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To cite this article: Z Y Li *et al* 2018 *IOP Conf. Ser.: Earth Environ. Sci.* **188** 012098

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Experimental study on random heat transfer of phase change heat storage device

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Abstract. In the study of the heat conduction of phase change materials, due to the inherent properties, the deviation of the measured data and the processing technology of the phase change material, the uncertainty of the parameters of the material properties and geometric properties of the phase change materials exist inevitably. But at the present stage, there are very few experimental researches content of uncertain heat transfer in phase change thermal storage devices. The purpose of this paper is to study the uncertain heat transfer process of phase change heat transfer experimentally. The influence of latent heat of phase transition on the heat transfer process is mainly analyzed. The latent heat of different phase transitions is transformed into internal heat sources, and simulated by electric heating. The thermal response of phase-change heat transfer is analyzed by constructing the electric heating quantity under different probability distribution and uncertainty. The experimental results show that when the uncertainty is the same as 1/7, the difference of the standard deviation between two mean values (560 W and 630 W) is not large. The standard deviation and the mean correlation of the experimental values are not significant under the same uncertainty.

1. Introduction

Phase change materials usually have large heat storage, high energy storage density, and temperature of them during thermal storage and release is approximate constant, so it has great potential in the storage of unstable solar thermal energy. In the study of the heat conduction of phase change materials, due to the inherent properties of the phase change material, the deviation of the measured data and the processing technology of the phase change material, the parameters of the material properties and geometric properties of the phase change materials exist uncertainty inevitably. Although the impact of these uncertainties on a single parameter is smaller in most cases, the coupling of multiple parameters may lead to a greater deviation in the thermal response. As a carrier for the application of phase change materials, the performance of the phase change heat storage device is very important. In addition to the uncertainty of the parameters of the phase change materials, the performance of the phase change heat storage device is also restricted by the different conditions of the system, the working environment and other conditions. At present, the research on uncertain heat transfer process is mainly focused on theoretical calculation. Such as Hu [1], he let the linear system theory under random excitation applied to the study of linear heat conduction problem, and solved the dynamic thermal conduction response problems of one dimension (flat wall, cylinder wall and so on) and multidimensional random excitation. Williams [2] applied stochastic method to study the influence of boundary conditions on the radiative transfer equation. Besides, he used polynomial mixing theory to



get the mean and variance of solution results under certain circumstances, what's more, the probability distributions were also derived from it. Alicja [3] applied direct method to solve the temperature field of two-dimensional plate unsteady heat conduction. All the thermal physical parameters are taken as interval variables, and the first order boundary element method and Gauss elimination method are used to solve the problem. The results show that the solution interval is obviously expanded with time. At the present stage, there are very few experimental researches content of uncertain heat transfer in phase change thermal storage devices, and little experimental analyze the influence of random parameters on heat transfer response. Therefore, it is very important to study the influence of the uncertainty of parameters on the heat transfer response of phase-change thermal storage devices by experiment.

In this study, the random heat transfer of phase change heat storage device is experimentally analyzed. The phase change latent heat is taken as a random variable, and we analyzed the response regulation of the temperature when the uniform distribution is applied to the latent heat of the phase change. The experimental results are compared with the response regulation of the temperature when the latent heat is the determined value. Finally got the differences of influence on temperature response regulation when latent heat of phase change between random variable and definite value.

2. Experiment

2.1. Experimental principle

In this study, phase change latent heat of different phase change materials is simplified as internal heat source, and simulated by electric heating. The thermal response of phase-change heat transfer is analyzed by constructing the electric heating quantity under different probability distribution and uncertainty. The conversion formula for heating quantity and latent heat of phase change:

$$q = 1000\rho HV \quad (1)$$

Which: H ——Latent heat, kJ/kg, V ——Heater volume, m^3 , Q ——Heater power, W, ρ ——Density phase change material density, kg/m^3 .

The experiment group and the control group were set up in this experiment. The experimental group received random power at the heater, while the control group received constant power at the heater. The power of the experimental group was the mean value of the random power corresponding to the probability type. The other experimental conditions were consistent in the experimental group and the control group.

2.2. Experimental platform construction

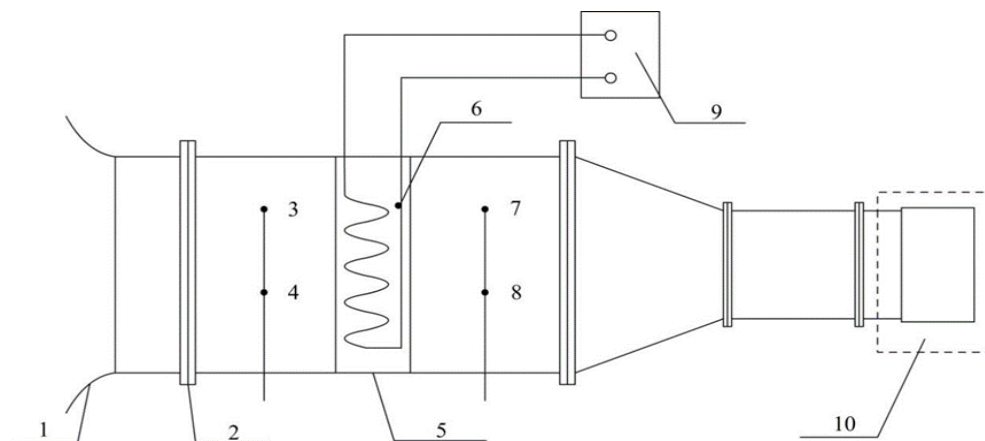


Figure 1. Experimental platform diagram.

**1.—Rectifying section 2.—Filter screen 3.4.6.7.8.—Thermocouple
5.—Heating section 9.—Power control device / Transformer 10.—Fan**

Figure 1 is the experimental platform diagram, the numbers express every part of the experimental platform. In the experiment, the air fan 10 is opened first and the air is filtered through the rectifying section 1 to enter the channel. Thermocouple 2 and 3 are used to measure the temperature before the air is heated. The air is heated by the heater 5. Thermocouple 6 is distributed on the heater to measure the surface temperature of it. Thermocouple 7 and 8 are used to measure the temperature of the heated air. 9 in the experimental group was the power control device, and in the control group 9 was the transformer. The heater of the experimental group and the control group were respectively connected with them.

The type of thermocouple used in the experiment is T. Which connected with the 34970 A data acquisition switch unit for real-time acquisition of temperature data. The power data of the experimental group is recorded by the upper computer corresponding to the power control device and the power data of the control group is directly read by the transformer. An anemometer was used to measure the wind speed at the outlet of the terminal channel. The heater used in the experiment is a heating belt with a power of 240 W. Six heating belts are connected together in parallel to form the experimental platform.

2.3. Experimental scheme

The experimental variables are: wind speed, probability type of input power of experimental group, mean value of input power of experimental group, and standard deviation of input power of experimental group. The control group regulates the steady voltage through the transformer, and the power corresponds to the mean value of the experimental group.

So far, the experiment is at the initial stage of exploration, so we only do experiments with a uniform distribution of input power probability. The wind speed of the experiment is 6 m/s. The mean values of the heating quantities are 630 W and 560 W respectively, and the uncertainty is 1/7 (corresponding to the standard deviation of 90 W and 80 W respectively). We just start the experiment with the uncertainty of 1/7, and the subsequent parameters are depend on the results of the experiment. The power of the control group is constant, for 630 W and 560 W respectively. During the experiment, the data acquisition time interval is 1s. The experimental conditions are shown in table 1.

Table 1. Experimental conditions.

Experimental conditions					
Conditions	Heater	Distribution	Wind speed	Mean value	Standard deviation
1	Heating belt	Uniform	6m/s	630	90
2				560	80

3. Analysis

3.1. Outlet temperature comparison

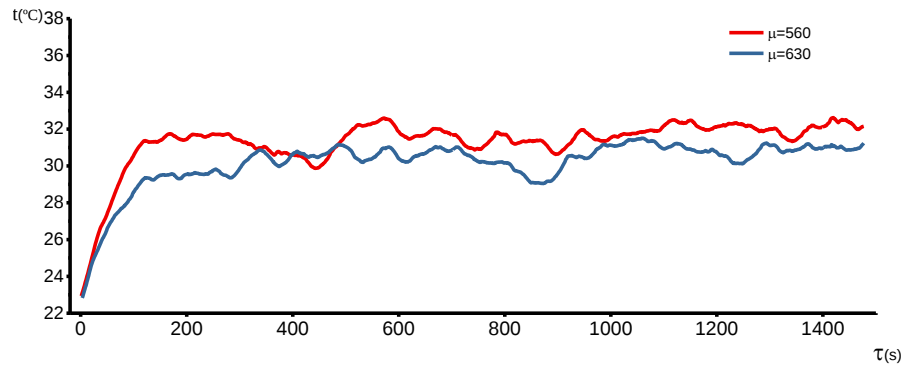


Figure 2. Mean value of outlet temperature comparison under the same uncertainty (1/7).

Figure 2 is a comparison chart of mean value of outlet temperature under the same uncertainty (1/7). Figure 3 is the Standard deviation of outlet temperature comparison under the same uncertainty (1/7). The red line is the parameter under the mean value of 560 W and the standard deviation of 80. The blue one is the parameter under the mean value of 630 W and the standard deviation of 90. As it can be seen from figure 3, the trend of temperature change is almost the same at all times, and the temperature is stable after 200s. By analyzing the standard deviation value in the stable stage from figure 3, it can be found that when the uncertainty is the same as 1/7, the difference of the standard deviation between two mean values (560 W and 630 W) is not large.

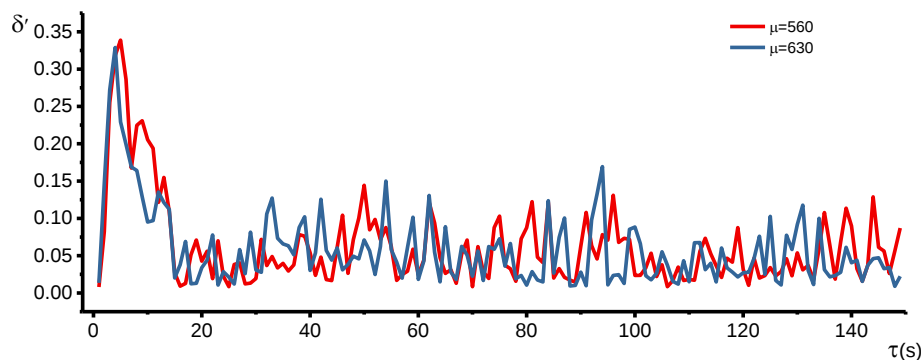


Figure 3. Standard deviation of outlet temperature comparison under the same uncertainty (1/7).

3.2. The experimental and the control group comparison

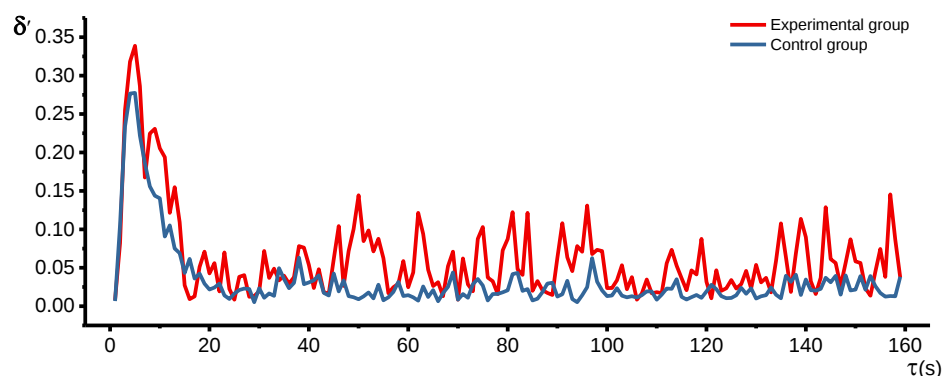


Figure 4. Standard deviation of outlet temperature comparison between different groups (560 W).

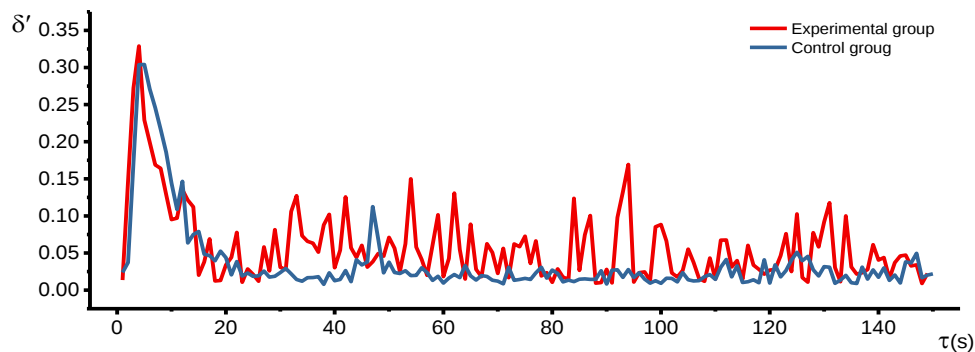


Figure 5. Standard deviation of outlet temperature comparison between different groups (630 W).

Figures 4 and 5 are standard deviation of outlet temperature comparison between different groups, for 560 W and 630 W respectively. The trend of the two lines in figure 4 is the same. During the heating stage, the standard deviation of the heater is larger, while the standard deviation decreases when the temperature gradually stabilizes. The fluctuation range of experimental value is larger than the control group. The change regulation of the two lines in figure 4 is similar to that of figure 5. The fluctuation range of the control group is smaller than the experimental group.

4. Conclusion

As the experimental conditions are still further improved and the experimental data are insufficient, the analysis of the random heat transfer characteristics of the phase change heat storage device is not specific. The preliminary conclusion is that the standard deviation and the mean correlation of the experimental values are not significant under the same uncertainty. More experiments will be carried out in the follow-up. There will have more data and content for the comprehensive analysis.

Acknowledgments

This work was supported by the National Natural Science Foundation of China (51568060 and 51508055). This work was also supported by the Science and Technology Innovation Project of North China University of Technology.

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