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Experimental Investigation of Direct Absorption Solar Collector UsingCuO-H_2O Nanofluid for Laminarand Turbulent Flow

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Abstract: An increasing demands of energy has made it necessary to harvest the energy in proper way and achieve more efficiency For this it is important to have best type of solar collector that can harvest maximum energy .To construct such collector it is very important to have such working fluids on which the collector works which have better thermo physical properties then other conventional fluids. The various thermo physical on which collector efficiency depends are thermal conductivity, specific heat, density, viscosity etc. The special new class fluids used here are known as nanofluids which have better properties as mentioned above compared to conventional fluids .In present work a direct absorption solar collector are used where film is formed over the plate and efficiency for laminar and turbulent flow have been measured.The glass plate on which film of nanofluids(CUO-H_2O) are formed for heating purpose .The idea is taken from previous studies in which we are using single plate[11] but no study is done on laminar and turbulent flow is done .The efficiency of collector is calculated using different mass flow rate as 3000ml/hr,6000ml/hr and 8000ml/hr for laminar and turbulent flow. It has been found that an efficiency of 2-3 % is increased when using nanofluid in case of turbulent flow as compared laminar flow .Comparison of collector efficiency different mass flow rate and concentration is done.ASHRAE standard has been followed while performing the experiment.

Keywords: Nanofluids, efficiency, volume concentration, flow rate etc.

I. INTRODUCTION

In recent years a lot of development has been done in field of solar energy but a very few studies has been done on working fluid as nanofluid and maximum use of solar radiation by proper harvesting and increase overall efficiency of solar collectors. Several developments and examinations were carried out in the area of solar energy. Everyday sun radiates enormous amount of energy and the hourly solar flux incident on the earth's surface is greater than all of human consumption of energy in a year [1]. So, problem lies in efficiently collecting and converting this energy into some useful form. Today most commonly used collector used are flat plat collector. The new class collectors developed here are direct absorption solar collector using single glazing. In order to achieve a high efficiency it is very important for proper film formation over plate and it is effected flow nature of fluid over plate which can convert maximum amount of solar energy into useful form .Therefore a setup of single plate direct absorption solar collectors has been Fabricated to achieve more efficiency. In the set up single glass are used on which film formation [9,10] takes place as shown in fabricated setup.The glass are placed in a such way that the volumetric absorption [9] takes place on plate. A header pipe is being used here for the plate and holes having 2.5 mm pitch in 120 no's[10,11] are drilled header pipe for turbulent film formation on plate .Again another header pipe is replaced by the pipe in overlapped holes are made for continuous film formation in form of laminar flow.Nanofluids are new class of fluids in which nanometer sized (1-100 nm) particles of metal/ nonmetals/ metal oxides etc. are dispersed in conventional fluids.

Hemant k gupta et al presented a prototype of direct absorption solar collector having gross area 1.4 m2 working on volumetric absorption principle is developed to investigate the effect of using Al_2O_3–H_2O nanofluid as heat transfer fluid at different flow rates. Experimentation was carried using distilled water and 0.005% volume fractions of 20 nm size Al_2O_3 nanoparticles at three flow rates of 1.5, 2 and 2.5 lpm[11].

Hemant .k guptaet. alpresented the effect of alumina water nanofluid, as heat transfer fluid, flowing as a thin film, on the efficiency of a direct absorption flat-plate solar collector was investigated experimentally. The volume fraction of alumina nanoparticles was 0.001%, 0.005%, 0.01% and 0.02% and the particles dimension was 20 nm.

Wang.X.Q.*et al.* presented a study of fluid flow and heat transfer properties of nanofluids in forced and free convection systems are done. The convective heat transfer can be enhanced by changing flow geometry, boundary conditions or by enhancing thermal conductivity of the fluid. They have measured the relative viscosity for Al_2O_3-H_2O and Al_2O_3-ethylene glycol nanofluids.
Timofeeva V E et al. presented an overview of systematic studies that address the complexity of nanofluid system and advance the understanding of nanoscale contributions to viscosity, thermal conductivity and cooling efficiency of nanofluids is presented.
Yousefi T et al.presented an efficiency variation of flat plate solar collector for Al_2O_3-H_2O based nanofluids is presented for various mass flow rates and also the effect of addition of surfactants on the efficiency of collectors is studied. The volume 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 surfactant. The mass flow rate of nanofluid varied from 1 to 3 Lit/min.
Tyagi H et al. presented paper that theoretically investigates the feasibility of using a flat plate collector with nanofluids and compares it's performance with that of a conventional flat plate collector. Here nanofluid a mixture of water and aluminium nanoparticles is used as the absorbing medium.

II. EXPERIMENTAL SECTION

The schematic of the experiment is shown in Fig.1. The solar collector was experimentally investigated at m.bm engineering college Jodhpur, India having latitude-26.2713 and longitude-73.0669. The flow rate of the nanofluids is controlled through the ball valve and with help of rota meter. Collector size so used in order to reduce the quantity of nanofluids used[10]-[11]. Nanofluids were stored in a bottle which was capable to supply desired mass flow rate of nanofluid. The inlet and outlet temperatures were measured with the help of digital thermometer [11]. Pyranometer (Kipp and zonen) [9] was used for calculating the global solar irradiation values .Various results in the graphical form were plotted between collector efficiency vs mass flow rate, in case of laminar and turbulent flow

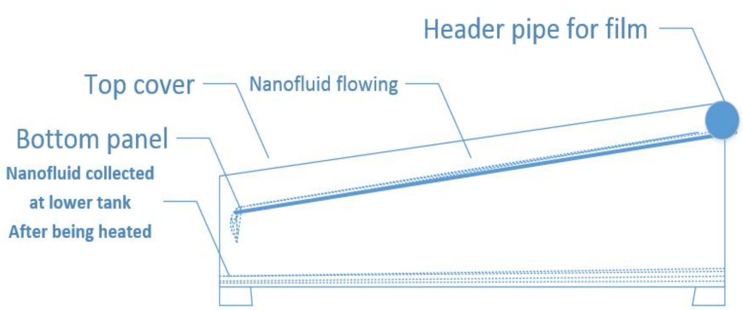

Figure. 1 (3D Model of the experimental set-up)

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A. Film formation arrangement for laminar and turbulent flow.

1) Header pipe for laminar flow- holes having 2.5 mm pitch in 120 no's[10,11] are drilled header pipe for turbulent film formation on plate .
2) Header pipe for turbulent flow- Again another header pipe is having an overlapped holes and are made for continuous film formation in form of laminar flow

B. Testing for solar collector

While performing the experiment the ASHRAE standard were adopted and the performance of solar collector was observed by calculating instantaneous efficiency of solar collector for both laminar and turbulent flow for different mass flow rate .Various mathematical relations were used for determination of efficiency of collector which are as follows .

1) Collector efficiency [6] $\eta = m\, C_{eff}\, (T2 - T1) / G_T A$ ---(1)
2) Mass flow rate [7] $m = \rho_{eff} \times A \times v$ -- (2)
3) Effective density of nanofluid $\rho eff = (1 - \varphi_p)\, \rho_f + \varphi_p \rho_p$ ------------------------------------ (3)
4) Volume fraction $\varphi_p = Vp / (Vp + V_f)$ -- (4)
5) Specific heat [7]$C_{eff} = \{(1 - \varphi_p)\, \rho_f c_f + \varphi_p \rho_p c_p\} / \rho_{eff}$ -------------------------------------(5)

Where η = Instantaneous efficiency (%)
m= Mass flow rate of the working fluid (ml/hr).
C_{eff}= Effective specific heat of the nanofluids (kJ/kg°c).
T2= Outlet Temperature of the working fluid (°c).
T1= Inlet Temperature of the working fluid (°c).
G_T = Global solar irradiation A=Area of the absorber plate (m^2)
ρ_{eff} = Density of the nanofluids(kg/m^3)
φ_p= Volume fraction of nanoparticle
ρ_p= Density of nanoparticles
V_P= Volume of the nanoparticles
V_f= Volume of the base fluid

C. Calibration (Rotameter, temperature sensors)

A measuring beaker and a stop watch was used to calibrate the Rotameter. Flow rate was fixed at different rates on the measuring scale and simultaneously the time was recorded with the help of stopwatch to fill the specified volume of the beaker. Reading were taken in time taken to fill 1000 ml fluid in the beaker and then converted into ml/min. flow rate was fixed at four different values on the measuring scale i.e. 3 LPH, 6 LPH, 8 LPH, and corresponding flow rate with the help of stopwatch was recorded. Similarly calibration of temperature sensors was done with the help of thermometers. Deviation found ±1°C to 1.5°C.

D. Testing method

Thermal performance of solar collectors is commonly evaluated using ASHRAE Standard 93-77. Collector thermal performance is calculated by determining collector instantaneous efficiency for different incident solar radiations, ambient temperatures, and inlet fluid temperatures. Intensity of incident solar radiations as well as useful heat gain by the working fluid is measured under steady state conditions.

E. Time attempt

As per ASHRAE Standard 93-77 [6] steady-state conditions should be maintained during the data period and also during a specified time interval prior to the data period, called the pre-data period. For attaining steady state conditions the mass flow rate must be within ±1%, irradiation must be within ±50 W/m^2[6], the outdoor ambient temperature must not vary more than ±1.5 K, and the inlet temperature must be within ±0.1 K for the entire test period[6].

F. Experimental Errors

As per ASME guidelines[6], absolute measurements do not exist and errors arise from many sources. Some of the common sources of error are: Calibration errors, data acquisition errors and data reduction errors. The major components to uncertainty in collector efficiency are the inaccuracy in flow rate measurement, temperature measurement and solar radiation intensity measurement.

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G. *Instruments*

Various instruments needed for the experiment as follows

1) Pyranometer (Kipp &jonen)
2) Digital Temperature indicator
3) Ball valve for control of flow rate
4) Rotameter
5) Heat exchanger

H. *Materials and chemicals*

1. *Anofluid preparation-Preparation of Nanofluids*

Purchased Sample of Nanoparticles: (General catalog no-RN-PL-A-ALP-10g)
CUO Nanoparticles were purchased from Reinste Nanoventures Pvt. Ltd. Ghaziabad.
Specifications of Nanoparticles:
Particle shape: Spherical
Average Particle Size: 40 nm
Particle size full Range: 5-150nm
Specific Surface :> $10m^2/g$
Purity :> 99.8%

To prepare the CUO nanofluid, there is a need to determine the weight of CUO for different concentration. The weight of CUOcan be evaluated by using the standard expression.

$X_{20} = V_P / V_{eff}$
Where, $V_P = W_P / \rho_P$
$V_{eff} = V_P + V_f$, $V_f = W_f / \rho_f$
Quantity of Base fluid (Water), V_f = 3000ml
Density of CUO particles, $\rho_P = 3.9\ gm/cm^3$
Density of water, $\rho_f = 1000\ kg/m^3$

The quantity of CUO nanoparticles required for preparation of nanofluid of different volume concentrations is calculated using formula in Eq. (1). A sensitive balance (make-citizen, model-CTG 602 resolution-0.1 mg) is used to weigh the CUO nanoparticles very accurately.

After calculating the desired weight of the nanoparticles for a particular volume fraction the required amount of distilled water is poured into it. After pouring distilled water to it then sonication of the fluid takes place for 6 hours with the help of Oscar ultra sonicator (probe type) to prevent settling of nanofluid for 3 to 4 hours. After sonication the uniformly dispersed nanofluids are ready to flow. The sonicator used for the sonication of the nanofluids is ultra sonicator which was probe type.

III. RESULTS AND DISCUSSION

A. *Effect of varying mass flow rate on working fluids in case laminar and turbulent flow.*

First of all the graphs are plotted with water for turbulent flow, then using Nanofluids for turbulent flow and for different flow rates of Nanofluids.

The instantaneous efficiency of the solar collector can be calculated by using given formulas

According to ASHRAE Standards:

1) Inlet temperature of the working fluid is assumed to be constant for all the experiments i.e. 26^0C.
2) The Experiments are performed in the solar noon i.e. from 10 am to 3 pm.

At low flow rates, the time delay between the entry and exit of working fluid into and out of the collector, i.e. the fluid residence time, is high, allowing for the fluid temperature to rise more. Since heat loss to the ambient including convective and radiative loss increased by temperature (especially, radiation heat loss from the fluid scales with the fourth power of temperature), the fluid suffered higher losses at lower flow rates, which resulted in smaller collector efficiencies. At higher flow rates, the temperature rise in the fluid is small. This resulted in a progressively weaker effect of heat losses described above, and hence, collector efficiencies were seen to be larger at higher flow rates.

It has been found that for turbulent flow the absorption of heat is less due in non uniform distribution of fluid over the plate and for laminar flow the distribution is uniform therefore the heat absorption is better for different mass flow rate in case of water and nanofluids.

It is observed in fig clearly that as the mass flow rate increases efficiency increases, this may be due to the higher value of the mass flow rate and minimum efficiency is reported between 12:00 pm and 1:00 pm because at that time the value of global solar irradiation is maximum.

It is clearly observed in fig that the temperature difference is increasing with low mass flow rates before 1 pm .After 1 pm temperature difference is almost same,this may be due to the reason that at higher mass flow rate increase in heat gain is more compared to heat gain due to low mass flow rate.

From Fig (1) ,& (2) it is observed that at higher mass flow rates the efficiency is higher than low mass flow rates, this may be due to the higher value of mass flow rate. The value of temperature difference is also almost constant between 10 pm to 12 pm and is maximum at 1:00 pm.

B. Effect of laminar andturbulent flow on efficiency of working fluids.

From fig this can be observed that the efficiency of the collector for different mass rate (3L/HR,6L/HR and 8L/HR) is higher for turbulent flow due to uniform film formation and due to this better absorption takes place and temperature difference is higher and for turbulent flow due to non uniform film formation and uneven flow over plate leads an decrease in temperature difference and Since heat loss to the ambient including convective and radiative loss increased by temperature (especially, radiation heat loss from the fluid scales with the fourth power of temperature), the fluid suffered higher losses at lower flow rates, which resulted in smaller collector efficiencies. At higher flow rates, the temperature rise in the fluid is small. This resulted in a progressively weaker effect of heat losses described above, and hence, collector efficiencies were seen to be larger

In case of higher Flow rate and therefore the efficiency is higher in case of turbulent flow in compared to laminar flow.

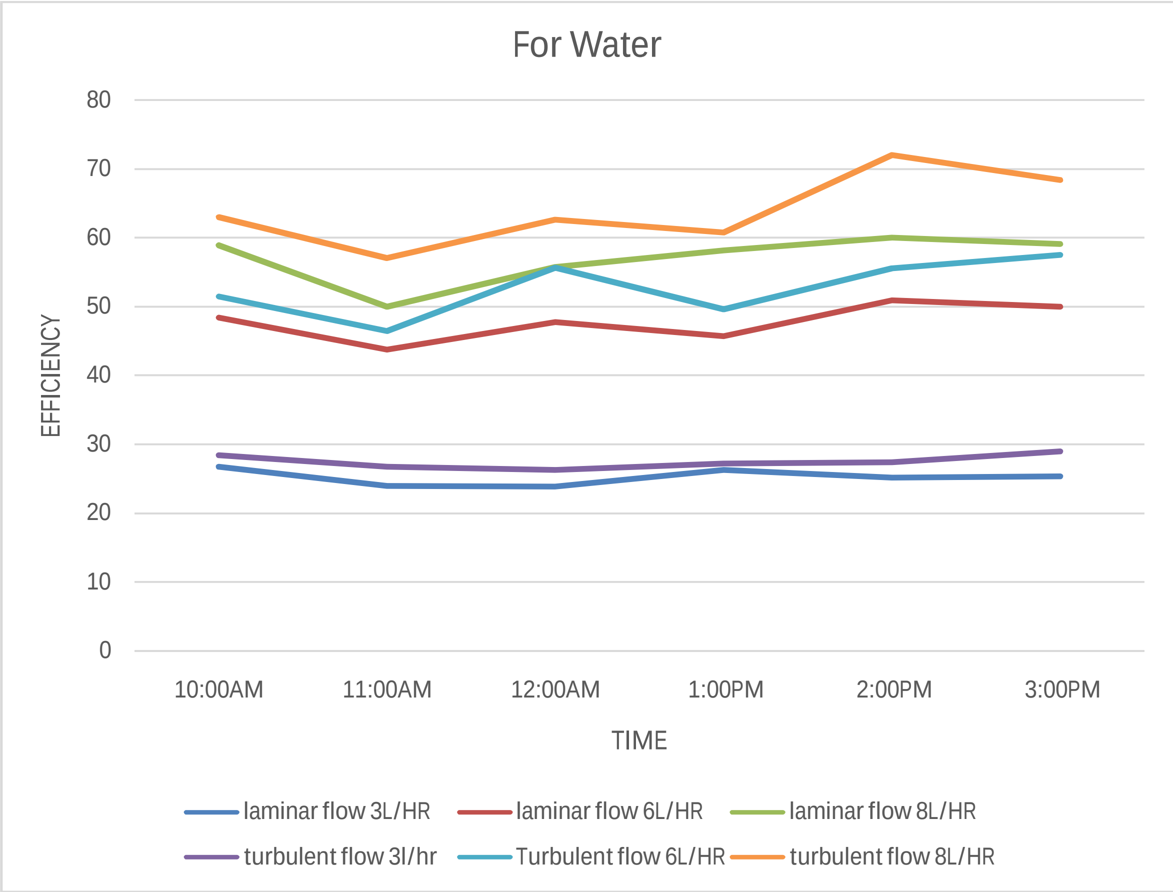

Figure 2: variation in collector efficiency for laminar flow and turbulent flow w.r.t time at different mass flow rates for water

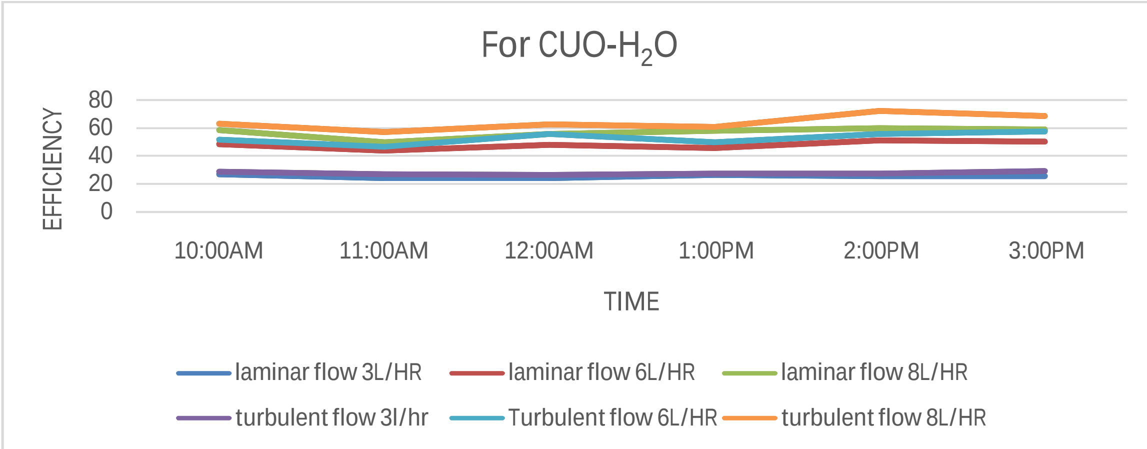

Figure3: variation in collector efficiency for laminar flow and turbulent flow w.r.t time at different mass flow rates for CUO-H_2O

IV. CONCLUSIONS

From the results obtained by performing the experiments, this can be concluded that -

1. The efficiency of the collector increases upto 2-3% in case of turbulent flow as compared to laminar flow because in case of laminar flow the temperature difference is more and due to this more losses is there as compared to turbulent flow.
2. For higher mass flow rate efficiency is more as compared to lower mass rate both in case of laminar and turbulent flow because of higher temperature difference in case of lower mass flow rate and more convective and radiative losses is there .
3. The overall size of set up is reduced with help of proper film formation over plate.
4. At higher mass flow rate the temperature difference decreases but efficiency increases.
5. The efficiency is found minimum near 12 to 1 pm. This is due to the higher value of global solar irradiance.
7. Higher efficiency can be obtained in case of Nanofluids if the settling of the nanoparticles in the fluid is prevented.

V. ACKNOWLEDGEMENTS

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