Effect of Volume Concentration on Direct Absorption Solar Collector in Laminar and Turbulent Flow Using CuO-H2O Nanofluids

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Abstract – It is very important to have solar collector which can have maximum efficiency with minimum radiative and convection losses. The various thermo physical properties 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 which are using a glass plate on which film of nanofluids(CUO-H_2O) is formed .The idea is taken from previous studies in which we are using single plate[11] .The volume concentration used here are.010%, .006% and .003%.The efficiency of collector is calculated using fixed mass flow rate as 3000ml/hr glass plate collectors. It has been found that an efficiency of 2-3% is increased when using nanofluid in case of higher flow rate due to less radiative and convective losses compared to lower flow rate and 3% efficiency is improved in case of turbulent flow as compared to laminar flow because in case of laminar flow temperature difference is more and radiative and convective losses are higher compared to turbulent flow. Comparison of collector efficiency different volume concentration is done.ASHRAE standard has been followed while performing the experiment.

Keywords-nanofluids, laminar flow, turbulent flow, efficiency, volume concentration, flow rate etc.

I INTRODUCTION

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 improvement and examinations were carried out in the area of this field. 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].therefore hurdles are there in proper collection of solar energy and still a a lot study has to be done 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 volume concentration 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 where different volume concentration are being used. 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 with 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. Following literature study is done in this field.

Hemant k gupta et al presented a prototype of direct absorption solar collector having gross area 1.4 m^2 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[10].

Hemant .k gupta et. al presented 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.

2 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]. 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 [10]. 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 concentration, temperature difference vs time and efficiency vs time for both laminar and turbulent flow for direct absorption solar collector

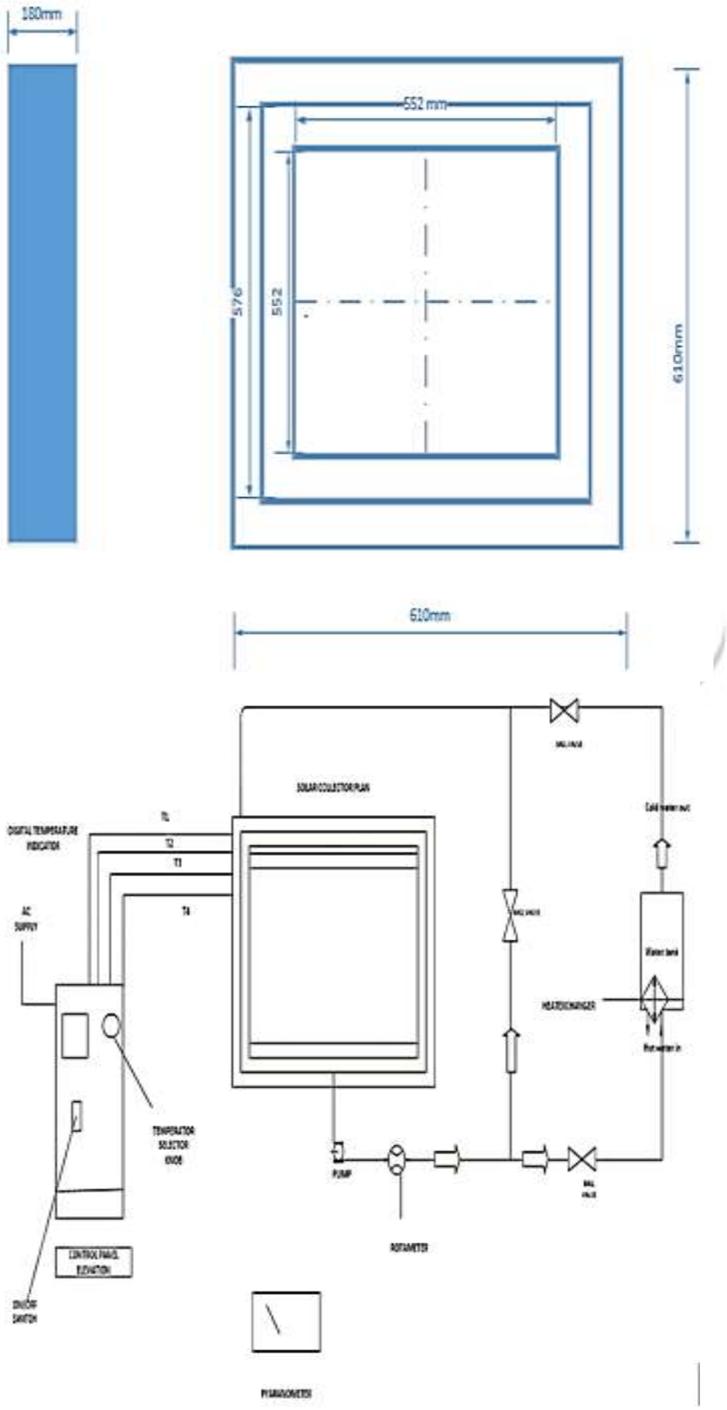

Figure 1. Experimental setup layout of direct absorption solar collector with arrangement of header pipes for laminar and turbulent flow

2.1 Testing for solar collector

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

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

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

2.2. Calibration (Temperature sensors)

Calibration of temperature sensors were done with the help of thermometers. Deviation found ±1°C to 1.5°C.

2.3. 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.

2.4. 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].

2.5. 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.

2.6 .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

2.7. Materials and chemicals

2.7.1. Nanofluid preparation-Preparation of Nanofluids

Purchased Sample of Nanoparticles: (General catalog no-RN-PL-A-ALP-10g)
Al_2O_3 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 CUO can 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 Al_2O_3 particles, ρ_P = 3.9 gm/cm^3

Density of water, ρ_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.

3 .RESULTS AND DISCUSSION

3.1. Effect of varying volume concentration on working fluids in case of laminar and turbulent flow.

First of all the graphs are plotted for turbulent flow using Nanofluids for turbulent flow and for different volume concentration 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^{0}C.
2. The Experiments are performed in the solar noon i.e. from 10 am to 3 pm.
From plots (Figure 2) it can be concluded that efficiency of the collector using nanofluid is higher for higher volume concentration and decreases as efficiency falls because more the nanoparticles more the surface area to volume ratio and more the Brownian motions .but higher concentration upto certain limits increases efficiency and after the due to settling problem the efficiency decreases. The efficiency is low at 12:00 PM this is because of the higher value global solar irradiation. Figure (2) and Figure (3) shows that there is increase and decrease of the efficiency, this is due to the windy conditions prevailing that day. From fig 1 and fig 2 it can be evaluated that for turbulent flow the efficiency is greater as compared to laminar flow for all three concentration due to more convective and radiative losses in laminar flow due to higher temperature difference and as we know that radiation losses are fourth power to temperature so for higher temperature difference efficiency are low i.e. in laminar flow.

3.2. Effect on efficiency of working fluids in case of laminar and turbulent flow at different concentration of nanofluids.

From figure (2), this can be observed that the efficiency of the collector for volume concentration (.003 , .006 and .010) in case of employing a turbulent flow is greater compared to laminar because in case of turbulent flow the temperature difference is low therefore losses are low as compared to laminar flow because in laminar flow due to uniform film formation more temperature rise takes place and therefore radiative and convective losses are fourth power to temperature by radiation laws. There is increase and decrease of the efficiency, this is due to the windy conditions prevailing that day.

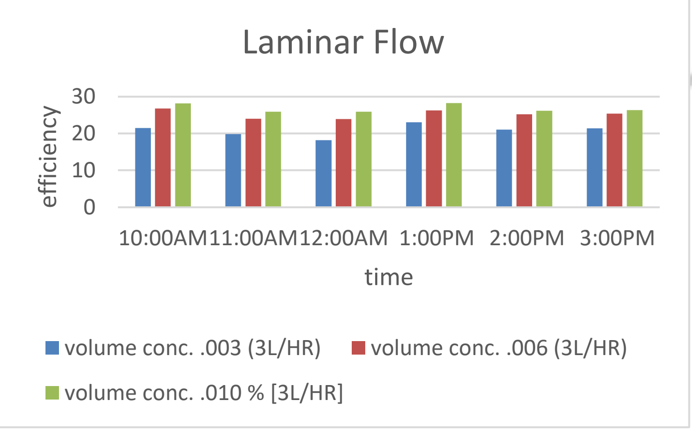

Figure 2: variation in collector efficiency due to variation of volume concentration in case of laminar flow for flow rate of 3L/hr

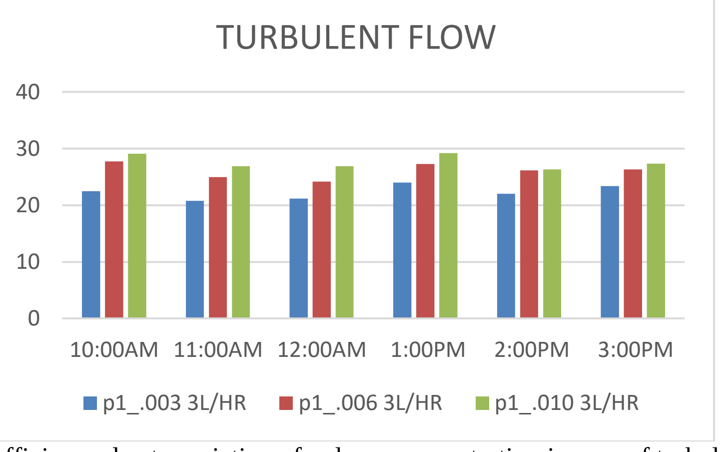

Figure 3: variation in collector efficiency due to variation of volume concentration in case of turbulent flow for flow rate of 3L/hr

4. CONCLUSIONS

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

1. The efficiency of the collector increases upto 2-3% on an average for higher volume concentration.
2. Efficiency of Direct Absorption Solar Collector is greater upto 3% on an average for turbulent flow for all volume concentration.
3. The overall size of set up is reduced due to increase in efficiency in case of previous studies [10]-[11]
4. The efficiency is found minimum near 12 to 1 pm. This is due to the higher value of global solar irradiance.
6. When we compare three volumetric concentrations of Nanofluids for same mass flow rate it is found that at higher volumetric concentration have higher efficiency due to increase in surface area. Hence, efficiency at higher volumetric concentration is slightly higher.
7. Higher efficiency can be obtained in case of Nanofluids if the settling of the nanoparticles in the fluid is prevented.

ACKNOWLEDGEMENTS

The authors thankfully acknowledge the support received from the Mechanical Engineering Department, M.B.M Govt. Engineering College Jodhpur in order to carry out the present research.

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