TEMPERATURE DISTRIBUTION IN A CIGARETTE OVEN DURING BAKING

by

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Baking treatment is one of the most important processes of cigarette production, which can significantly enhance quality of tobacco. Theoretical and numerical investigation on temperature distribution in a cigarette oven during baking was carried out. The finite volume method was used to simulate the flow field. The relationship between the uniformity of temperature field and impeller's speed was given finally, which is helpful to optimize cigarette oven with better quality and less energy consumption.

Key words: *cigarette oven, temperature field, rotating speed*

Introduction

Tobacco baking is an important step of cigarette production [1]. For the great impact of the oven on tobacco baking, extensive study has been carried out for the quality of the oven. Figure 1 shows the geometry of cigarette oven. Liu *et al.* [2] has simulated the internal flow field of the oven during the producing process based on the finite volume method.

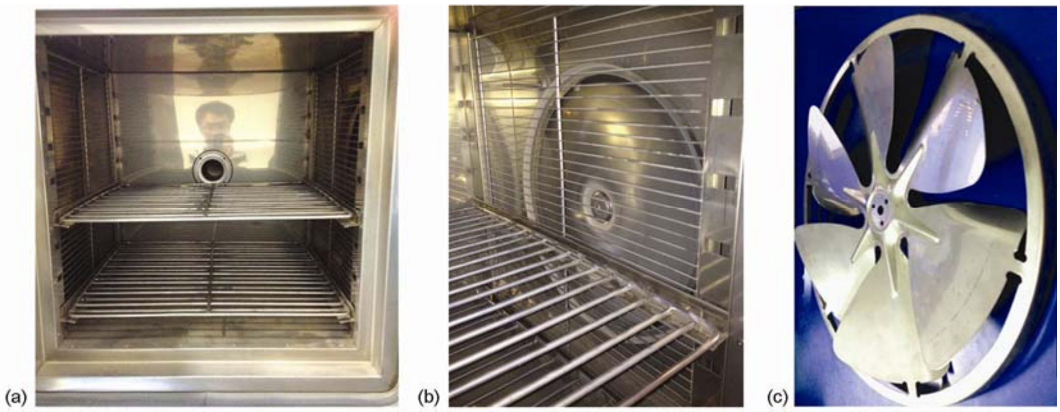

Figure 1. The physical model of the cigarette oven and impeller; (a) oven front view, (b) oven side face, (c) oven impeller

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Verboven *et al.* [3] has simulated the temperature field with great convection, and validated it with the experimental data. Dou [4] has simulated the gas flow of oven, and proposed an optimized design for the stability of the oven. Khatir *et al.* [5] has studied the air flow and temperature distribution of bread oven with experiments and numerical simulation. However, the relation between the uniformity of temperature and impeller's speed hasn't been given.

Numerical simulation and results analysis

The geometries of cigarette oven and impeller are shown in figs. 2 and 3, respectively. The number of mesh is about 2.4 million, as shown in fig. 4, which reflects geometries that showed less than 1% change in velocity profiles when the mesh was further refined. Pressure inlet and outlet boundary condition has been used.

Figure 2. Geometric model of cigarette oven

Figure 3. Geometric model of impeller

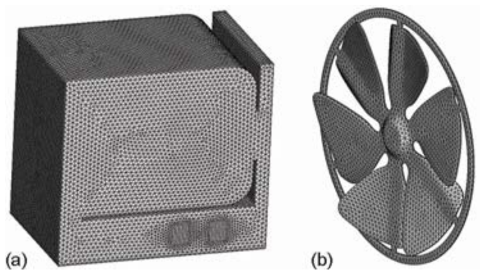

Figure 4. Schematic of the volume mesh of the oven (a), and face mesh of impeller (b)

From the streamline shown in fig. 5, it can be seen that the fresh air was sucked from ventilation entrance on the bottom of oven, then it was heated in the heating area, and heated drying air was driven into the baking chamber to dry tobacco leaves, part of hot and humid air was discharged to the ventilation outlets finally. Two obvious vortexes induced by the rotation of the impeller in the baking chamber can be found, which can increase the diffusion of energy and improve the uniformity of temperature.

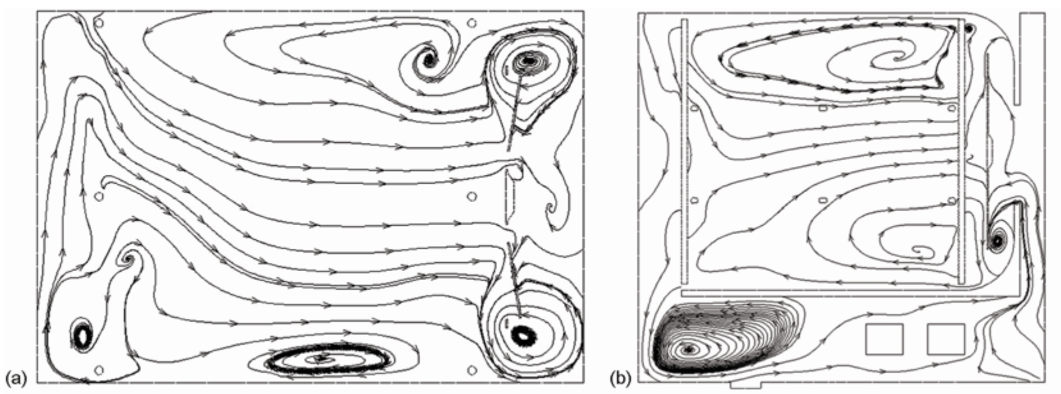

Figure 5. Streamline in the cross section of oven; (a) horizontal direction, (b) vertical direction

Steady temperature field after long time of heating has been obtained and shown in fig. 6, from which it can be found that the temperature ranged from 360 K to 410 K in the chamber and the heating element's temperature was about 470 K.

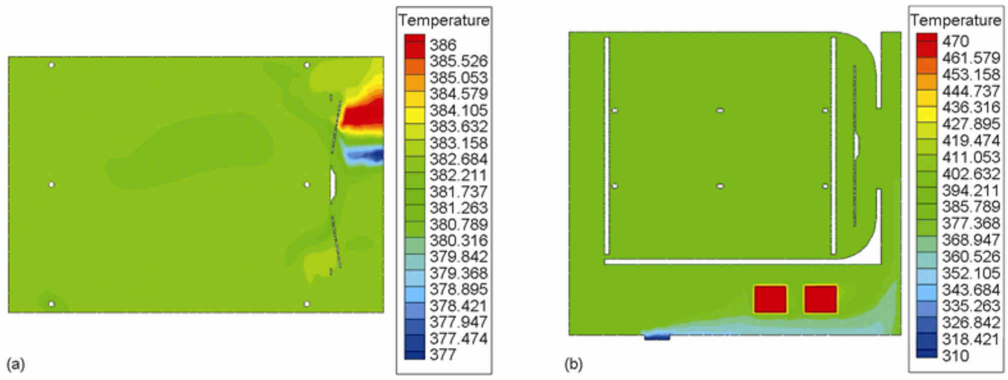

Figure 6. The contour of temperature in the cross section of oven [K]; (a) horizontal direction, (b) vertical direction

With the continued heating of oven, the temperature of the oven's center gradually increased. To observe the calculated results more intuitively, the data has been organized in fig. 7. It can be found that temperature of the oven increased obviously over time, and there is a good linear relationship between temperature and time.

Relative root mean square (RMS) method has been used to evaluate the uniformity of temperature field inside the oven:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} (T_i - \overline{T})^2}{(n-1)\overline{T}^2}}$$

where σ is the discrete rate, T_i – the temperature of measuring point, $\overline{T}$ – the average temperature of measuring point, and n – the number of measuring points. Usually, smaller discrete rate means better field uniformity.

A series of numerical simulations have been carried out, and the relationship between rotational speed of impeller and discrete rate has been achieved and shown in fig. 8, from which it can be found that σ becomes smaller firstly and larger next, for the minimum value of discrete rate, there exists an optimized rotational speed of impeller 250 rad/s, which corresponds the best temperature field uniformity. This conclusion means that larger speed than the optimized value not only wastes energy but also makes tobacco leaves fly randomly and fractured, which is helpful to the optimized design of cigarette oven with better quality and less energy consumption.

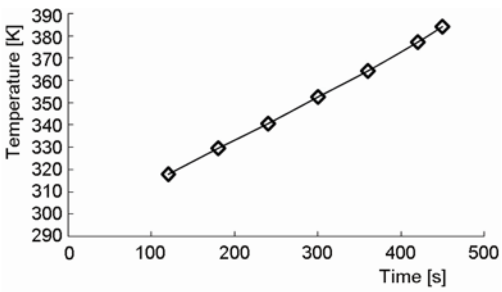

Figure 7. The relationship between temperature and time

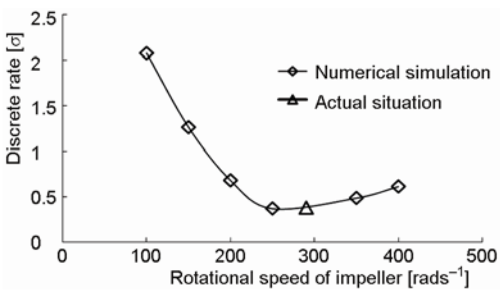

Figure 8. The relationship between rotational speed of impeller and discrete rate

Conclusions

Theoretical and numerical investigation on temperature distribution in a cigarette oven during baking was carried out. The finite volume method was used to simulate the flow field and the relative RMS value method was used as the criteria of the distribution of temperature. The relationship between the uniformity of temperature fields and impeller's speed was given finally, and for the best uniformity of temperature field, there always exists a moderate rotational speed of impeller.

Acknowledgment

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