EXPERIMENT AND CALCULATION OF CHARGE AND RELEASE CHARACTERISTICS OF PHASE CHANGE ELECTRONIC HEAT STORAGE SYSTEM

by

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A phase change heat storage device for an active thermoelectric heat pump was tested for its heat storage and release performance at different operating voltages and heat source temperatures. A study on heat release/discharge characteristics of a phase active heat exchanger is proposed. The experimental results show that there are significant differences in heating/discharging time and operating performance of the device under different operating conditions and heating conditions. When the operating voltage is high and the temperature of waste heat is high, the heating time of the device is short. Continuing to increase the voltage efficiency during this period will increase the temperature difference between the cold and hot ends of the semiconductor chip, decrease the heat coefficient of the device. Compared to passive phase change heating equipment, the best way of this equipment is to adjust the voltage. Adjusting the operating voltage in a suitable manner can maximize its heat/discharge efficiency, while overcoming the shortage of heat-supply equipment in low voltage secondary heat storage systems, and cannot improve the inequality between supply and demand in terms of time, position, and energy.

Key words: *active heat storage, charging and discharging characteristics, phase change heat storage, thermoelectric heat pump*

Introduction

The main characteristic of phase change energy storage is that during the process of absorbing and releasing heat, the thermal performance is constant, and more energy conversion can be produced at a small temperature. Figure 1 takes the solid-liquid phase change transformation for energy storage as an example. At present, there are a lot of standard methods of electronic storage, and a lot of work has been done to improve the thermal conductivity and the heat transfer efficiency of phase change products [1]. However, the different forms of the heat exchange equipment listed previously are all the heat exchange equipment without exception. On the one hand, the aforementioned heat exchangers can only store heat from the difference of temperature between waste material and energy storage material, and are not suitable for low temperature heat recovery and utilization. In the process of waste heat treatment, the heat exchanger cannot adjust the heat storage in a timely manner and the utilization of waste heat, in order to recover waste heat and improve recovery efficiency. At the same time, in the process of heat energy release, active release of heat energy cannot be achieved according to the require-

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ments of the energy user to meet different heat energy usage requirements. This device is based on the phase shift heat exchanger and converter, overcomes the shortcomings of passive phase shift heat mentioned previously, completes the heating/discharge process, and provides a new method for achieving heat recovery and maximum energy for valley conversion. Converting intermittent energy sources such as solar and wind energy into renewable energy [2, 3]. Therefore, we need to find a way to store temporarily unused energy like a reservoir and release it when needed. We use appropriate energy-saving methods and special equipment to store temporarily unused energy sources from special energy sources, and the process of reusing it when needed is called energy storage technology. The heater is a process of storing heat energy from the heater to increase temperature. Phase change heat storage is the use of melting heat generated during the transformation process of thermal storage materials to store thermal energy. The thermal storage medium that uses the liquid-phase converter latent heat storage is often called the phase converter. The advantages of phase change heat storage over sensible heat storage mainly lie in not only the simplicity and small volume of the device used, but also the high heat storage density, approximate isothermal heat storage (release) process, and easy control of the process. Therefore, it has become the most practical development potential, widely used, and important heat storage method at present. Due to its superior performance in thermal energy utilization, phase change heat storage has attracted the attention of various countries around the world, making it an emerging new technology field in the world today.

The rapid increase in energy consumption and environmental pollution, according to statistics, during the 20 years of reform and opening up from 1978 to 1997, the total energy consumption increased by approximately 1.5 times (from 57.144 millionns of standard coal to 14.20 millionns of standard coal). Moreover, due to the objective constraints of natural resources, the structure of energy production and consumption is extremely unreasonable. In this way, on the one hand, the increase in energy consumption will inevitably be accompanied by an increase in environmental pollution, and on the other hand, excessive burning of coal will further exacerbate China's environmental problems. Therefore, the environmental problems caused by high energy consumption are becoming increasingly serious and have received widespread attention from people. Environmental issues have become a hot topic in today's society, directly

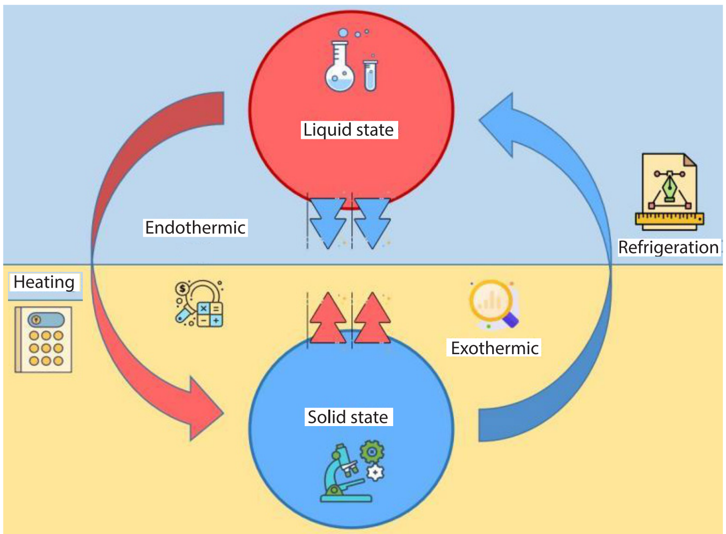

Figure 1. Solid liquid phase change conversion energy storage

related to the survival and development of human society. Therefore, solving or controlling the energy consumption process is already urgent.

Principle and device of phase change heat storage/release for thermoelectric heat pumps

Experimental device for phase change heat storage and exchange of thermoelectric heat pumps

The thermoelectric heat pump phase change heat storage heat exchanger is made up of heat storage cabinets, thermoelectric chips, heat pipe radiators, fans, air ducts*, etc.*, the thermoelectric chips, heat pipe radiators, air ducts, and so on. The phase change energy storage material used in this experiment is wax special $35^{\#}$. The thermoelectric chip model is TEC1-12706, with an overall size of 40 mm × 40 mm × 3.8 mm, with a maximum voltage and current of 15.4 V and 6 A, respectively, a maximum temperature difference of 609 °C, and a maximum cooling capacity of 51.4 W. A total of six thermoelectric chips are selected, with each set consisting of two chips. Each set of thermoelectric chips uses a heat pipe heat sink for cooling at the cold and hot ends. The size of phase change heat box is 400 mm × 200 mm × 200 mm, made of 1mm galvanized steel plate,with bottom plate made of 1.2 mm thick copper plate, in order to reduce heat dissipation loss, the four walls of the heat storage box are insulated with 6 mm thick polyvinyl chloride insulation material [4].

Phase change heat storage/release principle of thermoelectric heat pumps

Under thermal storage conditions, the exhaust gas containing low temperature waste heat undergoes heat exchange with the cold end heat pipe radiator of the thermoelectric heat pump through forced convection of the fan. The heat generated by the thermoelectric heat pump melts the heat stored in the tube heat sink and stores it in the phase transfer material as a high potential heat and a small amount of sensible heat [5]. In an exothermic condition, the cooling and heating ends of the first thermoelectric pump are changed by changing the direction of the current input of the thermoelectric heat pump,entering a small quantity of energy and releasing the heat stored in the solid phase change. At this point, the heat absorbing liquid radiator changes with the heat pipe radiator under forced convection of the fan, and is heated before discharge.

Results and analysis

The influence of working voltage on the thermal storage performance of thermoelectric heat pumps

According to the principle of thermoelectric heat pump heating, the higher the voltage input to the thermoelectric chip, the greater the heat output at the final temperature of the thermoelectric chip. But the heat dissipation condition is determined at the terminal temperature. As a result, as the terminal temperature increases, the difference between the end and the end is larger. Figure 2 is a comparative study of the insulation time and the temperature difference between the hot and cold ends of the thermoelectric heater.

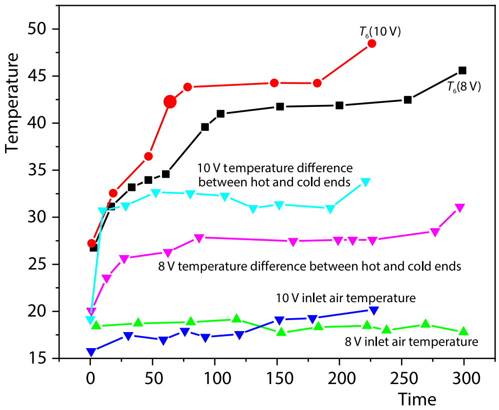

Figure 2. Comparison of thermal storage time and temperature difference between cold and hot ends of thermoelectric heat pumps under different voltages

From fig. 2, it can be seen that when different temperatures (*i.e.* temperature) can be ignored without time, the higher the voltage, the less time it takes to complete the entire insulation process. From the temperature curve of *T*, it can be seen that at 10 V, the time from the beginning of thermal storage to the completion of wax phase change is about 180 minutes, and then enter the state of sensible thermal storage. At 8 V, the time from the beginning of the heat storage to the end of the paraffin phase shift is approximately 260 minutes. From fig. 2, it can be seen that as storage time increases, temperature difference between low temperature and end temperature increases rapidly. After the paraffin absorbs the heat, the temperature rises rapidly, and as the heat storage time increases, the paraffin begins to undergo phase change, the heat generated by the hot end of the thermoelectric heat pump is stored in paraffin in the form of latent heat [6]. The temperature of paraffin is still near the phase transition and changes gradually, which results in small temperature change at the end temperature of the thermoelectric heat pump. Due to the variation of the temperature, it has influence on the temperature difference, especially at 10 V, which has obvious influence on the temperature difference.

Impact of waste heat source temperature on thermal storage performance of thermoelectric heat pumps

As the temperature rises, as the temperature rises, the temperature rises. Gas (waste heat) entering the atmosphere provides thermal energy for thermoelectric power generation. Because of the temperature change, the heat transfer process of the cooling system changes, which leads to the heat transfer between the cooling system and the end temperature. Thus, the thermal performance of thermoelectric heat pump heat storage device was studied. Figure 3 shows a comparison between the end cooler and the end cooler at different temperatures. Research has shown that when the inlet temperature increases, the temperature varies and the heating time decreases [7].

Figure 4 shows the variations of the thermal coefficient at the cold and hot ends of a thermoelectric heater with different temperatures. The temperature difference value in the figure is the unit value that is achieved every 15 minutes from the beginning of the heating process to the end of the heating process. The results show that as the temperature increases, the temperature difference between the cold and hot ends decreases, and its thermal conductivity also

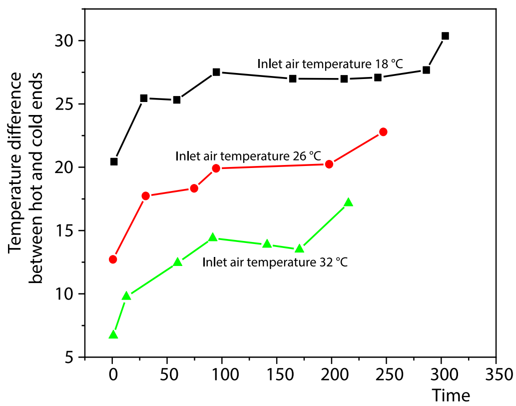

Figure 3. Comparison of temperature difference between the cold and hot ends of a thermoelectric heat pump under a voltage of 8 V and different inlet temperatures

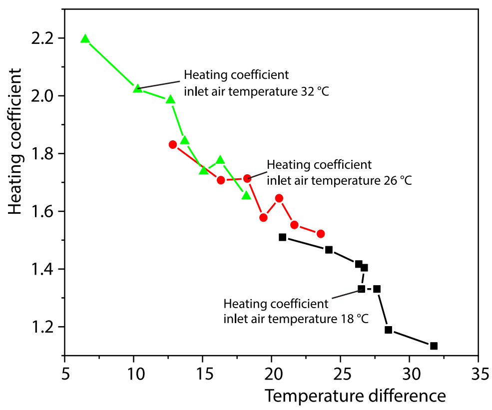

Figure 4. Comparison of heating coefficients for thermal energy storage with a voltage of 8 V and a thermoelectric heat pump

increases. The results show that in the inlet condition of about 18 °C, the temperature difference between refrigerant and heat pump in the whole heat pump process is 20.2-30.95 °C, and the thermal coefficient is 1.52-1.14. The results show that at the temperature range of 26 °C, the final deviation of the total refrigeration efficiency of the heat pump is about 12.55~23.2 °C, and the heat transfer coefficient is about 1.86-151. When the inlet temperature is 32 °C, the thermoelectric heat pump during the entire heat storage process mostly corresponds to a temperature difference between 6.5 °C and 17.39 °C at the cold and hot ends, and the heating coefficient varies between 2.23 and 1.71 [8].

Heat release performance of thermoelectric heat pumps under different operating conditions

The larger the thermal coefficient, the smaller the temperature difference between the cold and hot ends of a thermoelectric heater, and the smaller the input current of the chip, the larger the heating coefficient. However, the smaller the input power of a chip, the less heat is produced at the temperature end of the chip. The only way to meet the requirement of power consumption is to increase the number of chips used. Figure 5 shows the thermal performance of a thermoelectric pump during the thermal release of a voltage of 4 V, the temperature of about 25 °C, 6 V, and the temperature of about 20 °C [9]. From the figure, it can be seen that the higher the voltage, the temperature difference between the inlet and outlet, *i.e.* the higher the temperature. In the early stage of paraffin heat pump, because of the mature release of phase change products, the final cooling of thermoelectric heat pump quickly, and then entered the latent heat release phase. The temperature change at the cold end is flat.

Figure 6 shows the variation of the thermal coefficient with different temperatures at the cold and hot ends when the thermoelectric heat pump corresponds to fig. 5 generating heat at different voltages [10]. It can be found that during the exothermic process, the thermal coefficient decreases linearly with the increase of temperature difference, when this trend occurs when the radiation is low. When the outlet is 4 V and the inlet temperature is 25 °C, the temperature difference between the cold and hot ends of the thermoelectric heater is

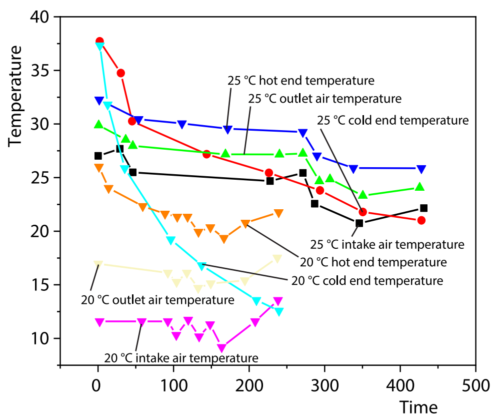

Figure 5. Performance changes of thermoelectric heat pumps with a voltage of 4 V, an inlet temperature of around 25 °C, and a voltage of 6 V, an inlet temperature of around 20 °C during heat release

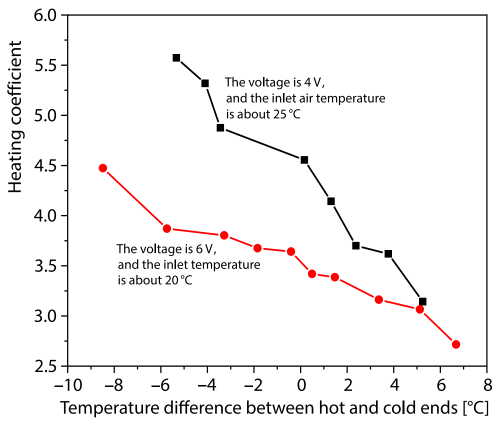

Figure 6. Changes in heating coefficient of thermoelectric heat pump with temperature difference under different voltages

between –6 °C to 6 °C, and the heating coefficient is between 5.6 and 3.2. When the voltage is 6 V and the proper temperature is around 20 °C, the heating coefficient during heating is between 4.5-2.8.

Conclusion

The experimental results of the active thermoelectric heat pump phase change heat exchanger are compared in different experimental conditions. Through the analysis of experimental results, it is found that the voltage performance is the main factor which affects the performance of thermoelectric heat pump phase shifting heat supply system. The larger the power supply, the faster the phase transition process and the shorter the heating time required. However, it also increases temperature difference between cold and hot ends, reduces heat coefficient. Therefore, the size control of the power supply is the key to control the heat storage/discharge intensity and the operation of the equipment. In terms of energy consumption, this device uses more energy than traditional passive phase shifting heat sources, and most of the circuits are focused on the electrons used by thermoelectric chips. In order to ensure a high heating coefficient, the input voltage of a single thermoelectric chip should not exceed 10 V. The input voltage of the thermoelectric chip is very small, and the excess energy consumed accounts for a very small proportion of the overall electrical energy consumption. The device will not increase heat storage due to the addition of thermoelectric chipsets. Heating time and material can also affect the performance of heat exchanger. However, this device improves the present situation that the traditional passive phase shifting heating equipment only relies on different temperature during the heating process. In terms of controlling the heating/discharge process, this device is superior to the traditional passive phase shifting heating equipment.

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