

A research on heat transfer enhancement for paraffin wax thermal storage

Zhang Xuelai Wang Wenguo Yang Pengcheng Shi Minmin

Cool Thermal Storage technology Institute of Shanghai Maritime University

1550 Pudong Ave, Shanghai, China

Abstract

The deficiency of paraffin wax is low in heat conductivity.

This paper has added metal thread into paraffin wax to enhance paraffin wax's heat conductivity, and analyzed the influence of metal thread on the paraffin wax's heat transfer property through a large number of experiments.

What the experiment demonstrated was that, the thermal efficiency of the paraffin wax was improved greatly if the metal wire was added in. It could compensate the deficiency of the paraffin wax as the heat-storage material and raise the feasibility of paraffin wax in thermal storage domain greatly.

KEY WORDS: paraffin wax, thermal storage ,solid-liquid interface, phase-change

0.Introduction

Paraffin wax, a phase change material, is now paid more attention to. It has big latent heat, low price, no super-cooling or phase-separation. At present, it is mainly used in solar energy storage system, building energy storage system, district cooling system, etc. But its coefficient of thermal conductivity is low. In order to improve its coefficient of thermal conductivity and accelerate the rate of flooding and releasing heat, we can add additives, which are beneficial to enhance heat conduction, as well as fix fins in the thermal storage equipment, or add skeleton materials, etc. However it is very difficult to find an additive whose density is similar to paraffin wax, and the additive can dissolve homogeneously in paraffin wax without sinking. Installing fins in thermal storage equipment can greatly strengthen heat transfer effect, but they have high requirement at the aspect of technology. This paper install metal wires in container to enhance the thermal conductivity of paraffin wax during the phase change process.

1.Methodology

The characteristic of PCM heat transfer is existing one phase change interface, which changes with times, and the moving interface is clear for pure substance under the determined phase change temperature. For the impure substance such as paraffin wax, whose melt happens in a temperature range, the moving interface is mushy two-phase area. During the heat

transfer process, with the incessant phase change of PCM, the thermal resistance of PCM increases gradually and the effective heat transfer area decrease gradually. As a result, the amount of heat which stored or released from the PCM in unit time decreases. In order to solve this problem, we can add metal wire or fiber net into the thermal storage equipment to make composite phase change materials, which greatly overcome disadvantages of single medium PCM. The structure made of metal wire and the composite phase change materials are divided into many heat transfer units which use each two groups of adjacent metal wires as the boundary. Compared with the single medium phase change material, the heat transfer changes greatly. Adding metal wires in paraffin wax strengthens the heat transfer, and raises the heat/cold storage performance of PCM.

On the basis of previous researches, in this paper we create an experimental device, study the heat transfer phenomenon in the melting process of PCM, analyzing the basic law and effect of strengthening heat transfer with the metal wires.

2.Experiment

2.1 Experimental sample and its physical property

Using the " YANJING " paraffin wax, whose melting point range is 58℃-60℃, and it is a kind of white massive solid without dissolving in water or ethanol.

2.2 Experimental device and procedure

As shown in Fig1, The device includes heat storage container, electric heating rod, voltmeter and ammeter etc. The data acquisition system includes thermocouple, intelligent modules, RS232/485Communicator and King View software, etc. The wall of heat storage container was made of iron with coefficient of thermal conductivity of 80W / m·K, internal diameter of 123mm, external diameter of 133mm and the wall thickness of 5mm. Thermal insulation material is used as polyethylene with coefficient of thermal conductivity of 0.04W/m.K and thickness of 5mm. The height of whole device is 300mm, and the device is shown in the Fig3. The diameter of the metal wire is 1mm and the thermal conductivity coefficient of the metal wire is 237W/m.K. Electric heating rod is made of red copper with the length of 225mm and the diameter of 8mm. The measuring range of the ammeter is 5A and the precision is 0.1. The measuring range of the voltmeter is 300V and the precision is 0.1.

Before experiment, the thermocouples are arranged in the heat storage device, and then the paraffin is mixed. After the solidification cooling, heat it through the electric heating rod and observing the heat transfer status. Then the metal wires which have been weaved (shown in the Fig2) are added in the heat storage container and a contrast experiment should be done.

2.3 The radial temperature distribution at different time

During the experiment without adding metal wires, the paraffin wax temperature between the heating rod and the inner wall of heat storage container is measured as shown in Fig.1, where the temperature distribution in radial orientation is shown in Fig4. Because conductivity dominates in the solid phase, the temperature gradient in radial orientation is larger before melt. The heating time longer, the smaller the slope of the distribution curve of the temperature distribution along the radial direction. The final slope is nearly zero. When the temperature

reaches melting point, paraffin wax starts melting. Free convection happens in liquidoid area, the heat transfer includes two forms—the conduction and free convection. However, the heat which the paraffin wax absorbs is mainly stored as latent heat. With the passage of time, solid

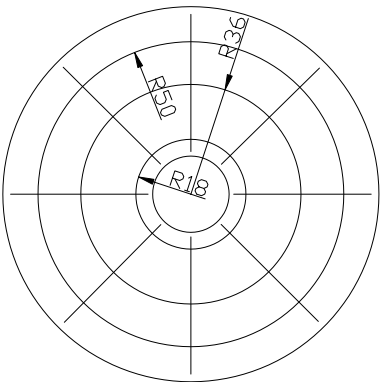
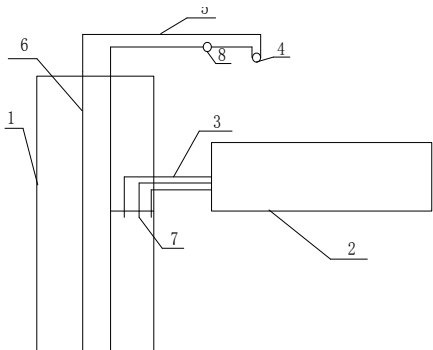


Fig. 1 Experiment system diagram of paraffin's melting process

Fig. 2 Top view of the metal wire

- 1 Heat storage container 2 Date acquisition system 3 Signal line 4 Voltmeter 5 Wire
6 Heating rod 7 Measuring point for temperature 8 Ammeter

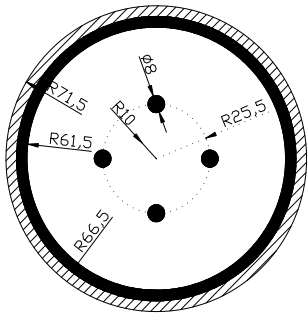
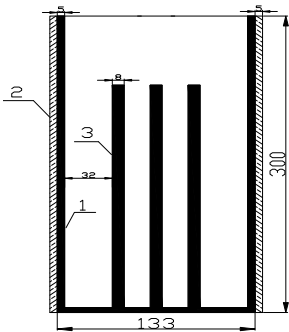
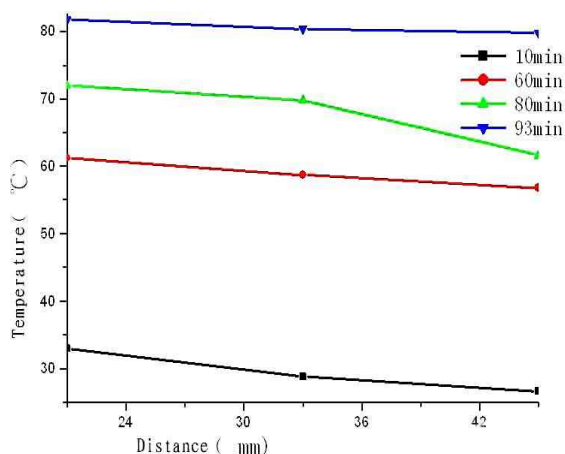


Fig. 3 Heat storage device

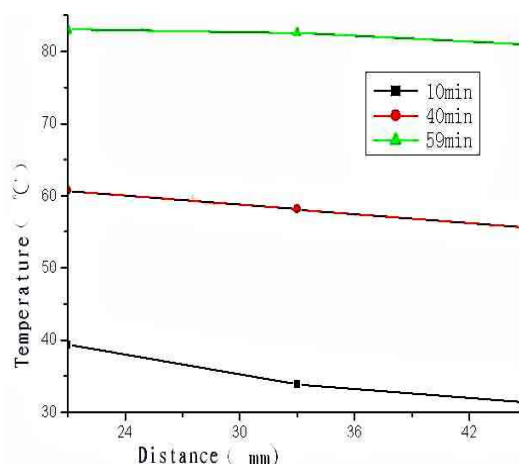
- 1 Wall of heat storage container 2 Thermal insulation material
3 Electric heating rod

liquid interface expands. The free convection will dominate until the paraffin wax melt completely.

As shown in Fig 4(a), when it is heated for 10 minutes, the temperature gradient of the three measuring points is larger because of the low conductivity coefficient. At the moment of 60 minutes, the temperature gradient is smaller, the reason is that the three points are in the phase change process where temperature changes slowly. Till the moment of 80 minutes, one part of the paraffin is in phase change process, another is in liquid phase, so the temperature gradient become big. when it is heated for 93 minutes, the paraffin wax is in the liquid phase, the temperature of the three points is nearly the same.



(a) Heating power :165W



(b) Heating power : 270W

Fig. 4 Radial temperature distribution at different time during melting process

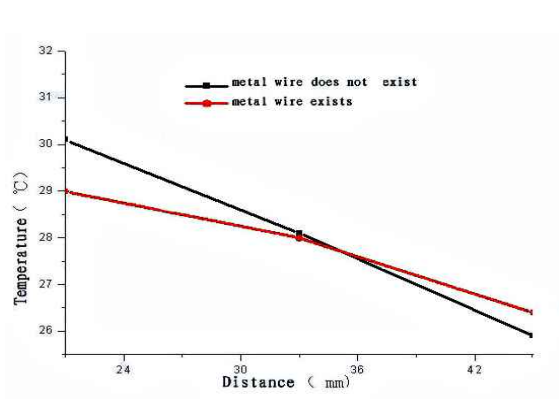
2.4 Analysis on heat transfer enhancement effect of metal wires

Though comparing the paraffin melting experiments in which metal wires exist with they don't exist, we can get following four figures.

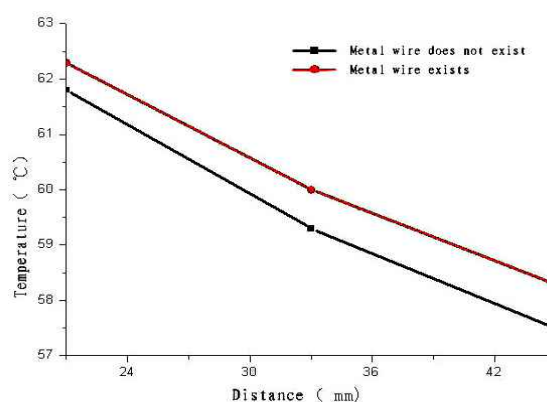
Fig5(a)、(b)、(c) respectively show the radial temperature distribution when paraffin is in solid phase, phase transition and liquid phase, reflecting the effects of adding metal wire in during it's melting process. Conductivity dominates in the solid phase, both convection and conduction exist in the phase transition and convection in liquid phase. Through comparing these heat transfer processes, it is seen that adding metal wires can enhance heat transfer.

Fig. 5(d) shows the influence on solid-liquid interface after metal wire is added. There are great differences on the moving speed of solid-liquid interface when metal wires are added. After metal wires are added, the heat which released from the electric heating rod can be easily transferred because of the reinforcement of metal wires. The reason is that the heat which absorbed by the inner layer paraffin reduces, and it increases in the outer layer paraffin. The inner layer paraffin takes more time to melt, otherwise the outer layer paraffin takes less.

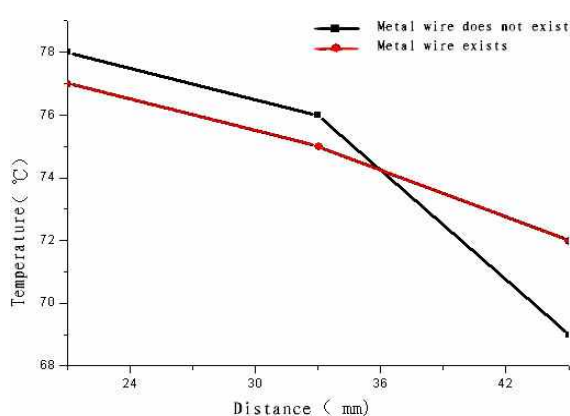
The results indicate that metal wires can improve the heat transfer property of paraffin wax, it mainly embody the function of thermal conduction channel. As heat storage material, the main defects of paraffin wax are that it has large thermal resistance and small effective heat exchange area, which lead to smaller heat exchange efficiency. Adding metal wire which has good thermal conductivity into paraffin can solve these problems. It is because that phase-change materials usually have very poor thermal conductivity, while the metal wire is good. In this way, metal wire is just like a thermal conduction channel which added into paraffin wax, improving the thermal conductivity of paraffin wax. As a result, large amounts of heat can be transferred through metal wires, which decrease the thermal resistance effectively and ensure the heating output quicker and smoother.



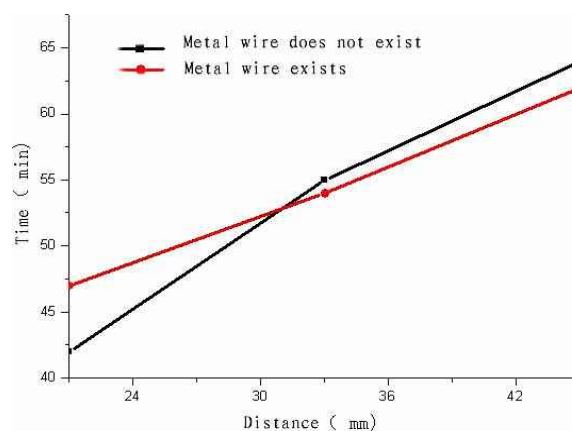
(a) Effects of metal wires in solid phase



(b) Effects of metal wires in phase transition



(c) Effects of metal wires in liquid phase



(d) Effects of metal wires on the movement of the solid-liquid interface

Fig.5 Influence of metal wires on heat storage process

3. Conclusions

- (1) The conductivity coefficient of paraffin wax is low. At the beginning of heating, the radial temperature gradient is very big.
- (2) Adding metal wires to paraffin wax can increase the coefficient of heat conductivity, and make up for the deficiency when it used as heat storage material. So it greatly improves the possibility for paraffin wax to be used in the heat storage.

References

- [1] Haiting Cui. Heat Storage Technology and Application[M]. Beijing: Chemical Industry Press, 2004
- [2] Jianfeng Wang. Progress in Phase-change Heat Storage Material. New Sources of Energy, 2000, 22(3): 31~35
- [3] Anaszek, R. Donmanski, M. Rebow, F. El-Sagier. Numerical analysis of the paraffin

wax-air spiral thermal energy storage unit [J]. Applied Thermal Engineering , 2000,20:323~354

- [4] N F., Makoto K. and Yoshikazu K. Thermal conductivity of energy storage media using carbon fibers[J]. Energy Conversion & Management, 2000, 41: 1543~1556
- [5] G Tang, Xiaowu Wang, Zhixin Zeng. A Theoretical Model and Performance Analysis of Fiber Composite PCM [J]. Journal of South China University of Technology, 2001, 29 (8): 33~35