Simulation Research on Heat Dissipation of the Inner Tank of Household Electric Cooker Based on Fluent

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Abstract. Aiming at the problem of heat loss from the inner pot of the rice cooker, based on theoretical analysis and CFD simulation technology, this paper establishes a three-dimensional model of the inner pot of the rice cooker, uses the SCDM model analysis in Fluent, and performs grid division and fluid calculations. Adding a reflection layer and a vacuum insulation layer to the outer wall of the inner tank can effectively reduce the heat dissipation of the inner tank, which provides an important reference for the improvement of household rice cookers.

Keywords: Rice cooker, Electromagnetic heating technology, Fluid simulation, SCDM model, Heat exchange.

1. Introduction

As the country gradually increases its policy support for green smart home appliances and residents gradually form a green and environmentally friendly life concept, green, energy saving, environmental protection, and intelligence have become factors that affect consumers’ purchase of home appliances. At present, the total number of rice cookers in my country has reached about 200 million. Therefore, the energy-saving technology of rice cookers is a development direction of green home appliances that deserves attention.

The rice cookers currently on the market are roughly divided into ordinary rice cookers, smart rice cookers, IH rice cookers and so on. The IH rice cooker uses electromagnetic heating technology to directly heat the inner pot. Through the research on electromagnetic heating technology, it is known that electromagnetic heating technology is a new type of heating technology. Traditional household appliances use electric heating wire heating technology and microwave heating technology. Compared with them, heating technology has obvious advantages [3]. Today, the market share of IH rice cookers has reached 40.3%. According to the New Thinking Industry Research Center, high-end intelligence represented by electromagnetic coil induction heating technology, namely IH technology, and environmental protection and energy saving are the current development trends of the rice cooker industry. After consulting the relevant information of the rice cooker, online and offline interviews, and research, it is found that although the IH rice cooker has eliminated the heat loss in the secondary heat transfer, it still has the problem of escape of heat radiation and heat conduction in the inner pot.
2. Rice cooker inner tank model
The inner container of the rice cooker is an axis-symmetrical rotating body structure, which equates the rice cooking process of the rice cooker to a process of steady heat transfer. The plane axisymmetric model is used to analyze the heat transfer process, and the simplified equivalent cylinder structure and cross-sectional structure of the inner tank are shown in the figure.

![Figure 1. Structure diagram of equivalent liner.](image1)

![Figure 2. Single-layer cylinder heat transfer model.](image2)

According to the above analysis results, a three-dimensional model of the inner pot of the rice cooker was established. The scale of the model is 1:1 actual model, and the model accurately reflects the geometric characteristics of the inner pot.

![Figure 3. Three-dimensional model of inner tank.](image3)

![Figure 4. Model section.](image4)

Import the 3D model into Fluent software for model analysis, and the following geometric dimensions of the model can be obtained.

| diameter | height | Computational domain range | smallest size | Volume |
|----------|--------|-----------------------------|---------------|--------|
| 238mm    | 140mm  | 450*445*445mm               | 0.684mm       | 220634mm³ |

The calculation domain of the model is meshed. The mesh adopts a polyhedral-hexahedral hybrid mesh. The mesh at the interlayer is encrypted, and the overall mesh is analyzed for independence. Finally, the number of meshes used is 202W.

![Figure 5. Model meshing result.](image5)
3. Theoretical basis and mathematical model

According to the established model of the inner pot of the rice cooker, combined with the knowledge of heat transfer, on the one hand, heat convection occurs between the inner pot and the outside air, resulting in heat exchange. According to Newton's cooling equation\textsuperscript{[1]} analysis:

$$q = \alpha(T_s - T_a)$$

In the formula, $\alpha$ is the convective heat transfer coefficient (or film heat transfer coefficient, heat transfer coefficient, film coefficient, etc.), $T_s$ is the temperature of the solid surface, and $T_a$ is the temperature of the surrounding fluid. From the analysis of the formula, it can be seen that when the temperature of the solid surface and the temperature of the surrounding fluid are known, the main factor that affects the heat flow density, and then affects the heat dissipation of the inner tank, is the convective heat transfer coefficient. Then the analysis can be obtained, using the convective heat transfer coefficient The extremely small vacuum environment can effectively reduce the heat dissipation of convection.

On the other hand, the inner bladder stays at a high temperature (90°C) for more than half of the time during the cooking process, according to the Stephen Boltzmann equation:

$$Q = \varepsilon_1 A_1 F_{12} (T_1^4 - T_2^4)$$

In the formula, $Q$ is the heat flow rate, $\varepsilon_1$ is the absorption rate (blackness), $\sigma$ is the Stephen-Boltzmann constant, $F_{12}$ is the shape factor, $T_1$ is the absolute temperature of the radiating surface 1, and $T_2$ is the absolute temperature of the radiating surface 2. The higher the temperature, the greater the heat flow rate and the faster the heat transfer rate.

The heat radiation from the inner tank conforms to the situation that the convex/flat diffused gray surface is surrounded by another diffused gray surface, so the above formula can be rewritten as:

$$\Phi_{12} = \varepsilon_2 A_1 \sigma_0 (T_1^4 - T_2^4)$$

The system blackness:

$$\varepsilon_2 = \frac{1}{\frac{1}{\varepsilon_1} + \frac{1}{A_2} (\frac{1}{\varepsilon_2} - 1)}$$

In the formula, $\varepsilon_1$ is the surface absorption rate of the liner, $\varepsilon_2$ is the absorption rate of the shell of the liner, $A_1$ is the area of radiation 1, $A_2$ is the area of radiation 2, $T_1$ is the absolute temperature of radiation surface 1, and $T_2$ is the absolute temperature of radiation surface 2. According to the analysis of the above formula, the strength of heat radiation is related to the absorption rate of the surface of the liner and the absorption rate of the shell of the liner, and then the analysis can be obtained, if the heat radiated from the liner in the form of heat radiation can be reflected by the heat radiation The high material reflects back to the inner tank, forming a multiple reflection, dynamic adjustment process, which can reduce the heat loss due to thermal radiation. Therefore, it is theoretically possible to use a high temperature resistant reflective coating with high reflectivity to reduce heat radiation energy loss.

4. Simulation experiment setting and result analysis

The idea of the simulation experiment is as follows. The simulation experiment is carried out through Ansys software, and the following four groups of experiments are set up to explore and find the most suitable energy-saving insulation plan for the inner tank.

1) Simulation results of heat dissipation temperature distribution in IH rice cooker
2) Simulation results of temperature distribution after adding a vacuum insulation layer outside the IH rice cooker
3) Simulation results of temperature distribution after adding reflective coating on the shell of IH rice cooker

4) A vacuum insulation layer is added outside the inner pot of the rice cooker, and a reflective coating is added to the outer shell of the rice cooker. The temperature distribution simulation results

According to the design ideas of the simulation experiment, the following assumptions were made: 1) The fluid is considered to be an incompressible ideal gas; 2) The flow is steady; 3) The fluid does not slip on the wall; and finally the temperature range of the temperature distribution cloud is selected. For 310K-380K, a comparative analysis of the simulation results, the simulation results are as follows:
According to the simulation data, the efficiency under the four working conditions can be calculated as shown in the table below (assuming the thermal efficiency of the control group is 100%). From the data in the table, it can be seen that both the vacuum insulation layer and the reflective layer can improve the heating efficiency of the rice cooker, but the increase in the efficiency of the reflection layer is far lower than the increase in the vacuum insulation layer, and the efficiency of the vacuum insulation layer combined with the reflection layer is not as good as the two. The sum of efficiencies under a single action.

**Figure 8.** Reflective temperature cloud map.

**Figure 9.** Temperature map of vacuum layer and reflective layer.
Table 2. Comparison of thermal efficiency between different groups.

|                      | Control group | Vacuum insulation layer | Reflective layer | Reflective layer of vacuum insulation layer |
|----------------------|---------------|--------------------------|------------------|--------------------------------------------|
| Thermal efficiency comparison | 100           | 112.2                    | 104.6            | 114.8                                      |

5. Conclusion

The temperature of the inner pot of the IH rice cooker rises under the action of electromagnetic heating. According to the basic principles of heat transfer, it can be known that while the heating inner pot heats the food inward, it will also dissipate heat outward, and the main forms of heat dissipation include convection heat exchange and thermal radiation. The simulation results in this paper further verify this conclusion.

In this paper, by building a mathematical model and analyzing the formula model, it is concluded that when the temperature of the solid surface and the temperature of the surrounding fluid are known, the main factor that affects the heat flow density and then the heat dissipation of the inner tank is the convective heat transfer coefficient, so it is reduced. The convective heat transfer coefficient is a way to reduce heat convection and heat dissipation, and then the analysis can be obtained. The use of vacuum insulation layer to partition can effectively reduce the convection heat dissipation. In addition, the radiation strength is related to the surface absorption rate of the liner and the absorption rate of the liner shell. Related, and then analyzed, the use of high temperature resistant reflective coating with high reflectivity can reduce heat radiation energy loss, and then the simulation experiment results verify these conclusions, and finally it is concluded that a reflective layer and a vacuum insulation layer are added to the outer wall of the inner wall of the rice cooker It can effectively reduce the heat dissipation of the inner tank.

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