Study on Heat Conduction Characteristics of Heat Insulation Wall Based on Airflow Reverse Osmosis Principle

Dingyu Cao, Lequn Fu and Chuangting Lin

School of Mechanical and Electrical Engineering, Wuhan University of Technology, Wuhan 430070, China

Abstract. Building energy saving is an important theme in the development of construction industry. It has important significance to achieve wall heat insulation. MATLAB software was utilized to model the heat transfer coefficient and obtain the main factors influencing airflow reverse osmosis principle based on the research of airflow reverse osmosis principle. The influence of seepage layer thickness and seepage velocity on thermal performance of airflow reverse seepage principle was determined and the optimal value was obtained through ANSYS simulation. An energy-saving plate was designed to build a removable house, and the heat conduction characteristics of air reverse osmosis principle were verified by experiments. The simulation results showed that heat conduction characteristics of the heat insulation wall based on airflow reverse osmosis principle were optimal when the thickness of the seepage layer is 40mm and the seepage velocity is 0.008m/s. The experimental results showed that the heat-shielding performance of the wall based on the airflow reverse osmosis principle was improved by 18.56%, and the thermal insulation performance was improved by 24.15% compared with that of the ordinary wall, and heat insulation wall based on airflow reverse osmosis principle had excellent heat conduction characteristics.

1. Introduction

Previous research was mainly concentrated on the analysis of the dynamic heat-shielding efficiency of the model and simplification of mathematical model. All structure parameters of the air reverse osmosis principle and heat transfer efficiency were not studied excessively. MATLAB software was utilized for modeling calculation on the basis of previous research in the paper, and main factors influencing the air reverse osmosis principle are obtained. The optimal values of all influencing factors of the air reverse osmosis principle were solved through ANSYS software simulation. The heat conduction characteristics of the air reverse osmosis principle verified through experiments.

2. Parameter design with ANSYS structure

CFD software (fluent) is utilized for simulating two working conditions of fluid-solid coupling heat transfer and air flow in the cavity in order to analyze the influence of seepage layer thickness and seepage velocity on thermal performance based on air reverse osmosis principle. An optimal
parameter is determined with inner wall air inlet flow velocity as the point variable and outer wall constant temperature as the fixed value, thereby minimizing inner wall temperature.

2.1. Selection of calculation model

According to the calculation formula of Reynolds number:

\[ \text{Re} = \frac{\rho v d}{\mu} \]  

(1)

In the equation, \( \rho \) refers to gas density, \( v \) refers to gas velocity, \( d \) refers to pipe equivalent diameter, \( \mu \) refers to gas viscosity coefficient. \( \rho \) refers to air density 1.293 kg/m³, \( v \) refers to 1 m/s, \( d \) refers to inner wall air inlet equivalent diameter 80 mm, and \( \mu \) refers to 20 °C air viscosity coefficient 1.81 \times 10^{-5} \text{ Pa s} according to use condition of the device.

Reynolds number is about 5714>4000 according to calculation. Values of other sections are substituted into the formula for calculation, and it is found that Re is greater than 4000. It can be seen that the flow in the model is completely turbulent, the gas type is incompressible, and the influence of molecular viscosity can be neglected, and standard \( k-\varepsilon \) model is adopted for the air flow in the wall cavity. The \( k-\varepsilon \) model is mainly composed of the turbulent kinetic energy differential equation \( k \) and pulsating kinetic energy dissipation rate differential equation \( \varepsilon \):

\[ \frac{\partial (\rho k)}{\partial t} + \frac{\partial (\rho u_j k)}{\partial x_j} = \frac{\partial}{\partial x_j} \left[ (\eta + \frac{\eta_t}{\sigma_k}) \frac{\partial k}{\partial x_j} \right] - \eta_t \frac{\partial u_i}{\partial x_j} \frac{\partial u_j}{\partial x_j} - \rho \varepsilon \]  

(2)

\[ \frac{\partial (\rho \varepsilon)}{\partial t} + \frac{\partial (\rho u_j \varepsilon)}{\partial x_j} = \frac{\partial}{\partial x_j} \left[ (\eta + \frac{\eta_t}{\sigma_\varepsilon}) \frac{\partial \varepsilon}{\partial x_j} \right] + \frac{c_p}{k} \eta_t \frac{\partial u_i}{\partial x_j} \frac{\partial u_j}{\partial x_j} - c_{\mu} \frac{\varepsilon^2}{k} \]  

(3)

When \( k-\varepsilon \) model is adopted for solving turbulence problem, the governing equations include equation of continuity, equation of momentum, equation of energy, \( k \), \( \varepsilon \) equation and \( \eta_t \) calculation method, wherein \( \eta_t \) calculation formula is shown as follows:

\[ \eta_t = c_D \rho k^2 = c_D \rho k^2 \frac{1}{3} = \frac{c_D \rho k^2}{3} \]  

(4)

2.2. Setting of physical model

We designed a plate with appropriate size and consistent structure as the simulation experiment wall based on the air reverse osmosis principle in order to simulate the heat transfer effect of the air reverse osmosis principle wall. The wall model was completed with 3D modeling software Inventor. The wall section view is shown as follows:
The final reflection effect of air reverse osmosis is inner wall temperature of the wall steel plate. The main influencing factors include the seepage layer thickness and the gas flow velocity in the seepage layer, $d$ is the seepage layer thickness, and the gas flow velocity in the seepage layer is changed indirectly through setting the seepage layer thickness.

The plate and the indoor area are combined in a model so that the flow of indoor gas is consistent with the actual situation after sufficient development. Solid area of the wall is suppressed, and only fluid area and solid area of the wall steel plate are left.

2.3. Design of seepage layer thickness

The air outlet flow velocity is set according to ‘Indoor Air Quality Standard’. The seepage layer thickness is 30 mm, 40 mm, 50 mm and 60 mm respectively. The temperature of the inner wall is simulated. The simulation nephogram is shown in figure 2. The specific value is shown in figure 3:
Analysis shows that the internal temperature of the wall is the characterization quantity of wall heat-shielding performance. When the seepage layer thickness is 40 mm, the seepage velocity is 0.008 m/s, the inner temperature of the wall based on the air reverse osmosis principle is the minimum in summer, which is the maximum in winter. The heat-shielding thermal insulation effect is best under the parameter.

2.4. Comparative simulation verification
The wall based on air reverse osmosis principle with the optimal values of all parameters is compared with ordinary walls based on the same condition for simulation in order to reflect the heat insulation effect of air reverse osmosis principle intuitively. Other environmental parameters are set to be the same, and the inner wall temperature of the two walls is compared. The thermodynamic simulation nephogram of winter and summer is shown in figure 4.
The simulation results show that the summer novel wall inner temperature is lower than ordinary wall by 7.15 °C under summer environment, the novel wall inner temperature is higher than ordinary wall by 7.66 °C under winter environment, and the heat-shielding thermal insulation performance of the novel wall is superior to the traditional wall prominently.

3. Experimental verification
We proposed an energy-saving plate based on the air reverse osmosis principle in order to verify the accuracy of simulation results. Its structure flat pattern is shown in figure 5. It is mainly composed of a plate main body and an external frame. The plate main body is composed of an internal pressure plate with an air inlet, an external pressure plate with an air outlet, internal and external hollow supports and a seepage layer. We used the designed energy-saving plate to build a removable house for building an enclosed space. Heat insulation performance experiment and energy consumption experiment are carried out. Meanwhile, ordinary plates were utilized for building a removable house in the same size for comparison experiment.

4. Conclusion
ANSYS simulation results show that the heat insulation performance of air reverse osmosis principle is the best when the seepage layer thickness is 40 mm and seepage velocity is 0.008 m/s. Experiment results show that the heat-shielding performance of the wall based on air reverse osmosis principle is improved by 18.56% compared with ordinary walls. The thermal insulation performance is increased by 24.15%. The wall based on air reverse osmosis principle has excellent good thermal performance. The single-day energy consumption of the wall based on air reverse osmosis principle is lower than the ordinary wall by 16.40%, thereby reducing the energy consumption of building heating and cooling effectively.

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