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Study on the Heat Transfer Process of Grain Drying Heat Exchange Bed

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Abstract: The study researches on heat exchange process of a new type of grain drying equipment by establishing a heat transfer equation between liquid heat and cold wind. The study onheat temperature and flow impact on heating process were reviewed in the study. We get the heat transfer ability of system and calculate outlet air temperature of every layer in the drying heat exchange bed. We had perform heat transfer experiments to verify the calculation of heat exchange. The experimental result shows that ventilation outlet temperature of the low layer can achieve 45.1°C, the second layer is 54.2°C, the top layer can reach 57.9°C. The results are consistent with the calculations.

Key words: Grain drying, heat transfer process, energy efficiency, layer, outlet

INTRODUCTION

The existing grain drying technology often requires large amounts of energy. Many developed countries begin to use solar energy to dry grain. However, the solar grain drying system mostly uses solar energy as the assistance energy or drying method of direct sunlight (Farkas *et al*., 2000). However, the utilization rate and the drying efficiency of solar energy are low. Besides, the drying equipment is huge anddifficult dismounting to move. What is more, there are still some problems such as uneven drying (Menshutina and Kudra, 2001). This research studies a new type of solar grain drying equipment which adopts solar energy as energy source. It uses solar heat collector to collect solar energy. The hot water heated by solar collector flows into the drying warehouse and then exchanges heat with cold air. The heat exchange efficiency directly affects the temperature of ventilation during the drying process. To calculate and analyze heat exchange process is the key of the whole drying system design.

DIVISION OF HEAT EXCHANGE REGION

The heat transferring process in drying warehouse mainly takes place in the heat exchange bed. Hot water flows from the water inlet into the collecting tube and flat tube in the heat exchange bed. And exchanges heat with cold air through the fin of flat tube. After heat exchanging, the hot water flows out of the outlet. Heat exchange bed shown in Fig. 1. There are three pieces of heat exchange beds in the drying warehouse. They are connected to the heat exchange area bypipes. The heat transfer area is divided into six parts. From bottom to up are respectively, region I-VI as shown in Fig. 2.

Fig. 1: Heat exchange bed

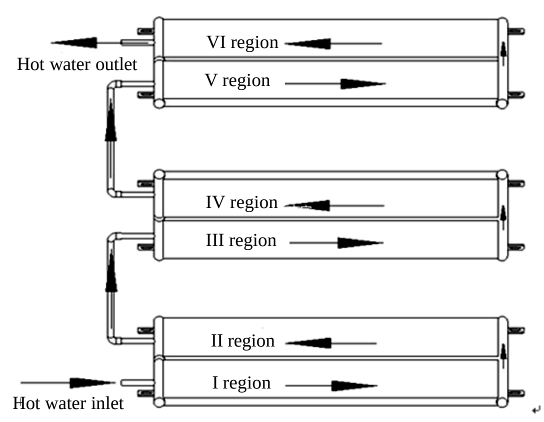

Fig. 2: The way of hot water flow

The hot fluid flows into the region I first and then exchanges heat with the air in the fin of region I. After the first time heat exchange, the hot water flows from the side

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collector tube into the region III and then carries on the second time heat exchange. After the second time heat exchange, the hot water flows from the side collector tube into region III and then carries on the third time heat exchange. After six times heat exchange, the hot water flows out from the hot water outlet of region VI.

HEAT TRANSFER CALCULATION MODEL

The heat only can be transmitted during the process of heat exchange between fluid but not disappear. It satisfiesthe heat balance equation (Zhang *et al*., 1989). In addition, according to the method of heat transfer units proposed by Nussle, we can calculate the heat transfer effectiveness of heat transfer process (Zhang and Litchfield, 1994):

$$q = -W_1(t_1''-t_1') = W_2(t_2''-t_2') \quad (1)$$

When:

$$W_1<W_2,\ \varepsilon = \frac{t_1'-t_1''}{t_1'-t_2'} \quad (2)$$

$$W_1>W_2,\ \varepsilon = \frac{t_2''-t_2'}{t_1'-t_2'} \quad (3)$$

Where:

- q = Heat transfer (J/sec)
- W_1, W_2 = The heat capacity of hot fluid and cool fluid, fluid mass flow and specific heat capacity (W/°C)
- t_1', t_1'' = Inlet and outlet temperatures of the hot fluid (J/kg)
- t_2', t_2'' = Inlet and outlet temperatures of the cold fluid (J/kg)
- ε = The heat transfer effectiveness

According to the design requirement, the hot fluid and cool fluid heat capacity respectively are 1674.4 and 300.56 W/°C. Heat transfer effectiveness is 0.42 (Taprantzis *et al*., 1997) determined by institutions of heat exchange bed and the way of heat transfer. The temperatures of hot and cold fluid in 6 heat exchange regions are different, so we should calculate the heat transfer process of each region separately. Inlet temperature of the hot fluid in region I is the water temperature heated by the solar collector, t_1 is 80°C. Inlet temperature of cold fluid in region I is the temperature of outdoor air, t_2 is 20°C (Siettos *et al*., 1999). The terminal hot water temperature of heat exchangerin region I is the initial temperature in region II. The terminal hot water temperature of heat exchangerin region II is the initial temperature in region III and so on and so forth. Similarly, terminal airtemperature ofheat exchanger in region I and II are respectively, the initial air temperature of exchanger in region III and IV. The terminal air temperaturesof heat exchanger in region III and IV, respectively are the initial air temperatures of exchanger in region V and VI. We can calculate outlet temperature of hot and cold fluid in each region, according to Eq. 1-3 as shown in Table 1.

Table 1: The basic amount value of heat exchange

Regions	I	II	III	IV	V	VI
t_1' (°C)	80.0	75.5	71.1	69.1	67.3	66.5
t_1'' (°C)	75.5	71.1	69.1	67.3	66.4	65.7
t_2' (°C)	20.0	20.0	45.5	45.5	55.9	55.9
t_2'' (°C)	45.2	45.8	56.2	55.6	60.7	60.5
q(W)	7574.1	7441.5	3216.0	2913.1	1442.7	1326.8

RESEARCH ON HEAT EXCHANGE BED HEAT TRANSFER PROCESS

Heat exchange bed heat transfer experiment has been done on the testing platform of air conditioner performance. The testing system can accurately measure hot water temperature, hot water flow, heat of heat exchange bed, wind volume of heat exchange and the cold wind device and some datum (Liu and Bakker-Arkema, 2001) are shown in Fig. 3 and 4.

Researchers have done three groups of experiments totally. In the first group we input 80°C hot water and 20°C cold wind into the equipment. In the second group we input 71.1°C hot water and 48.5°C cold windinto the equipment and in the third group, we input 67.3°C hot water and 55.9°C cold wind into the equipment. Water flow is set to 0.4 kg sec^{-1} and ventilation flow is set to 29 m^3/min. Then, we measure and record the hot water and air outlet temperature as shown in Table 2.

Fig. 3: Air wind-turnel test

Table 2: Heat exchange bed experimental datum

Parameters	First group	Second group	Third group
Hot water inlet temperature t_1' (°C)	80.0	71.1	67.3
The hot water outlet temperature t_1'' (°C)	69.6	65.9	64.2
Air inlet temperature t_2' (°C)	20.0	45.5	55.9
The ventilation outlet temperature t_2'' (°C)	45.1	54.2	57.9

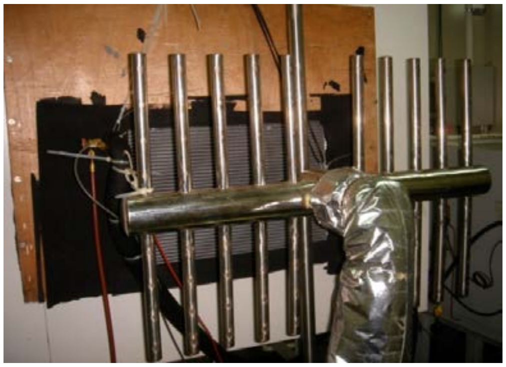

Fig. 4: Air data sample intrument

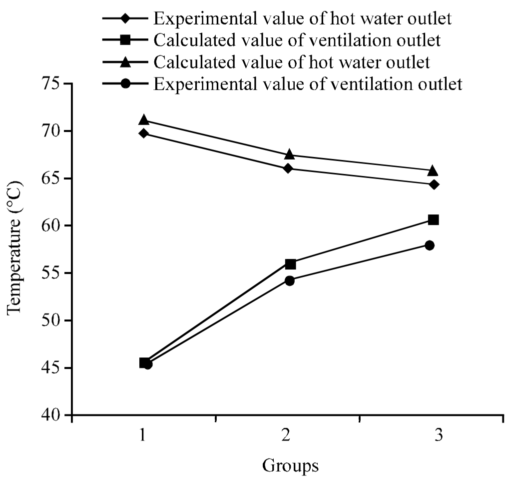

Fig. 5: The comparison of heat exchange bed heat temperature

We have compared the experimental datum with the theoretical calculated datum. The 2 regions are group test. When comparing experimental and theory result, we also compare 2 regions together as shown in Fig. 5.

From Fig. 5, we can find that simulated results are well consistent with experiments. Due to a little of heat flow out from the collector, the experimental results smaller than the theoretical calculation results. Through the analysis, we can find thatthe air temperature can reach 45~60°C after passing through every layer of the heat exchanger. It meets the requirement of rice drying ventilated temperature.

CONCLUSION

- We study on the process of hot water and cold air exchangeheat in the heat exchange bed. Then, we calculate heat transfer coefficient between hot water and heat exchange bed. We calculate heat transfer coefficient between the heat exchange bed and cold air. We study on hot water temperature and flow effect on cold air heating temperature. Moreover, we calculate air outlet temperature of the heat exchange bed in each layer
- According to calculation, the quality flow is 0.4 kg sec^{-1} in the flat tube. The air outlet temperature in region I~VI, respectively is 45.2, 45.8, 56.2, 55.6, 60.7 and 60.5°C
- In order to validate the heat transfer calculation of heat exchange bed, we carry on heat exchange experiment. Experimental results show that ventilation outlet temperature in the low heat exchange bed can reach 45.1°C. The ventilation outlet temperature in the second layer of heat exchange bed can reach 54.2°C. The ventilation outlet temperature in the third layer of heat exchange bed can reach 57.9°C

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