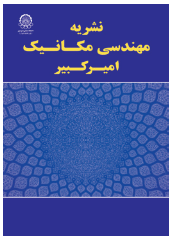

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Experimental Study of Charge of Paraffin Wax Along with Nanoparticles in an Eccentric Double Tube Heat Exchanger for Storing Energy in a Solar Water Heater

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ABSTRACT: Use of thermal energy storage using latent heat fusion of phase change materials is an effective and efficient way for energy storage in solar water heaters. The present paper is an experimental study carried out at last week of August 2014, in Jundi-Shapur Industrial University of Dezful City. First, in this study, two eccentric double tube heat exchangers with different eccentricities were built and each was separately placed in the circuit of a forced solar water heater including a flat plate solar collector, a storage tank, and a hot water circulating pump. Through the internal tube of heat exchanger passes the water heated by the solar collector, while the shell contains paraffin wax as the phase change material to which copper oxide nanoparticles are added to increase thermal conductivity. This study experimentally investigates the effect of copper oxide nanoparticles and also the effect of eccentricity on the charge of paraffin wax as the phase change material and energy storage due to the change in both of these parameters. Experimental results indicate that paraffin wax containing 3%, 1% and without nanoparticles, have reached their melting points at 14:20, 15:20 and 16:20, respectively, in the heat exchanger with 1 inch eccentricity , Paraffin wax with 3% nanoparticles has reached its melting point at 14:20 and 15:40 in the heat exchangers with 1-inch eccentricity and 0.5-inch eccentricity, respectively. . It is worth noting that lowering the heat exchanger internal tube and adding nanoparticles significantly improve the fusion (charge) of paraffin wax and also thermal energy storage.

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1- Introduction

Use of thermal energy storage system using latent heat fusion of Phase Change Materials (PCMs) is an effective and efficient way for energy storage in solar water heaters. This energy storage system saves thermal energy with high density and approximately constant temperature during the phase change process [1]. This system is useful for different applications such as solar dryer [2], air conditioning systems [3].

There are many studies on this subject carried out by researchers [4, 5]. The previous studies are accomplished fusion of NePCM by using an artificial thermal source with constant heat flux such as an electrical element, but none of them has checked the effect of usage of heat flux resulted in hot water of a solar water heater for fusion paraffin wax in annulus.

2- Experimental Setup

Solar water heater system used in this research is shown in Fig. 1. In this research, two eccentric heat exchanger with eccentricities 0.5 and 1 inch are designed whereas their dimension and substance is the same. Moreover, it is used a flat plate collector, a hot water storage tank, a circulation pump, and a data logger.

The melting temperature of paraffin wax as phase change material is 55 °C. 9 (nine) temperature sensors are placed in the output of heat exchanger in different angular and radial positions for recording temperature of paraffin wax (Fig. 2).

For each experiment, 5 kg of paraffin wax is melted and is poured in the shell of the heat exchanger. The nanoparticles which are used in the research are CuO with 40 nm dimension.

Fig. 1. A view of the solar water heater system

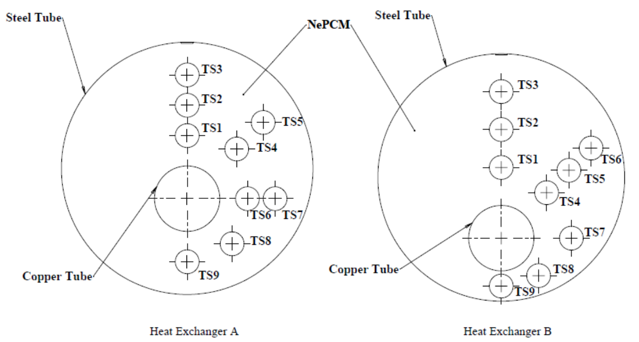

Fig. 2. A side view of heat exchangers in which the positions of temperature sensors can be seen.

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3- Results and Discussion

The charts of temperature variations of sensor TS9 (high-temperature sensor) are drawn in Figs. 3 and 4 for different loads of nanoparticles in the heat exchangers A and B in order to investigate the effect of nanoparticles CuO on fusion (charge) process of paraffin wax. The Figs. 3 and 4 show that adding nanoparticles CuO improves fusion (charge) process of paraffin wax as a phase change material.

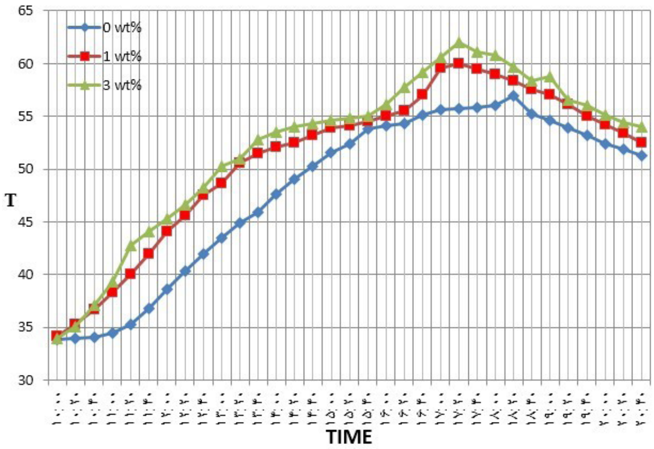

Fig. 3. Temperature variations of sensor TS9 for different loads of nanoparticles in the heat exchanger (A)

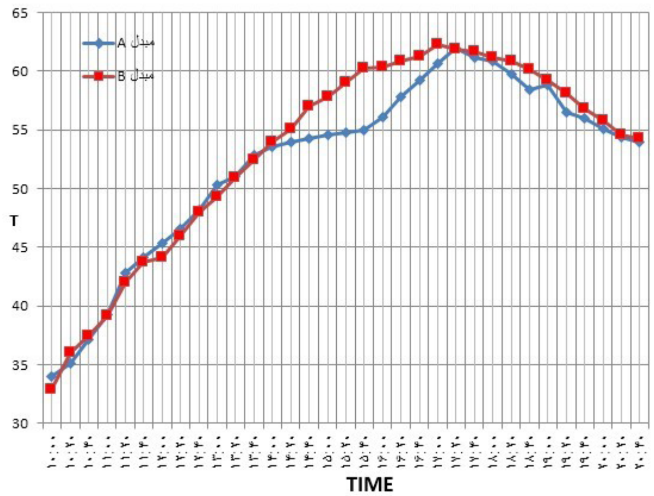

Fig. 4. Temperature variations of sensor TS9 for different loads of nanoparticles in the heat exchanger (B)

The temperature variations of sensor TS9 in the heat exchangers (A) and (B) are compared for loading 3wt% nanoparticles in Fig. 5 to investigate the effect of eccentricity on fusion (charge) process of paraffin wax. Fig. 5 shows that paraffin wax is melted sooner in the heat exchanger (B) because it has more eccentricity than heat exchanger (A).

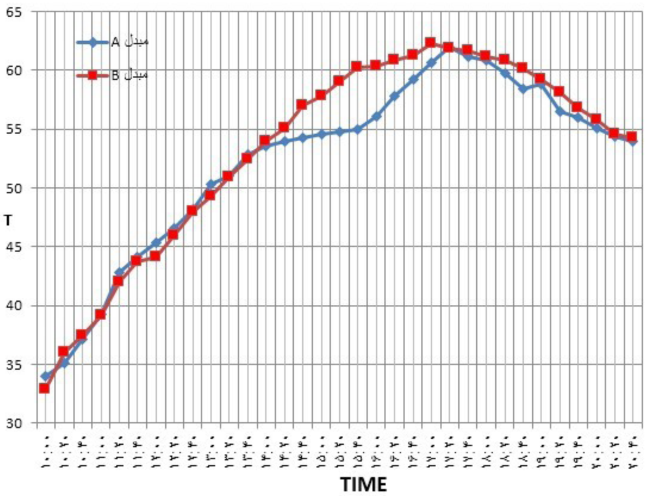

Fig. 5. Temperature variations of sensor TS9 for paraffin wax with loading 3wt% nanoparticles in the heat exchangers (A) and (B)

4- Conclusions

Experiments have led to the following conclusions:

1. The magnitude and rate of enhancement of the charging time increase with augmenting the applied heat flux.
2. Adding the nanoparticles enhances the effective thermal conductivity of the PCM and improves the melting characteristics such as increasing the melting rate and expediting the charging time.
3. Melting is dominated by conduction at early stages indicated by concentric solid-liquid interfaces parallel to the circular heat tube. At later times, natural convection is augmented which affects the shape of the melting front and consequently results in unsymmetrical melting about the vertical plane.
4. Higher melting rate and temperatures are recorded within the upper part of the capsule due to the role of strengthening natural convection. Therefore, melting of NePCM can be expedited through using an eccentric shell and tube arrangement by lowering the center of internal cylinder or tube to increase the area, volume and amount of NePCM that is exposed to the effect of the buoyancy-driven convection.

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