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Research on the heat transfer rules of natural convection in a building with single heat source

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Abstract

Taking buildings' cooling problem as the background, the natural convection were numerically simulated in a cavity with single heat source using SIMPLE algorithm with a QUICK scheme. The temperature field, flow field and rules of heat transfer were studied. The results showed that two symmetrical vortex appeared in a single heat source with the different ratio of length and height. With the increase of the ratio, vortex's number unchanged, and shape became wide. The influence of the heat source on around became weak with the increase of the aspect ratios. After considering the radiation on the building walls, the distribution of each section temperature changed. When the ratio of length and height became smaller, the distribution changed obviously. On the contrary, it had a little change. The ratio of radiation to convection basically was stable at 0.42, radiation had a greater impact to heat transfer.

Keywords: Building, Heat source; Convection; Radiation; Lateral walls

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1. Introduction

Today, energy problem was one of the major challenges in the society, energy conservation and emissions reduction caused more people's attention. However, with the human living standard gradually improving, we must ensure the construction environmental comfort conditions with energy conservation and emissions reduction. Therefore, building energy efficiency and the research of building environment comfort must be closely combined. The study of natural convective thermal dissipation had important theoretical and realistic significance to improve indoor air environment, saving building energy and inhibit pests spread.

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There were a number of related researches on this topic. As early as 1901, Benard found it that the atmospheric temperature difference would produce thermal convection. Krishnamurti, one of the earlier researchers about Rayleigh Benard convection, observed Rayleigh Benard convection-vortex forms through the experiment. Man studied heat transfer of natural convection in a square cavity with a heat source. Manab studied the influence of the tilt angle. Sharif simulated heat transfer of natural convection in a square cavity with a heat source and confirmed that the influence of the lateral walls on the national convection. Dong etc. confirmed the influence of geometry of the cavity. Q.W. Wang conducted experiments to study on natural convection in inclined square cavity with isolated plates. They confirmed the influence of the plate position, inclined angle of the cavity and the Rayleigh number on heat transfer. H.L. Jiang conducted experiments to study on natural convection in a rectangular cavity with scattered heat sources, and showed it that the plate temperature and heat transfer coefficient of scattered heat sources was only related to the self-heating power and heat transfer condition.

By analyzing the results mentioned above, it was found that there was rather little work on radiation coupling of convection. In this paper, the natural convection was numerically simulated in a cavity with single heat source using SIMPLE algorithm with a QUICK scheme. The influence of geometry and radiation on natural convection and interior rule were studied through simulation.

2. Mathematical formulation and method of solution

2. 1. The problem and mathematical formulation

The problem considered, as shown in Figure 1, refers to the 3-D (3-dimensional) natural convection and heat transfer in a cavity with single source. The temperature of heat source in the cavity is T_h. The temperature of the bottom plate and the temperature of the top plate are T_c ($T_h>T_c$). The height of the cavity is H. The length of the cavity is L. The width of the cavity is W. The height of the heat source is h(h=0.5H). The heat source lies in the center of the cavity. The air is considered as Boussinesq fluid. Prandtl number of the fluid is 0.701. The lateral walls are adiabatic. The aspect ratio parallel to the z-axis is L_z and the aspect ratios parallel to the x-axis are L_x, respectively.

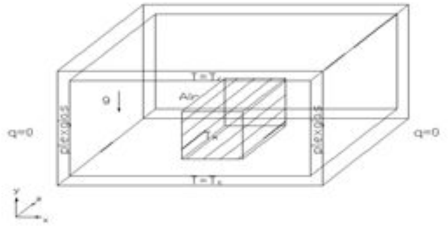

Figure 1 Geometry of the cavity

2. 2. The governing equation

The dimensionless governing equations for the conservation of mass, momentum and energy are expressed as follows.

$$\frac{\partial U}{\partial \tau}+U\frac{\partial U}{\partial X}+V\frac{\partial U}{\partial Y}+W\frac{\partial U}{\partial Z}=-\frac{\partial P}{\partial X}+\sqrt{\frac{Pr}{Ra}}\left(\frac{\partial^2 U}{\partial X^2}+\frac{\partial^2 U}{\partial Y^2}+\frac{\partial^2 U}{\partial Z^2}\right) \qquad (1)$$