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Analysis of temperature field of grain and drying medium for grain drying integrated mechanical device.

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Abstract: In order to improve the working efficiency of the drying tower and the hot blast stove in the process of grain drying, this paper proposes a method to solve the problems of air pollution and energy waste caused by excessive combustion or insufficient combustion of the hot blast stove. Based on finite element analysis, this paper uses ANSYS software to simulate the drying process of grain. This paper briefly introduces the grain drying device model and working mechanism, analyzes the temperature field of the drying device, and studies the influence on the drying effect of the working parameters (hot water, hot air, hot air hot blast stove combustion temperature) during the grain drying process. The results show that the hot air temperature is 85°C, the hot water temperature is 90°C, the combustion chamber temperature is 480°C, the grain drying effect is good, the combustion efficiency of the combustion furnace is the best, and the energy utilization rate is the highest.

1 introduction

The process of grain drying is the process of separating the free water and grain in the grain through a drying medium [1]. When the drying tower dries grain, the temperature of the drying medium is generally too low or too high, which will result in unsatisfactory drying performance. The temperature is too low, resulting in high moisture content [2]. The second drying will not only affect the drying effect but also increase the drying cost. Excessive temperatures will deactivate the grain [3]. It is mainly determined by the amount of fuel added that the temperature of the drying medium is too high or too low. At present, most of the drying tower work is based on the master's experience and lacks theoretical basis. Now we analyzed the temperature field of the drying tower device and combine the actual experimental data to obtain the hot water when the drying medium meets the grain drying temperature. The temperature value of the combustion chamber in the hot blast stove, in the future work, only needs to maintain the temperature of the combustion chamber at the required temperature, so that the drying tower can work normally. The operational factors affecting the performance of the drying device include the temperature of the drying medium (hot water, hot air) and the temperature of the combustion chamber in the hot water hot blast stove. Studying the operating parameters of the grain drying equipment has positive and important scientific significance for improving the drying efficiency, increasing the energy efficiency and reducing the loss rate.[4]

2. Drying device integration model and working mechanism

Hot water hot air stove uses biomass particles as fuel for combustion [5]. Hot water hot air stove produces hot water hot air, which is sent to the drying tower through fan and water pump to dry food. The grain is lifted with the hoist to the top of the drying tower. Under the action of gravity, the hot water in the drying section of the drying tower is used to transfer the moisture inside the grain to the grain surface, and then the hot water in the drying section is used to evaporate the moisture on the grain surface. Thus drying the grain [6]

3. Drying device integrated model modeling, parameter setting and test parameter setting

3.1 Drying Device Integrated Modeling

The model of this paper is based on the physical design of a drying integration device jointly designed by Jining Design Institute and Jinan University. The physical map is shown in Figure 1. In order to facilitate simulation and improve efficiency, the model was built considering only the size of the actual working part, without considering other factors. In the actual measuring device size, we use a tape measure with an accuracy of 1mm to measure the dryness of the drying tower, the drying section, and the hot air hot-blast furnace. The dimensions are: 1900mm long and 800mm wide. High 1000mm, drying section length

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1800mm, width 1896mm, height 2400mm, hot water hot blast furnace length 2400mm, width 1600mm, height 1500mm. We use the drawing software to design the simplified analysis model of the drying device as shown in Figure 2. We use ANSYS to mesh the analysis model as shown in Figure 3.

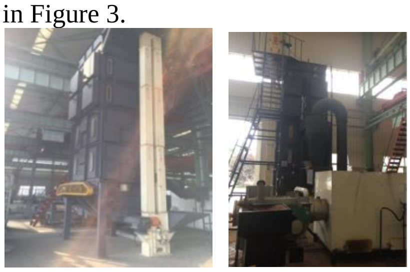
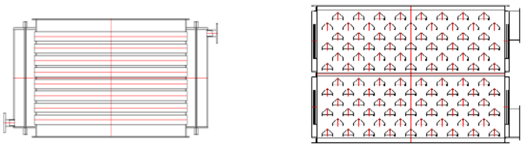
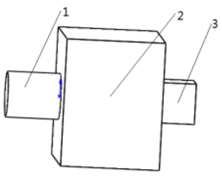


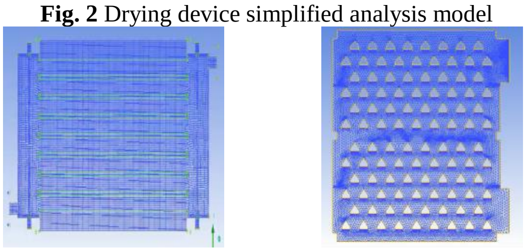
Fig.1 Drying device physical map.



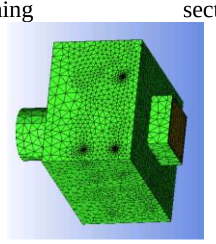
(a) Dry tower drying section model (b) Dry tower drying section model



1. Hot water hot air furnace combustion chamber 2. Hot water hot blast furnace exchange room 3. Hot water hot air furnace exhaust passage.
(c) Dryer Hot Water Heater Model
Fig. 2 Drying device simplified analysis model



(a) Drying Tower Drying Section Meshing (b) Drying tower drying section meshing



(c) Hot water hot blast grid mesh
Fig.3 Analysis model meshing

3.2 The simulation parameters

In the analysis process, the grain area is treated as a porous medium area. ANSYS software needs to set some parameters for grain drying.. Assuming the fluid is laminar, the turbulent viscosity is set to zero. The porosity of the grain pile refers to the gap between grain particles and grain, the volume of voids in the grain piles as a percentage of the total grain volume, and the common grain types, porosity and levitation speed parameters are shown in Table 1. In this paper, we choose the specific heat $C_s$of grain moisture to be 4186.8$\frac{J}{Kg*K}$, and the dry matter specific heat C_g of grain is 1425$\frac{J}{Kg*K}$. The thermal conductivity changes with the change of its internal moisture content. We choose the thermal conductivity of grain as 0.159 $\frac{W}{m*k}$. The air density ρ is generally $1.225\ kg/m^3$. The specific volume of air is the reciprocal of the density. The inlet speed of hot water is 0.4m/s. The speed of hot air is 5m/s. The flue gas in hot-water hot blast stove is designed to be Specific heat capacity $1.4475\frac{KJ}{m^3\times°C}$, smoke enthalpy $0.3457\frac{kcal}{m^3\times°C}$, thermal conductivity $0.0570\frac{w}{m\times°C}$, kinematic viscosity $6.04\times 10^7\frac{m^2}{s}$,, density$0.25\frac{kg}{m^3}$.

Table 1 Common food types and porosity and levitation speed parameters

Types of food	wheat	corn	rice	barley	peas
porosity	35-45	35-55	50-56	45-55	35-37
Suspension speed	9-10	9.8-14	8.1-10.1	8.4-10.8	15-17.5

4. Simulation mathematical model

4.1The simulation mathematical model

In this paper, the mathematical model of heat and moisture coupling transfer is determined, following the three basic laws of physical conservation law: the law of conservation of mass, the law of conservation of momentum and the law of conservation of energy. If the flow contains different components, the flow must also comply with the law of conservation of components. In addition, most of the flow in the natural world is turbulent flow, and the turbulence transport equation is also followed. We regard the grain in the drying tower as a porous medium, and the heat transfer model adopted in the hot-water hot blast stove is a standard k-ε model. Considering that the object studied in this paper is the energy transfer and hot-water hot wind in grain piles. The hot water heating problem in the furnace can be used to specify the general energy equation of the drying tower. The equation for the heat balance mathematical model of the grain drying process is shown in in formula 1. The semi-empirical formula of the hot-hot stove is shown in formula 2,3:

$$Q\times\rho\times t\times(T_1-T_2)+C_1\times M_1\times(T_3-T_4)=M_2\times\omega_l\times C_2\times(T_5-T_6)+M_2\times C_2\times(T_7-T_8)\quad(1)$$

In the formula1,
Q - hot air flow in the drying tower. m^3/h;
ρ—Air density kg/m^3;
t—The time of hot air circulation. H;
T_1、T_2—The inlet temperature and outlet temperature of hot air. °C;

C_1、C_2—Drying tower moisture, wheat specific heat capacity. , $J/(kg \times ℃)$;

T_3、T_4—The inlet temperature and outlet temperature of hot water. ℃;

M_1、M_2—Water quality and grain quality in drying tower. Kg;

ω_l—Grain drying moisture content .

T_5、T_6 —The corresponding initial and ending temperature of grain in drying moisture content decreases; ℃;

T_7、T_8 —Drying tower grain outlet temperature, inlet temperature. ℃;

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_i} \times (\rho k u_i) = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right] + G_k - Y_k + S_k \quad (2)$$

$$\frac{\partial}{\partial t}(\rho\varepsilon) + \frac{\partial}{\partial x_i}(\rho\varepsilon u_i) = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}\right] + C_{1\varepsilon}\frac{\varepsilon}{k}(G_k + C_{3\varepsilon}G_b) - C_{2\varepsilon}\rho\frac{\varepsilon^2}{k} + S_\varepsilon \quad (3)$$

In the formula 2,3,

G_k: Turbulent kinetic energy generated by laminar velocity gradient;

G_b: Turbulent kinetic energy generated by buoyancy;

Y_k: The fluctuation of the transition in compressible turbulent flow;

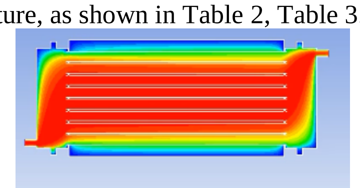
$C_{1\varepsilon}$、$C_{2\varepsilon}$、$C_{3\varepsilon}$ is a constant;

It is the number of turbulent Prandtl for the k equation and the epsilon equation.

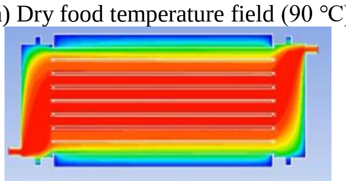
S_k and S_ε are user-defined;

5. The test results and simulation analysis

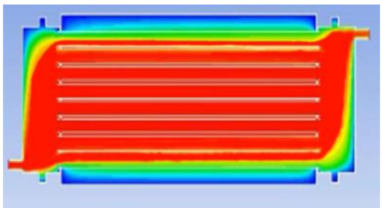
This paper analyzes the temperature field of the grain drying section and the drying section. The simulation of the temperature field distribution of hot water at 70°C, 90°C, and 100°C is shown in Figure 4.The temperature field distribution of grain at simulated hot air temperatures of 90°C, 150°C, and 210°C is shown in Figure 5.Record the temperature of food under different hot water and hot air temperature, as shown in Table 2, Table 3.



(a) Dry food temperature field (90 ℃)

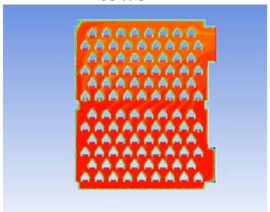


(b) Dry food temperature field (70 ℃)

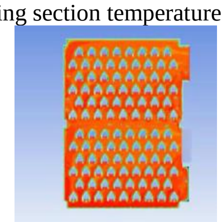


(c) Dry food temperature field (100 ℃)

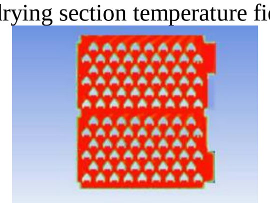
Fig. 4 Analysis of temperature field in dry section of drying tower



(a) Grain drying section temperature field (150 ℃)



(b) Grain drying section temperature field (90 ℃)



(c) Grain drying section temperature field (210 ℃)

Fig. 5 Drying tower drying section temperature field analysis

Table 2 The temperature of food at different hot water temperatures

Hot water temperature（℃）	70	90	100
Wheat grain（℃）	36.5	44.2	56.7

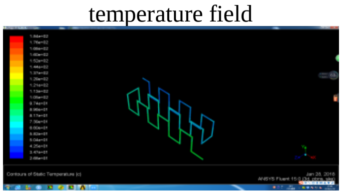
Table 3 The temperature of food under different hot air temperatures

Hot air temperature（℃）	90	150	210
Wheat grain（℃）	36.7	42.3	68.3

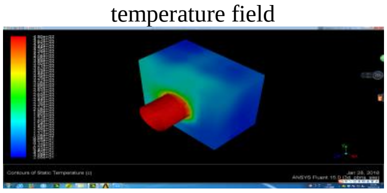
From Table 2 and Table 3, it can be seen that the grain temperature of the dry section and the drying section of the drying tower rises with the increase of the hot and hot air temperatures. When the temperature of the hot water reaches 100°C, the grain temperature reaches 56.7°C. Too high a water temperature will lead to the loss of the combined water of the food and lead to a decline in the quality of the food [7].When the temperature of the hot water reaches 70°C, the temperature of the wheat is 36.5°C. Although the temperature of the hot water is too low, the quality of the wheat can be ensured but the drying time is increased, and the efficiency is decreased, resulting in waste of energy. When the temperature of the hot air reached 210°C, the temperature of the grain reached 68.3°CExcessive temperature would deactivate the grain. When the temperature of the hot air reached 90°C, the temperature of the grain reached 36.7°C,and the temperature was too low to increase the drying time, resulting in a drop in efficiency and wasted energy. According to the characteristics of thermal stability and damage sensitivity of grain, the temperature of grain should be the best around 43°C. Through experiments, we can find the optimal hot water temperature of 90°C and hot air temperature of 150°C.

According to the optimum drying medium temperature of the drying tower, the temperature field analysis is performed on the hot air blast furnace, and the optimum temperature for the combustion chamber of the hot water hot blast stove is obtained when the drying medium is optimized. The results of the analysis are shown in Figure 6.

(a) Hot air hot blast furnace exchange indoor duct temperature field



(b) Hot water hot blast stove exchange indoor water duct temperature field



(c) The overall temperature field of hot-water hot blast stove

Fig. 6 Hot water stove analysis results

Grain drying reaches a steady state (higher drying efficiency) The results of the test parameters are shown in Figure 7.

Fig. 7 results of test parameters.

The experimental parameters were obtained by experimenting with the grain drying integrated system, and the experimental parameters were compared with the simulation results. Although the data was errored but within the allowable range, the simulation analysis results were in line with the actual situation.

6. Conclusion

This paper considers the best combustion efficiency of the combustion furnace, the highest energy efficiency, good grain drying effect, and keeps the grain active. Through experiments and simulation analysis, it is concluded that the hot air temperature is 85°C, the hot water temperature is 90°C, and the combustion chamber temperature At 480°C, the drying equipment works better

Acknowledgements

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