Enhancement Thermal Conductivity of PCM in Thermal Energy storage

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Abstract

An experimental investigation of different thermal energy storage materials in the solar collector is studied in this paper. Both, sensible energy storage materials and latent heat storage materials (PCMs) are used to enhance the storage system of thermal energy. The size of the tested solar collector 2 m*0.8m*0.15 collector length, width, height. Experimental results obtained from the proposed model indicate that the solar collector model, having a composite of paraffin wax with 5% aluminum powder can continuous operation, and the maximum air temperature difference (∆T) between air enter to collector and exit from the collector if the ambient of 24.7 ºC, the effect on the efficiency of the collector

Keywords: PCM, solar energy, enhance thermal storage, latent heat storage

1. Introduction

The benefit of solar air collector was studied in 1931 study a numerical and theoretical investigation of (PCM) consist of paraffin wax with additives as aluminum powder. The important experimental modifications on the thermal storage material in the collector to help in enhancing the air temperature difference of the collector. The thermal behaviors of the solar collector with 24 hours under the effect of thermal energy storage were investigated experimentally in this work. Solar chimney power plant one kinds of solar conversion techniques that convert solar energy or clean energy to thermal energy and electric energy. the performance of this power plant by carried out the air after heating from solar energy and then make the air lighter make draught towards the pressure-staged wind turbine chimney because of the important two-parameter (geometry and temperature difference) these two parameters improve the performance of the power plant, the four major components: (1) the solar air collector, (2) up draught chimney, the fundamental research for solar chimney technique and the construction of the plant began of the minister of research and technology in
Germany by Haaf et al. [1] in 1983 discussed the performance of collectors with different levels in soil ground. Ming et al. [2] studied the optimization collector efficiency for the solar chimney to investigate the behavior by using a model of calculation, which has shown that the longwave radiation balance could be sustainably improved by using IR-reflective coated cover material. Schlaich [3] studied the effect of many types of ground and the varied height on the performance of solar chimney pilot. Haider [4] investigate the model and the performance evaluation of a solar chimney power plant and has been verified by the experimental data of the Spanish prototype. Rafea [5] studied the behavior of solar chimney element with added storage system (latent and sensible) heat storage to operate 24 hours in one day. In this work, two types of thermal energy storage materials were introduced as heat storage to develop the performance thermal storage of the solar collector model.

2. Experimental setup

The experimental setup is shown in Figure 1. schematic diagram of solar air collector consists PVC pipe of 2 mm thickness, 1000 mm high and 100 mm outer diameter, the glazing cover of the collector, 4 mm thickness Perspex sheet, Phase change materials (paraffin wax, and paraffin wax + 5% aluminum powder) for thermal energy heat storage from day to night, collector ground made up of black absorbing aluminum plate 1 mm, sidewall: made of 4 mm thickness Perspex sheet glass, heat insulation material: 15 mm thickness glass wool material is placed on the outside of the sidewall and ground to prevent heat loss. The collector inclination angle was fixed at 30º [5] and collector inlet height was fixed at 160 mm. The K-type thermocouples with 12 channels recorder Model: BTM-4208SD Data Logger were used to measure the temperature at different locations. The airflow velocity is measured using the electronic anemometer Model: AR816 (at exit pipe in the bottom). The solar meter Model: 776 was used to measure solar intensity. The data are recorded every 1 hour [6]. The experimental measurements are carried out in April 2019 and the experimental study starts with poured the paraffin wax was into the galvanize container in the liquid state and allowed it to reject the heat to solidified the paraffin wax in the atmosphere conditions: as shown in Figure (2). Paraffin wax was behind the aluminum (Al) plate (absorption). The paraffin wax mass was 12 kg.
Figure (1) Schematic and photo of the solar collector

Paraffin wax is the famous commercial organic storage of heat PCM [7]. The effect of paraffin wax attracts great attention because it possesses desirable properties such as chemically inert, commercially available, high latent heat, and no phase segregation.

Figure (2) Paraffin wax inside the collector

Paraffin wax has been used for application thermal storage energy systems. This is because it is properties for both large energy amounts and storing. However, the overall power of the thermal energy storage will be decreased due to the low thermal conductivity. Add a powder of aluminum which has a good conductivity to overcome the low thermal conductivity of paraffin wax [8]. This work presents the new composite of PCM consisting of paraffin wax with a mass fraction of 5% of the additives such as powder of aluminum [9]. The aluminum powder size of particles has been considered was (50-150 mm in particle size) the physical properties of aluminum powder of 2700 kg/m³ density and 247W/m. °C thermal conductivity [10]. In mixing preparation, the aluminum powder was poured onto molten paraffin wax and was mixed by a high-speed mechanical mixer. It is then heated above the melting point of the paraffin wax for 2 hours. Afterward, under normal atmosphere, the paraffin wax was solidified by cooling the system [11]. This composite was put into the container and the process of mixing and heating happen simultaneously [12]. The composites of paraffin wax+ aluminum powder and paraffin wax thermal conductivity have been measured experimentally. From results, the composites of paraffin wax+ aluminum powder have thermal conductivity (0.596W/m K) 2.773X compared with paraffin wax only (0.215W/m K).[13]
Thermo-physical properties of both, paraffin wax are given in table (1).

| PCM type         | Melting temperature °C | Density kg/m³ | Thermal conductivity W/m. °C | Fusion Latent heat kJ/kg | Specific heat kJ/kg.°C |
|------------------|-------------------------|---------------|-------------------------------|--------------------------|------------------------|
| Paraffin wax     | (62-64)                 | 970           | 0.27                          | 224.4                    | 3                     |
|                  |                         | 833.3         | 0.233                         |                          | 4.8                   |

3. Results and Discussion

Two types of thermal energy storage materials were used in this work. Figure (3) gives the variation of time versus air mass flow rate during the period of operation. The mass flow rate represents one of the most important performance parameters [14]. This is because it reflects immediately how large the plant output power as shown in the equation (1).

\[ P_{output} = 0.5 \dot{m} V_T^2 \quad (1) \]

![Figure (3) Variation of mass flow rate versus time](image)

Figure (3) Variation of mass flow rate versus time

Figure (4) shows the hourly represents the variation of absorbing aluminum plate temperature during 24 hours for paraffin wax and figure (5) paraffin wax+ 5% aluminum powder respectively. It is difficult to find ways describing the variation
of absorbing plate temperature and explaining all the reasons for increasing or decreasing [15]. This is because this temperature is a function of many parameters such as ambient conditions, collector design, heat transfer between absorber plate, and PCMs.

Figure (4) Temperature variation of the aluminum plate during day time

![Paraffin wax temperature variation](image)

**Figure (4) Temperature variation of the aluminum plate during day time**

Figure (5) Temperature variation of the aluminum plate during day time

![Paraffin wax+ Aluminum powder temperature variation](image)

**Figure (5) Temperature variation of the aluminum plate during day time**

Figure (6) presents the PCMs temperature variation of time, transferred the solar energy collected to the PCM. The PCM temperature will be rising due to the absorption plate up to the melting point. In the beginning, the temperature change is fast due to the biggest transfer [16]. After melting the PCM, the temperature will be reached to the maximum value for paraffin wax 63.2 °C, at 13 pm, at 16 pm, and for paraffin wax+ 5% aluminum powder 52.3 °C, at 15 pm, as shown in figure (6).
Rising air temperature through the collector ($\Delta T$) indicates the amount of thermal energy gained by the air stream [17]. This is noticeable when it is flowing over the absorbing plate of the collector, increasing its enthalpy [18]. The hourly variation of temperature rises for the solar collector using two thermal energy storage materials is shown in figure (7). In this figure, it can be noticed that their variations trends follow that of the incident solar radiation on the collector surface. Their values come into maximum in midday which is the time of highest solar radiation. This represents the logical behavior of such thermal installations. From the figure, it was found that the air temperature differences ($\Delta T$) continuous for 24 hours using the composite of paraffin wax +5% aluminum powder. [19]
The variations of collector efficiency for different thermal energy storage materials is shown in figure (8). Collector efficiency is mainly dependent on the product of \( \dot{m} \) and \( \Delta T \) as shown in equation (2) and [20] which also governs the plant performance as a whole. The solar collector efficiency represents the measure of how much thermal energy is gained by the working air when it is flowing over the absorbing plate. It can be noticed that the collector efficiency has higher values when the solar collector generate higher \( \Delta T \) [21]

\[
\eta_c = \frac{C_p \dot{m} \Delta T}{\pi R^2 I_T}
\]  

(2)

![Figure (11) Thermal efficiency of the collector versus time](image)

4. Conclusion

Two types of thermal energy storage materials were introduced as heat storage to develop the performance thermal storage of the solar collector model. After comparing among thermal energy storage materials, PCMs have good thermal storage because, small temperature variation from storage to retrieval, large heat storage, and high heat storage capacity. The main points of the conclusion are:

It was observed from the comparison of air temperature difference \( \Delta T \) among thermal energy storage materials the composites of paraffin wax+ 5% aluminum powder were a good thermal storage material because it is capable to provide the continuous operation for 24 hours.

The paraffin wax with aluminum powder increases the thermal conductivity, so the power of the storage.

Solar collector efficiency was dependent on the product of \( \dot{m} \) and \( \Delta T \).[22]
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