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A Review On Active-Passive Solar Water Heating System Using Phase Change Material

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***Abstract*: A solar collector (or) solar trough is a device that collects and (or) concentrates solar radiation from the Sun. These devices are primarily used for active solar heating and allow for the heating of water for personal use. In our project we are going to incorporate solar collector (or) solar trough and Phase Change Material (PCM) for heating the water. In this project we are going to utilize the PCM heat for heating water for the second time in the additional tank.**

***Keywords*: Solar trough, Phase change material, Copper tube.**

1. Introduction

Solar water heating is well established, high effective, pollution free technology for domestic water that can be used through the country for various applications. The solar water heater captures the sun's heat in the form of discrete packed of photons, that sun heat is utilized in the system for heating the water; the system receives sun's heat by the solar trough collector and transfers that heat to the water.

A. Solar Parabolic Trough

The solar air heater's performance is examined by using the copper and aluminum U-shaped heat exchangers (UHX) with and without fin alternately, inside the absorber tube placed at the focal length of the nickel-coated stainless steel parabolic trough. The system is examined in the form of temperature difference achieved at the outlet for both the heat exchangers and the solar air heater's efficiency.

Further, it has been found that the efficiency of the solar air heater is increased by 9.29% at a high flow rate when using a copper heat exchanger in place of the aluminum heat exchanger. The temperature difference achieved by the system is also increased by 2.34% at a low flow rate. [1].

In the design it was considered the parabolic aperture of 0.5m wide and 0.95m long. The results of the evaluation to determine the thermal performance of the parabolic trough collector have a maximum outlet temperature of 47.3 °C for a direct solar radiation of 783 W/m2 at a flow rate of 0.200 L/min [2].

As a promising application of solar energy, this paper takes the SEGS VI parabolic trough plant as the research object and proposes an improved 30 MW parabolic trough solar thermal power plant. An optimization model is established for the overall plant efficiency, and the design of the solar field of the improved plant is presented with an explanation in this paper. The solar field efficiency increases by 0.52% and the overall plant efficiency increases by 0.24% under the design conditions. The daily mean solar field efficiency data increase by 0.53%, and the overall plant efficiency increases by 0.22% under operating conditions [3].

B. Phase Change Material

The execution of the concentrated on Phase change material storage system was noted maximum when melting point of Phase change material was 22.5°C in winter season and 28.8°C(∼29°C) during summer period. Summer, whereas 26.8°C was found during remaining part of the year. When the temperature goes below 26.8°C, cooling capacity of system is more as compare to heating capacity. Study also concludes that the effect of melting point of PCM has a great effect on cooling in summer period and its storage can be used in winter season. [5].

Different cases have been simulated: tanks modeled as sensible (water) storage, only hot side tank modeled as PCM storage and only cold side tank modeled as PCM storage. In the second case, two different sub-cases have been further considered: "hot" (temperature of fusion 89°C) and "warm" (temperature of fusion 44°C) PCM heat storage. Results indicate that energy consumption and the highest solar ratio provide a 3000 l "warm" tank filled with PCM melting at 44 °C and a 2000 l "cold" [6].

This paper provides a state-of-the-art review on phase change materials (PCMs) and their applications for heating, cooling and electricity generation according to their working temperature ranges from (−20°Cto+200°C). Four working temperature ranges are considered in this review:(1) the low temperature range from (−20 °C to +5 °C) where the PCMs are typically used for domestic and commercial refrigeration; (2) the medium low temperature range from (+5 °C to +40 °C) where the PCMs are typically applied for heating and cooling applications in buildings; (3) the medium temperature range for solar based heating, hot water and electronic applications from (+40 °C to +80 °C); and (4) the high temperature range from (+80 °C to+200 °C) for absorption cooling, waste heat recovery and electricity generation. Different types of phase change materials applied to each temperature range are reviewed and discussed. The review shows that, energy saving of up to 12% can be achieved and a reduction of cooling load of up to 80%

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can be obtained by PCMs in the low to medium–low temperature range. [8].

The methods applied to fulfill this objective were numerical modeling by Energy Plus, Grouped Method of Data Handling (GMDH) type of Artificial Neural Network (ANN) and Non-Dominated Sorting Genetic Algorithm II (NSGA-II).

In this study, design variables were melting temperature and thickness of PCM, thermal resistance of exterior walls, internal gain and infiltration rate. Additionally, objective functions included annual cooling and heating loads of the building that should be minimized. According to the obtained results, the thickness and melting temperature of the optimum PCM layer in the residential building in Tehran were equal to 0.032 m and 24.58°C, respectively. [13].

To understand their heat transfer performance, the heat transfer experiments in a horizontal circular tube were performed. The horizontal circular tube possessed thermocouples embedded in a circumferential direction and a constant heat flux incident on the flowing phase change material emulsion. A significant temperature distribution was observed when phase change material emulsion flowed with phase change material particle melting. Moreover, it was found that the local Nusslet number at the upper position of the horizontal tube was significantly enhanced and the Nusselt number of phase change material emulsion was up to about 2.5 times higher than that of the single- phase fluid.

On the other hand, no temperature distribution was observed when phase change material emulsion flowed upward, even with phase change material particle melting. These results imply the presence of a secondary convection induced by phase change material particle melting owing to the density difference between the solid and liquid phase change material particles. The present findings suggest that the flow direction should be considered when using phase change material emulsions as thermal energy storage and transport media. [14].

C. *Paraffin Wax*

From the thermo physical properties of the carbon nanotubes added to paraffin in variable mass fractions, 3 wt% was selected. The addition of nanoparticles caused a slight increase in product density and viscosity. The percolation threshold of 3 wt% CNTs increased its thermal conductivity by 12%, reducing the melting and solidification points by 4.5 °C and 9°C respectively. The SWCNT/paraffin Nano composite has improved the stored thermal energy by 20.7% for natural convection, and by 21.2% for forced convection compared to pure paraffin. Results of practical tests confirmed the possibility of using the proposed air heater to work in Iraqi weather conditions. [7].

In this study, accelerated thermal cycling is performed on Paraffin wax (PW) and Paraffin Wax/Polyaniline (PWP-1) composite up to 3000 cycles to evaluate its durability. The latent heat of PW reduced by 6.7% at the end of 3000 cycles, whereas the composite PWP-1 reduced by 9.8% but PWP-1 had higher latent heat values compared to PW. The melting temperature showed an increment with the number of thermal cycles with 11.7% and 23% increment for PW and PWP-1 composite respectively. Visual and microscopic images of the samples are analyzed. From the study it can be concluded that PWP-1 composite has better thermal reliability in terms of latent heat as compared to PW and can be used in the field of solar application like flat plate solar collector, photovoltaic thermal system and low concentrated photovoltaic thermal systems for the production of domestic hot water application. [9].

The present work aims at increasing the effective thermal conductivity of a paraffin wax, the RT70, having a phase change temperature of 70 °C.

This paper proposes the addition of a 3D metallic periodic structure to the PCM.

To optimize the geometry, three different structures with 10, 20, and 40 mm base sizes were designed and manufactured via additive manufacturing. Experimental tests were run during the melting and the solidification of RT70 at three different heat fluxes (10, 20, and 30 W). The addition of the 3D aluminum structure in the PCM remarkably improved the heat transfer performance as compared to the reference empty box. [11].

D. *Solar Water Heater Using PCM*

The overall performance of the system depends on external climate data, type of PCM used and its mass, and flow rate of water. Neicosane is considered as PCM in this application while hourly weather data corresponding to the city ER- RACHIDIA is used for the analysis. A detailed 2-D transient simulation has been established to optimize the system performance by studying the effect of different design variables and operating conditions. A deep analysis was also made to understand the PCM melting and solidification processes for a better exploitation of this storage technique. Optimized results are obtained when a mass flow rate of 0.0015 kg/s is used with a PCM thickness of 0.01 m and a set temperature of 313 K. [10].

Paraffin wax as a PCM and a Nano composite of paraffin wax with 1.0 wt% of 20-nm Nano-Cu particles were tested as the energy storage medium for TES. Three cases have been investigated, namely without PCM, with PCM, and with the Cu- PCM Nano composite, at 10°, 20°, and 30° inclination angles of each case. The system performance was evaluated for water heating. The process involved a total change of the 60-l water tank at 7:00 PM and 7:00 AM. The use of water circulation of 0.5 kg/min and setting the collector at a 10° inclination angle was found to be the best operational condition. The measurement result of the tank water temperature at 7:00 AM, after 24 h of operation, was 35.1 °C when the system operated without TES, while the operation with the PCM and with the Cu-PCM Nano composite resulted in 40.1 °C and 40.7 °C tank water temperatures, respectively. The best performances analyzed were at 10°, with efficiencies of 47.6%, 51.1% and 52.0% for the cases without PCM, with PCM and with Cu-PCM Nano composite, respectively. This indicates that the enhancement of the system using TES with paraffin wax is considerable, while further enhancement is not significant in the case of Nano composite. [12].

One of the abundantly available energy resources among all the natural resource is solar energy. Nowadays, Phase Change

Materials (PCM) is used for storing the heat energy in the heaters to get efficient system. The function of solar water heater is to heat the water and supply the hot water during day time from the storage tank. But, the PCM installed solar water heater stores the heat energy during day time and supply the hot water even at night time for domestic purposes. From the obtained results, PCM absorbs more the heat energy and release the heat for longer duration. The Nano filler also improved the water temperature of 33% more than other commercial water heaters. [4].

The test procedure involved observing the total variation of temperature in the tank water from 6.00 am. to 6 a.m. of the following morning. For all three situations, performance of the device was analyzed using energy efficiency, energy quality, and hot water supply temperature during the next morning. Examples of the investigation are tank water temperature at 6.00 a.m. After one full day of operation, PCM and NCPCM improved significantly to 53 °C and 56 °C respectively, whereas for the case without PCM it was 45 °C. The energy efficiencies for the three cases were found to be 33.8 percent, 38.3 percent, and 41.7 percent, respectively, and the system's energy efficiencies were estimated to be 1.78 percent, 2.18 percent, and 3.23 percent, respectively, for without PCM, PCM, and NCPCM, respectively. It was also shown that the thermal conductivity of paraffin wax nanoparticles was significantly increased to 22.53 per cent. [15].

2. Conclusion

From these studies we can find that the usage of the Phase change materials has the major advantage. This field is in the developing stage and the scope is at large. Through these references we could find that Paraffin wax has the most area of scope in heat absorption due to its phase changing property. Combining of this two solar trough and phase change material could form a suitable low costing and at the same time a high efficient water heating system. The usage of copper tube is also an important note with solar parabolic trough. Thus, through these results we could see that the usage of solar trough, paraffin wax, copper tube may meet our need.

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