INVESTIGATION ON UTILIZATION OF HEAT EXCHANGERS AND SOLAR ENERGY FOR THE DRYING PROCESSES

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Abstract

Nowadays the non-renewable energy sources, their availability and consumptions have become the areas of concern due to people's growing needs and utilizations. The current status of the society and environment is to find an energy source which should be an alternative for the depleting fuels and ecofriendly. Further to add to our worries are the harmful effects of these fuels. These have resulted in ending up with the choice of solar energy utilization. Sometimes the industries have to go for the design of economic hybrid systems. The remedies for the international issues like oil crisis, global warming, ozone depletion and harmful emissions are the applications of the renewable solar energy. The current work is about the investigation of different types of drying systems and solar dryers. The aim of the study is to design a heat exchanger system using solar energy for drying processes and enhancing their performances. Advanced nanotechnology applications like the utilization of the nanoparticles and fin profiles for heat transfer enhancements are found to be one of the areas of research and improvement in this field. Solar energy has been finding its hopeful and promising applications nowadays.

Keywords: *renewable energy sources, solar energy, solar collectors, heat exchangers, dryers, nanotechnology.*

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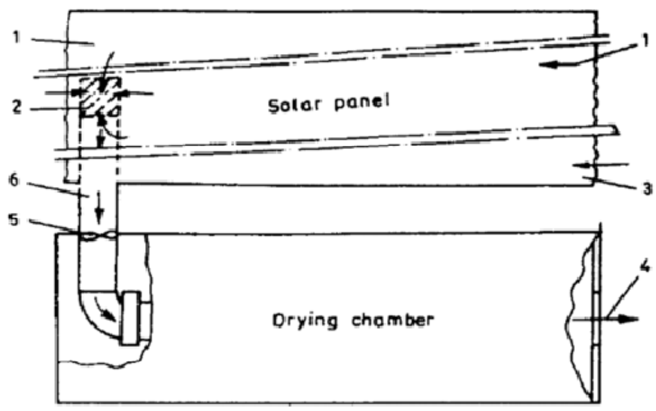
I. INTRODUCTION

The industrial processes require a huge quantity of electrical power supply. Due to the non-availability of the alternative choices, there is a gap in the supply of this energy. In order to fill this process gap, we are going for the solar energy utilizations. The drying process in the domestic purpose industries are analysed and a solar drying concept by means of heat exchangers has been proposed in this paper. Generally the solar dryers should be vested with the following features like solar collector setup, heat exchanger chamber and exhaust provisions. The industrial processes like leather processing, coconut oil extractions, rice processing, etc., requires the effective drying applications by trapping the renewable solar energy. Even though, the solar energy could not be the complete solution for these energy issues, it can be used as hybrid economic facility. The solar drying may be of direct solar drying and indirect solar drying types. The indirect solar drying process is preferred over the other process as the former possesses certain advantages like property restoration of the products after processing. The review has been done about the solar collectors with their different profiles. Another category of work has been done about the usage of water and nanofluids as the Heat Transfer Fluid.

II. LITERATURE SURVEY

Kalogirou et al. (2015) conducted a review on the different solar collectors and dryers. A comparative exergy analysis of the different types of solar collectors has been carried out. The exergy analysis has been found to be a useful method for evaluating the performance of the solar dryers [1].

Roosevelt et al. (2000) conducted an experimental work for identifying the hybrid drying system for leather industries. The solar dryer setup as shown in Figure 1 had been used for the analysis. They carried out a comparative analysis among the characteristics of the open, solar and electrical dried leathers. They have found that the specific energy consumption using electrical drying system is about 1.47 KW/ kg while that of solar drying system is about 0.232 KW/ kg. The solar drying systems for leathers have been found to be cost effective in cases of large scale drying [2].



1. Cold air inlet 2. Roof Aperture 3. FRP glazing 4. Damp air outlet 5. Wall fan 6. Timber outlet

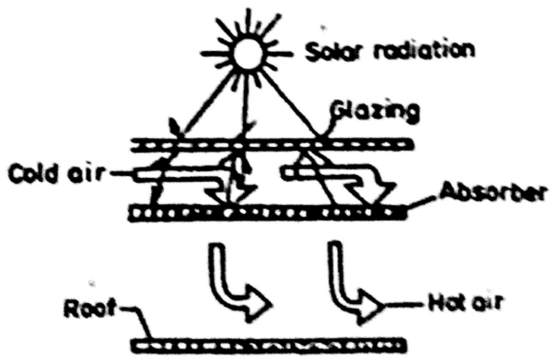


Figure 1: Schematic Solar dryer setup by Roosevelt et al (2000)

Pierrick Hauranta et al. (2014) had conducted the experimental work of a photovoltaic - thermal (PV-T) hybrid system for domestic hot water applications. It is a PHOTOTHERM process using covered water based PV-T collector as shown in Figure 2. The temperature of the fluid has been raised up to 55º C and sometimes to 100º C during sunny days. Small models can be developed into large scale PV-T collectors and studied for effective performances [3].

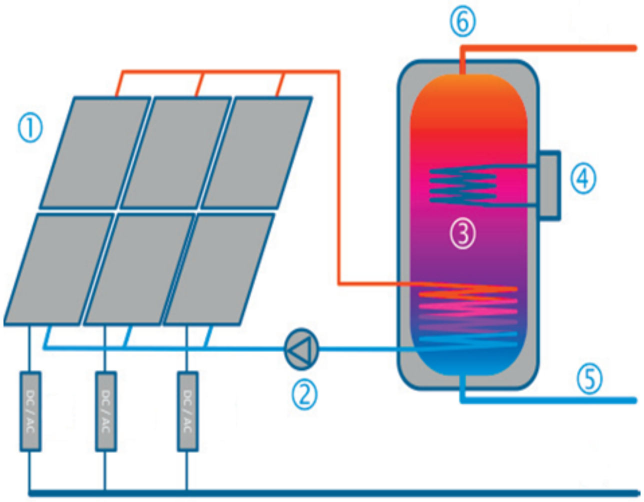


Figure 2: Schema of the domestic hot water system by Pierrick Hauranta et al (2014)
1- PV-T collectors; 2 – Pump; 3 - 300L water storage; 4 - Electrical auxiliary heating; 5 - Cold water inlet; 6 - Warm water out

David Gudiño-Ayala et al. (2014) had conducted the experimental work for the pineapple drying process. They had compared the performance of the solar dryer and hybrid (with LP gas) dryer system for the pineapple processing. The efficiency of the solar dryer is about 23.4% while that of the hybrid system is about 13.4% [4].

Sethi et al. (2013) had conducted the experiments with double slope active solar still setup under forced circulation mode. The setup has a solar still and solar collector used for the water desalination purpose as shown in Figure 3(a) and 3(b). The temperature rise of the water is found to be around 42ºC and above. Black paint or dye coating is provided to the basin for improving the absorptivity of the solar radiations. It is observed that the peak summer conditions exhibited the improved performances of the experimental setup [5].

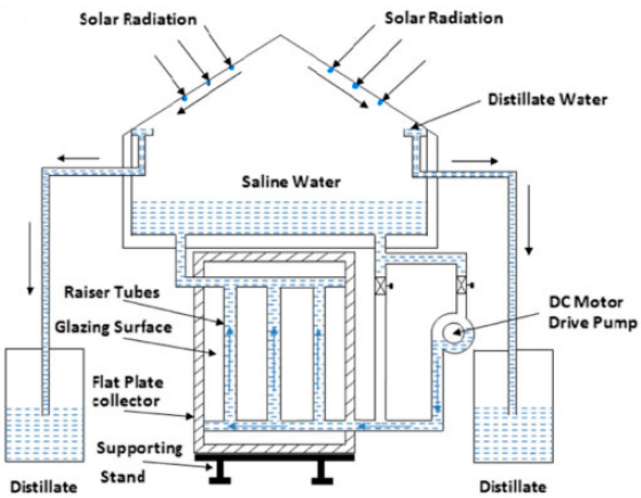


Figure 3. (a):Cross sectional view of a Double slope active solar still

Figure 3. (b): Double slope active solar still setup by Sethi et al (2013)

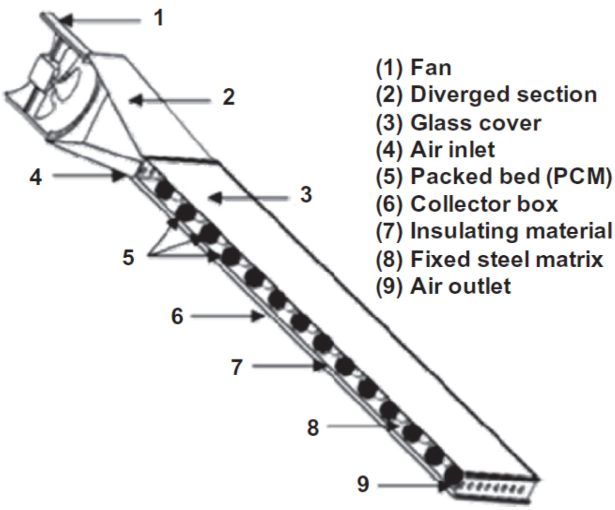


Figure 4: Schematic view of SAHLSC by Salwa Bouadila et al (2013)

Salwa Bouadila et al. (2013) had conducted an experimental analysis to estimate the thermal performance of the solar air heater collector with packed bed latent storage energy as shown in Figure 4.The Phase Change Material has been used in spherical capsules in this solar collector. A comparison has been made between the Commercial Solar Air Heater (SAHC) and Solar Air Heater Collector with PCM on the performance basis. The Nocturnal usage of the solar air heater with PCM spherical capsules is an optimistic area of research and development of the solar renewable energy systems [6].

Shanmugam et al. (2013) had modelled and conducted experimental studies on Oscillating Inclined-Bed Solar Dryer. This solar dryer has been modeled for drying products by controlling the relative humidity of the process. It is observed that the increase in the relative humidity decreases the moisture content of the products [7].

Farshad Farahbod et al. (2014) had performed the experimental study of solar-powered desalination pond. The process is a zero discharge desalination process. The comparison has been made between the performance of solar powered desalination pond and conventional solar pond. June and July months showed more productivity and the wind factor has to be considered [8].

Lidia Roca et al. (2008) had modelled and conducted experiments with a solar seawater desalination plant. The multieffect distillation process had been used in this process of desalination. This could help us in minimising the usage of fossil energy consumption [9].

Fadi Alnaimat et al. (2013) had analysed to enhance the performance of solar diffusion driven desalination process. They had included the heat exchanger for preheating the air used in the process and thus increasing the performance of solar desalination process [10].

Ganguly et al. (2011) had done the performance analysis of a Floriculture Greenhouse. Integrated Solar Photovoltaic Fuel cell system had been used to provide power to this greenhouse. It had been observed that the temperature ranges are found to be almost 30ºC. The forced air circulation had been arranged in this process [11].

Mehdi Hosseini et al. (2014) had done the investigation of a hybrid Photovoltaic-Biomass system. This system also had the energy storage facilities. The controlling parameters were identified. The increase in the steam to carbon ratio (SC- 1 to 3 mol/ mol) increases exergy and energy efficiencies to 29% [12].

Gholampour et al. (2015) had considered the design considerations of the Photovoltaic/ Thermal Air systems. The PV/T air collectors as shown in Figure 5 had been analysed. They had done the analysis by the energetic and exergetic approaches. This work is a theoretical model and various parameters like glass cover, channel depth, fin numbers and height were considered and analysed.

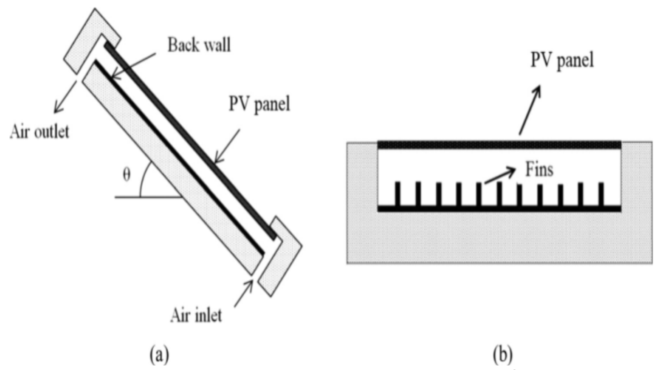


Figure 5: Schematic cross-sectional view of PV/T air collectors (a) without fins and (b) with fins by Gholampour et al (2015)

The exergy analysis had been carried out. It was observedthat theincrease in packing factor increases the temperature of the PV system. System with increased fin height showed improved performances. The Ratio number can be considered for increasing the performances [13].

Robert Hendron et al. (2007) had done the evaluation of a high performance of a Solar Home. This work had been done to improve the future prototype designs of solar home. The utilization of the solar energy for domestic purposes had been emphasized in this paper. The constructions of the setup were made in recommendations with ASHRAE standards. The TRNSYS simulations software was used for evaluating the contributions of solarenergy [14].

Said et al. (2014) had analysed the exergy efficiency of a conventional flat plate solar collector. Further the pumping power of this collector had been analysed using single walled carbon nanotubes (SWCNTs) based nanofluid. The experimental analysis had been carried out to enhance the heat transfer capability by using nanofluid instead of water as heat transfer fluid.The effect of different nanoparticles injection into the base fluid had been observed and inferred as shown in Figure 6. The heat transfer coefficient has been increased by 15.33% in comparison with water [15].

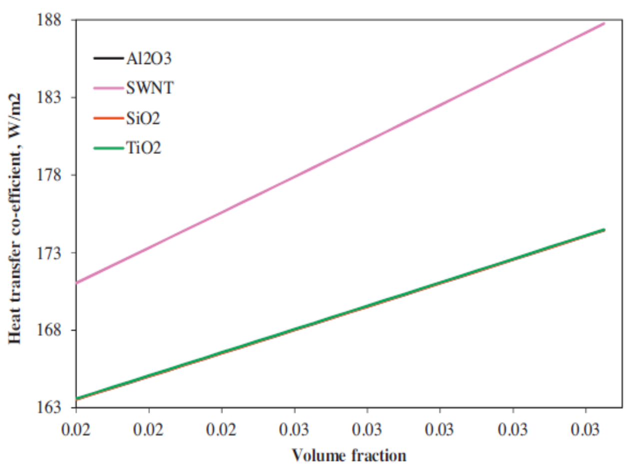


Figure 6: Effect of different nanoparticles injection into base fluid on heat transfer coefficient by Said et al (2014)

Seitz et al. (2014) had proposed the thermal storage concept for solar thermal power plant using direct steam generation. It is an experimental work carried out to increase the efficiency of solar thermal power plants. The range of the operating temperature of the heat transfer fluid (HTF) is about 400ºC. The Phase Change Material (PCM) used in this analysis is Sodium Nitrate [16].

Wong et al. (2014) had reviewed the nanotechnology and nanoparticles in solar applications. The Nanotechnology applications in the solar cells are found to be promising future after overcoming their cost issues. The efficiencies of the solar cells can be increased by reducing the reflectivity of their solar plates. The coatings for the solar plate collectors had been developed with the help of nanotechnology. It was observed that these coatings had improved the solar plate conversion efficiencies from 13.93% to 14.37% [17].

Liwu Fan et al. (2012) had done a theoretical and experimental investigation of unidirectional freezing of nanoparticle-enhanced Phase Change Materials. The analysis had been carried out in using the nanoparticles with Phase Change Materials for enhancing the heat transfer. The experimentation of the paraffin in additions with micro-sized aluminium powders (80µm)as Phase Change Material (Nanoparticle enhanced) in the collector had been done. It is found that the efficiency had improved from 32% to 82% [18].

Gianluca Puliti et al. (2011) had reviewed the different types of nanofluids. This review work had stressed the importance and potential growth in the field of nanofluids. The initial works in the nanofluid field had been started with the numerical analysis. The increasing heat transfer surfaces in the nanofluids enhance the heat transfer rate. Further in reference with many advantages, the nanofluids are preferred for several heat transfer applications. The base metal nanoparticles and carbon nanotubes provide better heat transfer enhancements. The changes in the heat transfer rate at different concentrations and sizes of the nanoparticles can be considered for further research work [19].

Chougule et al. (2014) had analysed the thermal performance of the Two Phase Thermosyphon Flat plate solar collector. This collector had used the nanofluid for the heat transfer purpose as shown in Figure 7(a) and 7(b). The thermal performance of the collector with different concentrations of the CNT nanofluid (Carbon Nano Tubes) had been analysed. The absorber plates are painted black in order to increase the solar radiations absorption. The effect of various tilt angles of solar collector pipes had been analysed.

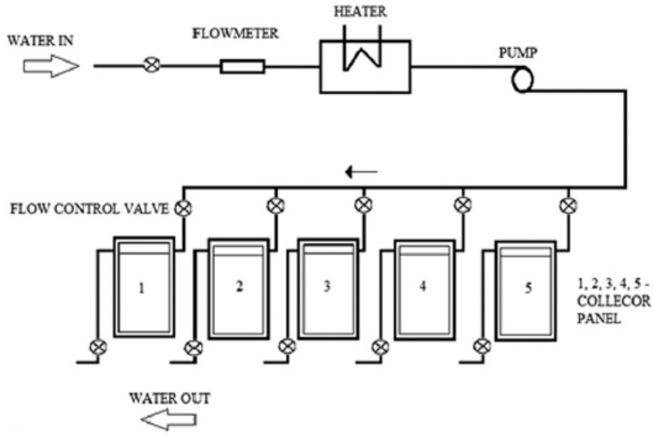


Figure 7. (a):Schematic diagram of solar test facility by Chougule et al (2014)

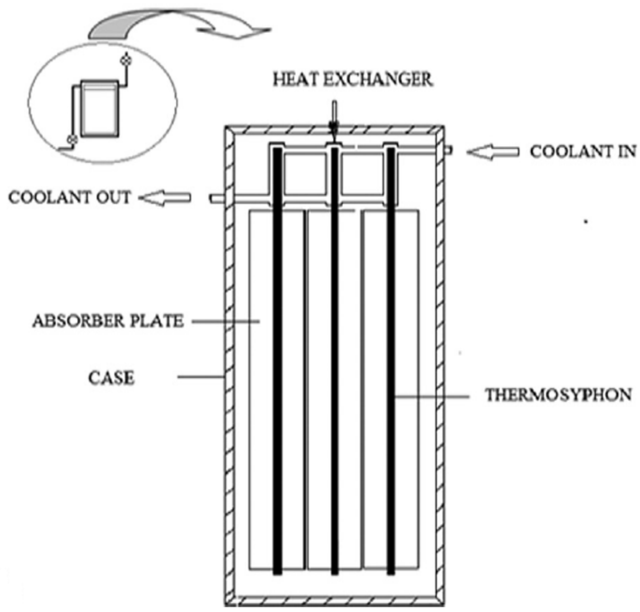


Figure 7. (b):Thermosyphon by Chougule et al (2014)

It had been observed that the solar heat pipe exhibited the maximum efficiency of 57.31% with 0.60% volume concentration of CNT nanofluid. The efficiency of the collector pipes increases with the increase in the tilt angles and decreases while exceeding 50 deg. The base metal nanoparticle analysis can be extended further for research work [20].

III. CONCLUSION AND FUTURE SCOPE

In this work, the review had been done about the features of the solar collectors and their various configurations. Further, the utilization of water along with the aids of nanotechnology as heat transfer fluid and the possibilities to enhance the performance of the heat exchangers and dryers had been analyzed.The following are some important conclusions drawn from this study.

- Solar drying concept can be used as hybrid system effectively.
- Mostly indirect solar drying has to be preferred.
- Nocturnal usage of solar energy by means of PCM.

- Fin provisions in solar panel container increases the performances.
- In conventional flat plate solar collector, the efficiency increases by 15.33%.
- The efficiency of solar collector has increased by using PCM enhanced with nanoparticle from 32% to 82%.

Further the following future works can be taken up in considerations with this work:

- Research on the utilization of nanoparticles in enhancing heat transfer.
- Utilization of fin profiles in the heat transfer surfaces for enhancement.
- Relative humidity conditions analysis in relations with heat transfer enhancements
- Phase change materials review for nocturnal usage and heat transfer enhancements.

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