PERFORMANCE ANALYSIS ON FLAT PLATE SOLAR COLLECTOR USING Cu_2O-WATER NANOFLUID

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Abstract: Solar thermal energy is one of the most popular renewable sources of sustainable energy with less environmental impact, no requirement of transportation and open availability for every human being all over the world. The present review is an extensive perspective of the research progress arisen in the performance of flat-plate solar collector using nanofluid which will absorb more heat energy from solar radiation. Application of nanofluid to increase the thermal efficiency of a traditional solar collector is getting tremendous attention among the scientific community. The aim of this work is to enhance the heat absorption rate by using the nanofluid. In this, work thermal analysis of a flat plate solar collector is done by using Cu_2O-water as a working fluid for various mass flow rates and its effect on the efficiencies of a flat plate solar collector was examined experimentally.

***IndexTerms* - Flat-plate solar collector, Cu_2O nanofluid, Heat transfer enhancement.**

I.INTRODUCTION

Due to environmental concern and limited fossil fuel resources, more and more attention is being given on renewable energy sources. A new government study shows that Indian's are using less energy overall and making more use of renewable energy resources. In recent years solar energy has been strongly promoted as a feasible energy source. One of the simplest and most direct applications of this energy is the convergence of solar radiation into heat which is done by the use of a solar panel. Using the sun's energy to heat up water is not a new idea. More than one hundred years ago, black coated water tanks were used as simple solar water heaters in many countries.

Most solar water heating systems consist of two main parts: a solar collector and a storage reservoir. Solar collectors are an important component of solar-heating systems. They collect the sun's energy, transform its radiation into heat, and then transfer that heat to a fluid (usually water or air). Solar water heating systems are in the form of either active or passive, but the most common are active systems. Active systems use pump to move the liquid between the collector and the storage tank, while passive systems rely on gravity and the tendency for water to naturally circulate as it is heated.

II. LITERATURE REVIEW

Abbas Sahi Shareef et al.,(2015) experimentally investigated the effect of Al_2O_3 Nanofluid on a flat plate solar collector as a heat transfer agent, on the efficiency. The Base case has experimented with de-ionized water with a flow rate of 1 pm. In the second case, Al_2O_3nanoparticles are mixed in de-ionized water to get nanofluid of 0.5% volume fraction concentration. The maximum difference between outlet and inlet temperatures of the solar collector was14.4˚C with the solar irradiance of about 788 W/m^2 while in case of water the maximum temperatures difference was 10.7˚C with a solar irradiance of about 781 W/m^2.

Tooraj Yousefi et al.,(2011) experimentally investigated the effect of Al_2O_3–H_2O nanofluid on the efficiency of flat-plate solar collectors. The weight fraction of nanoparticles was 0.2% and 0.4%and the particles dimension was 15 nm. Experiments were performed with and without Triton X-100 as a surfactant. The mass flow rate of nanofluid varied from 1 to 3 Lit/min. The ASHRAE standard was used to calculate efficiency. The results show that, in comparison with water as absorption medium using the nanofluids as working fluid increase the efficiency. For 0.2 wt%, the increased efficiency was 28.3%. From the results, it can be concluded that the surfactant causes an enhancement in heat transfer.

Ali Jabari Moghadam et al.,(2014) experimentally investigated the Effects of CuO/water nanofluid on the efficiency of a flat-plate solar collector. The volume fraction of nanoparticles is set to 0.4% and the mean particle dimension is kept constant at 40 nm. The working fluid mass flow rate is varied from 1 to 3 kg/min. The experiments are conducted in Mashhad, Iran with the latitude of 36.19°. The experimental results reveal that utilizing the nanofluid increases the collector efficiency in comparison to water as an absorbing medium. The nanofluid with the mass flow rate of 1 kg/min increases the collector efficiency of about 21.8%. For any particular working fluid, there is an optimum mass flow rate which maximizes the collector efficiency. Adding nanoparticles to a base fluid produces a nanofluid which has enhanced thermal characteristics compared with its base fluid.

Saleh Salavati et al., (2015) experimentally investigated the thermal efficiency and performance characteristics of a flat plate solar collector using SiO_2/EG-Water nanofluids for mass flow rates between 0.018 and 0.045 kg/s. Nanofluids in three different volume concentrations including 0.5%, 0.75%, and 1% were prepared. The results elucidated that despite the low thermal conductivity of SiO_2 nanoparticles, they make a noticeable enhancement in thermal efficiency when are suspended in EG/Water with an increase in nanofluid concentration from 0 to 1% results in an efficiency enhancement approximately between 4 and 8'5. It was observed that the thermal efficiencies associated with concentrations of 0.75%, and 1% are very close. Hence, it is better to use a lower volume fraction to reduce the preparation cost and instability problems.

III. METHODOLOGY

3.1 Synthesis of Cu_2O nanoparticles

Sol-Gel method involves the evolution of inorganic networks through the formation of a colloidal suspension (sol) and the gelation of the sol to form a network in a liquid phase (gel). In this, the synthesis of Cu_2O is performed by Sol-Gel route because this method is easy and economical. The solution of $CuSO_4$ (0.5M) was prepared in the cleaned bottom flask. The previous solution was added with CTAB of 0.5g & NaOH (2N) and then H_2O_2 of 4 ml was added with the previous solution. The solution was heated in magnetic stirrer till the solution turned down to brown color and a large amount of brown precipitate formed immediately as shown in Fig. 1 and Fig.2. The precipitate was centrifuged and washed 3-4 times with de-ionized water. The obtained precipitate was dried in an oven for 24 hours. The chemical reaction is,

$$CuSO_4 + 2NaOH \xrightarrow{CTAB} Cu(OH)_2 + Na_2SO_4$$

$$Cu(OH)_2 \xrightarrow{\Delta} CuO + H_2O$$

$$2CuO + H_2O_2 \rightarrow Cu_2O + H_2O + O_2$$

3.2 Preparation of nanofluid

The high density (6000kg/m^3) of the Cu_2O nanoparticles compare to the base fluid, water (1000 kg/m^3), causes the immediate settlement of the Cu_2O nanoparticles at the bottom of the beaker. Hence, a compatible amphiphilic surfactant, namely, polyethylene glycol of 10% weight of the amount of nanoparticle to be added, was first dispersed completely in distilled water using in a magnetic stirrer, and then Cu_2O nanoparticles of the required quantity are slowly added with constant stirring for 30 min. The solution is further sonicated using an ultrasonic vibrator for 60 min to break the agglomerated particles and facilitate a homogeneous mixer of the Cu_2O nanoparticles and water, called Cu_2O-water nanofluid as shown in Fig.3 & 4.

Fig. 1.The black color solution after adding NaOH pellets

Fig.2 The dried brown precipitate of Cu_2O

Fig.3 Sample Cu_2O nanofluid

Fig.4 Cu_2O-water nanofluid

3.3 Experimental procedure

The fabricated set is shown in Fig.5. It consists of a storage tank, supply reservoir, Multistem Thermometers, Pump, Flow control valves and a Flat plate collector in which the cold water enters through the inlet side of the collector. The riser tubes in the collector are made up of Copper material to absorb more heat energy from the absorber plate.

After setting the required mass flow rate cold Cu_2O-water nanofluid is allowed to flow through the inlet pipe of the collector. An increase in temperature of Cu_2O-water nanofluid at the outlet of the collector is found due to the heat energy absorbed from the solar radiation. Temperature of Cu_2O-water nanofluid inlet and outlet of the collector is measured by using K-type thermocouples. The measured temperatures are stored in the computer at regular intervals of time. The time interval at which the temperature values to be recorded in the computer is given by the user at the beginning of the experiment.

Fig.5 The fabricated set

IV.DATA REDUCTION

The rate of useful energy gained by water is given by

$$Q = mC_p\,(T_{out} - T_{in})$$

where,

Q - Rate of useful energy gained by working fluid (kW)
m - mass flow rate of working fluid (kg/s)
C_p - Heat capacity of working fluid (kJ/kgK)
T_{out} - Outlet Temperature of Solar Collector (^{0}C)
T_{in} - Inlet Temperature of Solar Collector (^{0}C)

Thermal Efficiency of the collector is given by

$$\eta = Q/A_c * G_T$$

where,

A_c – Surface area of collector (m^2)
G_T – Global solar radiation (W/m^2)

V.RESULTS AND DISCUSSION

5.1 Nano-characterization tests

This A large number of techniques are available to measure the properties of nanoparticles, but different techniques measure different properties of the nanoparticle, and hence, the results are not identical. Since the nanoparticles used in this study were synthesized; a few characterization tests were conducted to understand the properties of the prepared nanoparticle and nanofluid.

5.1.1 Scanning Electron Microscopy (SEM) method

The morphology of Cu_2O nanoparticle was studied by passing a fine beam of high energy electrons on the surface of the sample. The image formed, as shown in Fig.4.4, due to the scattered electron beam and sampled interaction, shows that the synthesized nanoparticles are tubular in shape.

5.1.2 Energy Dispersive X-ray Spectroscopy (EDX) method

The EDX method is used to characterize the elemental composition of the sample, by analyzing the emitted X-rays from the sample after being bombarded by the SEM electron beam. From Fig.4.5, it was observed that the peaks obtained correspond to the copper and oxygen elements. No other peaks where formed suggesting the absence of any impurity.

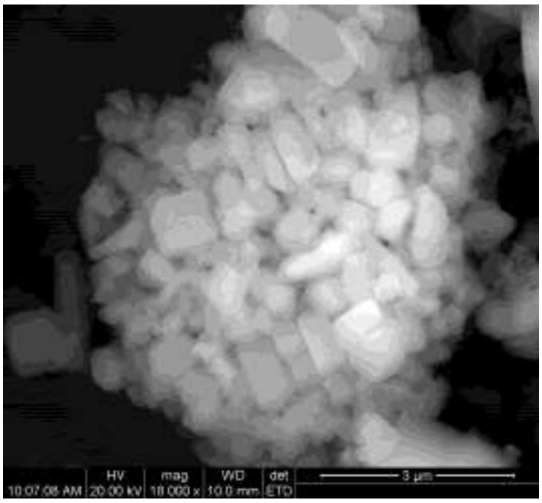


Fig.6 SEM photograph of Cu_2O nano particles

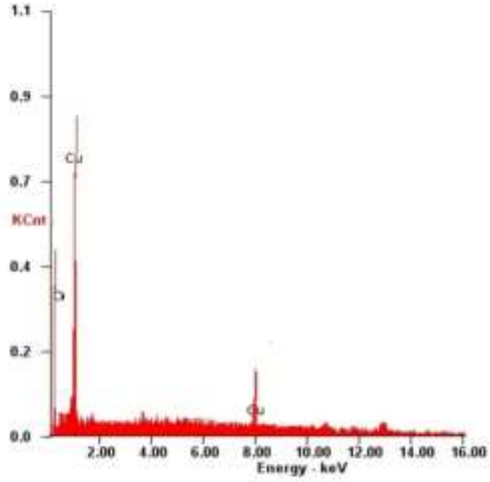
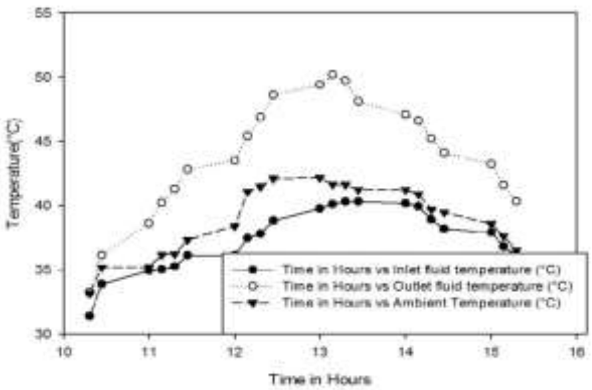


Fig.7 EDX photograph of Cu_2O nano particles

5.2 Results

The efficiency of Flat plate solar collector was determined at different mass flow rates (0.011, 0.0139and 0.0167 kg/s) around 10.30 am to 3 pm. Each experiment had conducted for several days and best experimental data which had minimum errors have been selected and presented. It was found that the increase in mass flow rate affects the efficiency of Flat plate solar collector.

1) For mass flow rate, m= 0.011 kg/s ,



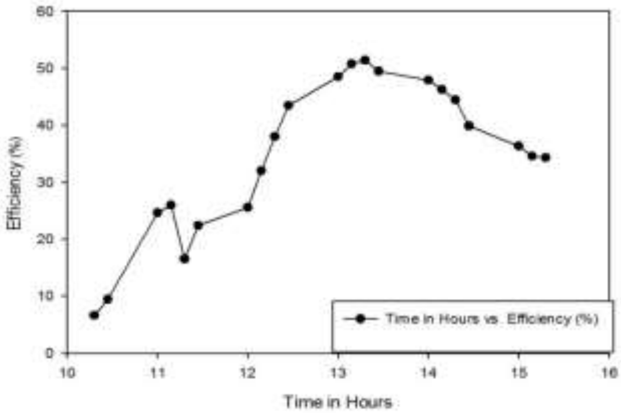


Fig.8 Time (Hours) Vs Temperature (^{0}C) Fig.9 Time (Hours) Vs Efficiency (%)

2) For mass flow rate, m = 0.0167 kg/s,

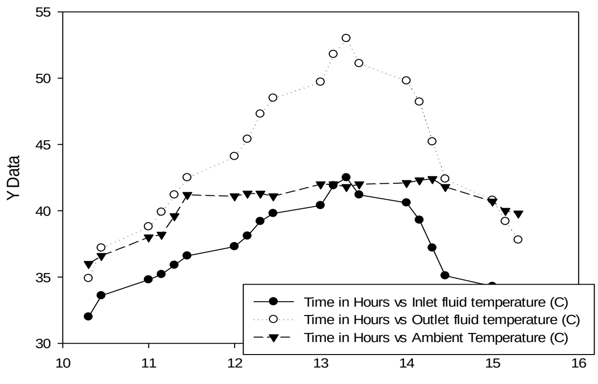


Fig.10 Time (Hours) Vs Temperature (^{0}C)

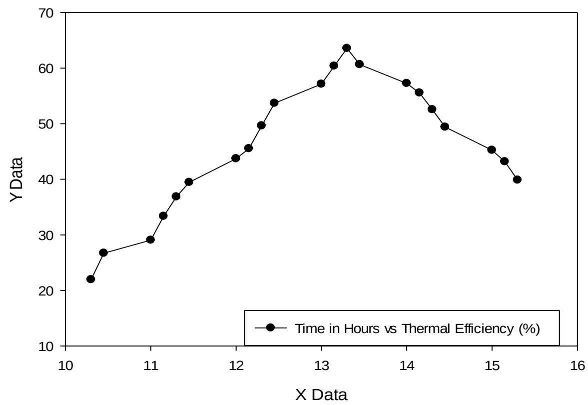


Fig.11 Time (Hours) Vs Efficiency (%)

3) Comparison of efficiencies for various mass flow rates

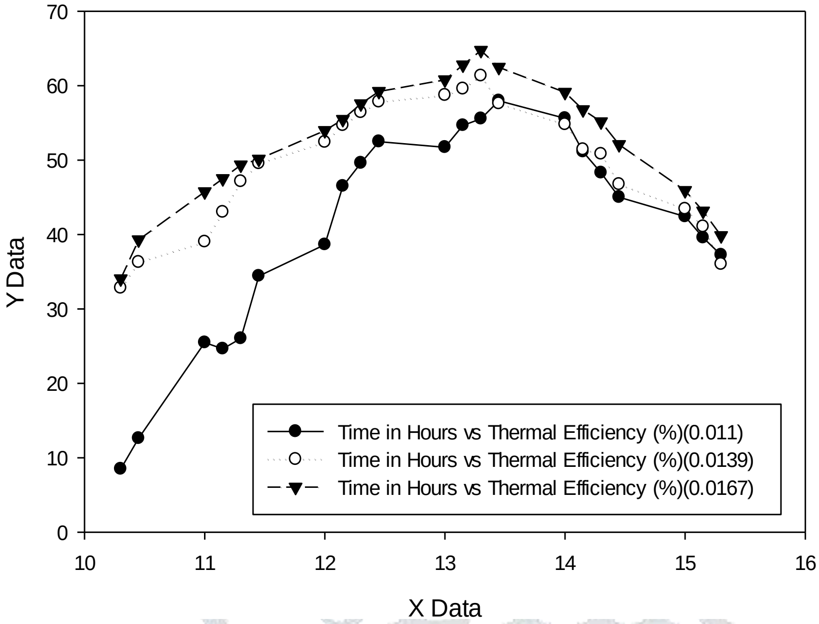


Fig.12 Comparison of efficiencies for various mass flow rates

5.3 Discussions

The graphs provide the various data's for corresponding times. Time versus Inlet, outlet and Ambient temperatures of the collector for different mass flow rates was shown in the Fig 8 and 10 respectively. Time versus efficiency of Flat plate solar collector for different mass flow rates were shown in Fig 9 and 11 respectively. Maximum efficiency of Flat plate solar collector obtained during the mass flow rates of 0.011, 0.0139 and 0.0167 kg/s was 57.99 %, 61.35 % and 64.77 % respectively.

Solar radiation was high around 12.30 to 13.30 after that the radiation decreases gradually. During the period of high solar radiation the heat energy obtained by the working fluid in Flat plate solar collector was very high. Consequently, the efficiency of the collector was also high during this period. It is found that the efficiency of Flat plate solar collector is directly dependent on the mass flow rate of the tubular Cu_2O-Water nanofluid fluid. If the mass flow rate increases, the efficiency of the collector also increases but the temperature difference between the inlet fluid and outlet fluid decreases. Hence the mass flow rate plays a vital role in the efficiency of the Flat plate solar collector. The identified optimum mass flow rate is 0.0167 kg/s.

VI. CONCLUSION

Thermal performance of Flat plate solar collector was experimentally analyzed by varying mass flow rates of tubular Cu_2O-Water nanofluid. The experimental set up was fabricated successfully. It was concluded that the efficiency of Flat plate solar collector depends on solar radiation, tubular Cu_2O-Water nanofluid and mass flow rate of absorbing fluid.

The temperature difference between inlet and outlet of absorbing fluid decreases with an increase in mass flow rate, in the range between 0.0111 kg/s to 0.0167 kg/s. Results showed that the efficiency of Flat plate solar collector increases with an increase in mass flow rates. Further increase in efficiency is possible if the effectiveness of the heat exchanger inside the thermal storage tank is designed for nanofluid operation.

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