1. EXPERIMENTAL AND THEORETICAL INVESTIGATION OF HEAT PIPE COLLECTOR USING PHASE CHANGE MATERIALS PCM

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Abstract

The present thesis involves two divisions: theoretical work and experimental work for a solar collector with wax as phase change material (PCM). The use of the thermosyphon was studied with solar collector type evacuated glass tube, with a tank for storing water, and containers of paraffin wax which represent the internal surface of the tank as water is in contact with the surface of the containers. The PCM can be benefitted for heat storage and using this heat to obtain water with high temperatures even during the absence of the heat source or during night. The study was done with different cases: with and without PCM, and with and without loads, as loads are 0.15, 0.27, 0.353, 0.36, 0.39, 0.6, 0.8, and 0.866 l/h.

The numerical work comprises three parts to simulate the thermosyphon to find out its distribution of temperatures, the water tank to find out its distribution of temperatures in addition to velocity contours of water, and temperatures distribution of the PCM. This has been performed through using CFD technique and the construction of programs in Fortran 90 language, these programs comprise subroutine program of the thermosyphon through which the energy equation has been solved, the main program is concerned with the water of the tank and solving the Navier Stokes equations in 3D by finite volume method and SIMPLE algorithm to find out the distributions, and subroutine for PCM containers which solves the energy equation in 3D without viscous dissipation by control volume - finite difference approach.

In the experimental work, a rig has been constructed to perform the experiments in this study. The rig consists of the first part which is an evacuated glass tube as a solar

collector with external diameter 46 mm and internal diameter 36 mm; the second part is a thermosyphon which is used to transfer the heat, it is a copper tube with a diameter of 16 mm consisting of two sections: the evaporator, which is inserted into the evacuated glass tube, and the condenser, which is inserted into the water of tank which is the third part. The solar simulator system is composite of seven halogen lamps which work with different voltages and currents to produce different heat fluxes as required. The heat flux falling on the evacuated tube is collected and transferred to the thermosyphon and then the heat is transferred to the water in the tank and finally the heat is given to the paraffin wax in the containers. Here, the paraffin wax changes from the solid phase to the liquid phase.

The melting temperature of the paraffin wax is 38-43 °C. The period of falling heat lasts for 9 hours and is called the charge period. Then the solar simulator is shut down, this period is called the discharge period during which the stored heat in the PCM transfers into the water. Therefore, water with high temperatures can be obtained overnight.

The experiments were carried in the lab conditions, incidence angle (θ) 90°, filling ratio FR=50%, with paraffin wax mass of 3.6 kg. The work continued from April 2016 to March 2017. Each experiment lasted for 24 hours.

The results show that, the increase of heat flux with a rate of 33.3% leads to an increase of average temperatures for the thermosyphonof 18.1%, 23.37% for the water in the tank, and the average time of PCM melting decreases to 25%.With different loads, it was found that the best performance was with load 0.36 l/h and heat flux 750 W/m^2.It was also found that with or without load, the temperatures of water are higher with PCM, so these temperatures with PCM and high load 0.866 l/h are no less than 35 °C, and higher than 40.5 °C with load 0.15 l/h all night. Different

increasing load conditions results in a decrease of the time for PCM solidifying with 20.8% to 29.16 %.It has been found that the use of a small mass of paraffin wax has led to an increase in the temperatures of storedwater with a rate of 17%, which can be used during absence of the sun or sources of energy.

From the experimental and numerical results appeared clearly a good agreement with a difference of 5.5% to 17.4%.