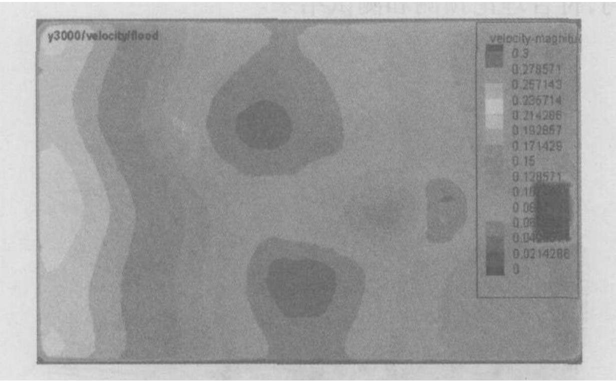

图 **5**　距孔板 200mm 平面速度分布图

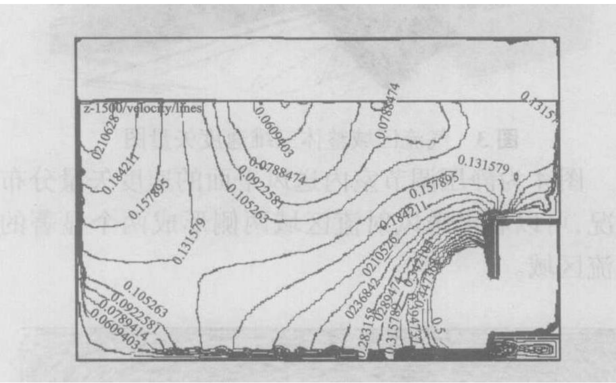

图 **6**　距门 1500mm 平面等速度分布图

通过孔板后流速分布均匀的直接原因。图 8 为静压室送风平面等压力过渡图，可以看出射流区域两侧有两个近似圆形的低压区，中间区域压强最低，两侧压强逐渐升高，相对一侧靠近墙壁附近压强最大，静压调节室内压强分布不均匀是气流速度分布不均匀的直接原因，气流压强和速度的分布是直接相关的，所以我们可通过改变压强的分布来改进气流速度的分布。

5 结论

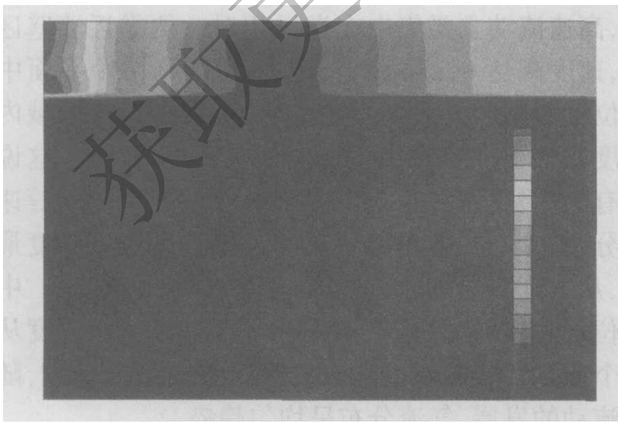

图 **7**　距门 1000mm 等压力过渡图

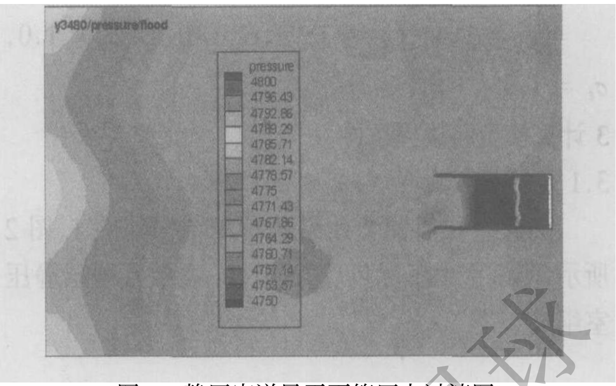

图 **8**　静压室送风平面等压力过渡图

（1）本物理模型的独特之处在于把入口和出口边界放在了非研究区域的送风管道中，而且首次用整个流场回路作为数值模拟计算的对象，这样就把入口和出口简化假设对研究区域的影响降到最小，或者说把简化假设带来的误差引入到非研究区域。通过扩大模拟范围，来达到净化研究区域的目的。

（2）从原始模拟结果来看，孔板送风气流分布不均匀，特别是接近孔板的区域，还存在一定的回流，中间区域流速低，接近于零，两侧流速高，送风口相对一侧墙壁区域附近气流速度最高，中间部分形成两个明显的低速涡流区域。由于工况机附近负压的影响，造成墙壁一侧和地面上方气流速度偏大，测试室中心区域流速偏低。

（3）分析可知气流初态决定于静压室内压强分布，气流终态决定于工况机附近负压分布，其他区域为两者相互作用相互影响的过渡区域。

（4）改变通过孔板的气流分布只能从静压室几何结构考虑，在静压室喷嘴前 2500mm 处垂直放置调压板可起到明显改善气流分布的作用。

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ABSTRACTS

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Refining-chemical industry new energy-conservation advances

QIAN Bo-zhang, ZHU Jian-fang

The refining and chemical production processes that the greats quantity are in separate process, heat exchange and reaction processes, the energy conservation potential is tremendous. The original commentary new technique of a series of energy conservation that yet the expenses adopt in the refining and chemical industry production process, main possess: microwave separation, electromagnetism separation, adsorption separation, ultra sound separation, complex separation, membrane separation, dividing wall distillation tower and so on the separation technique, along with the reaction distillation technique, the supercritical reaction technique, the membrane reaction technique and so on the new reaction technique, and new pattern heat exchanger and the heat energy recovers technique are presented.

Key words: refining; chemical process; energy conservation; separation; heat exchange; reaction

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The study of a novel voltage space vector PWM control technique for teh induction motor in oil extractor

GAO Chun-xia, ZHANG Lei, ZHANG Jia-sheng

A large number of oil extractor are used in oil field, in general, its motor ofter uses the three phase induction motor; because the control of the three phase induction motor which is much more mature at present often adopts the two-level PWM VVVF control for energy conservation, the output voltage also contains lots of harmonics in addition to the fundamental wave, which results to the aberrance of the voltage wave, thus the operating efficiency is much lower and results to the waste of lots of electrical energy. The paper has introduced a method of using the voltage space vector PWM control technique to control the motor in oil extractor, in contrast with the traditional control method, it can reduce the torque pulsation and the iron loss, and can improve the utilizatio factor of the electrical source, therefore realizes the good performance of energy conservation.

Key words: oil extractor; induction motor; voltage space vector; PWM control; energy conservation

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Inquire into about air-condition control technology & develop orientation

CHENG Gang, WU Chang-ju

This article presents the method about air-condition control technology. Point out them merits and defects. We also prospect its direction and prospect in the future.

Key words: air-condition; control technology; develop orientation

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The status quo and prospect of the air-source heat pump water heater

ZHOU Feng, MA Guo-yuan

In lately years the air-source heat pump water heater is being given attention by more and more consumers because of its obvious safety, energy conservation and a large market in China. This paper briefly introduces the backgrounds of the air-source heat pump water heater, the principles and R&D situations in China. Meanwhile this paper compares the air-source heat pump water heater with three kinds of traditional water heaters, summarizes the national marketing and points out the present problems of this product.

Key words: air-source heat pump; water heater; energy saving

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Experimental study on gas turbine inlet air cooling by using CO_2

JIANG Xue-lin, TAO Zheng-liang, HE Ming-xun, et al.

It is a attempt to cool the gas turbine inlet air by using CO_2 as refrigerant to build up a two stage closed circulation system. In terms of the parameters of our customer' s combined units, an experimental system is designed and set up. In this paper, the structure dimensions of the experimental system, control system of date collecting and methods of data processing are introduced. The experiment validates the cooling effect of the gas turbine inlet air by using this equipment and it also meets with the working requirement of the air-cooling in the practical gas turbine.

Key words: gas turbine; carbon dioxide; air-cooling; experimental study

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Airflow numerical simulation on small-sized residential air-conditioning test room

ZHAO Qing-xiao, LI Ting-yong, HU Di, et al.

Airflow numerical simulation on small-sized residential air-conditioning test room is conducted by FLUENT, air flow data with heat ray anemoscope assists the simulation. We carry numerical simulation optimization work based on original simulation and identify the methods on how to improve the airflow.

Key words: air-conditioning; air flow; FLUENT; airflow test; optimization

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The numerical study on heat transfer and pressure drop characteristics of tube-fin heat exchangers with the vortex generators

GUAN Yong, HU Wan-ling

A numerical study has been carried out to investigate the heat transfer and pressure drop characteristics of staggered circular tube-fin heat transfer with the WVG. The velocity fields and transverse average *Nu* and average surface convective behavior and pressure drop characteristics of both the smooth plate and the lower wall with WVG are compared, which provide the evidence for enhancing heat transfer and modifying the fin structure and designing the new heat transfer.

Key words: heat exchanger; heat transfer enhancement; vortex generators; numerical analogy

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Environmental influence and energy-saving characteristic of oxygen-enriched combustion

ZHENG Xiao-feng, FENG Yao-xun, JIA Ming-sheng

Environmental influence and energy-saving characteristic of oxygen-enriched combustion were discussed in this paper. With the development of low cost of oxygen making technology, utilization of oxygen-enriched combustion can save energy because its high combustion efficiency. In the same time, using this technology muse notice its influence to the environment.

Key words: oxygen-enriched combustion; energy-saving; environment

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