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Performance Analysis of Flat Plate Collector (SFPC) by Using [AL2O3 & CuO] Nano Fluids

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Abstract— *The growth in population of a world and the demand for energy is increased very fast. To meet the demand, proper way of thermal energy utilization from sun is a solution. Utilization of Nano fluids in solar flat plate collectors will plays major role enhancement of thermal efficiency of Solar Flat Plate Collector. Nano fluids are colloidal mixture of nano meter sized metallic(or)ceramic particles in a conventional fluid (or) base fluid such as water ,ethylene glycol, oil etc…. thermal conductivity of working fluid plays an important role in the thermal efficiency of solar flat plate collector. Experimental testing method was selected based on EUROPEAN STANDARD EN 12975-2 as a quasi-dynamic test method (QDT). The main intention of this work is to analyze the thermal efficiency of a solar flat plate collector by means of (AL_2O_3 & CuO) Nano fluid as the media for transfer of heat. In this work, solar flat plate collector is used for studying the effect of different nano particle concentrations of AL_2O_3 & CuO in distilled water as base fluid. Three flow rates (i.e. 2ml/s, 4ml/s, 6ml/s) and two particle concentration ratios (i.e. 0.06, 0.08%wt) were investigated.*

Keywords— solar flat plate collector (SFPC), thermal efficiency, AL_2O_3 & CuO/H_2O nano fluid , thermal conductivity, flow rates, particle concentrations.

I. INTRODUCTION

The sun is credited with being a free, abundant and inexhaustible source of energy which has a beneficial of low environmental pollution. Solar energy widely availed, and carbon free, But more energy from the sun strikes the earth every hour than is consumed on the planet in a year. Solar energy like wind ,is an alternative option from among the renewable sources as post initial investment in equipment, it has low maintenance and close tozero variable costs[1]. Compared to conventional and other renewable energy sources, solar thermal energy is essentially attractive because it can be easily scaled up (or) down. Solar energy can also be collected near to demand for energy utilization. Solar energy coming from the sun in the form of electromagnetic radiation is not constant throughout the year. It's day light is changing with respect to seasons is more in summer than winter. Solar thermal system performance depends upon the solar radiation coming from the sun. solar collectors are used to absorb the solar energy and transferred it to a fluid in contact with it. So there is need to absorb more energy from the sun and convert into thermal energy [2]. Solar collectors are classified as: Non concentrating (or) flat plate collectors and concentrating collectors. Flat plate collectors are simple in their construction and are used for low temperature applications (< 100^0C) such as house hold equipments as water heater and solar cooker and air heater etc.. Concentrating collectors are more efficient than the non concentrating collectors. But they require special tracking which costly, so it has high installation costs. The performance of the Solar Flat Plate Collector (SFPC) depends upon the physical and thermal properties of the base fluid flowing through it. Conventional fluids which are used in solar collectors are suffer from poor thermal properties. Performance of solar collector could be improved by several methods, for example, use of high voltage electric fields [3]and sound waves [4] etc.. Another method used to improve the performance of SFPC is by using high thermal conductivity working fluid to get more heat from the collector and then by heat loss rate could be reduced. This high thermal conductivity could be achieved by dispersion of nanometer sized particles into conventional fluids like water and ethyl glycol etc. these fluids are called nano fluids, which is coined by chio[5]. As we go towards the nano meter, it has been found that properties of the postponement get changed drastically. In this work, the attempt has been made to investigate the variation in the thermal efficiency by means using nano fluid in base fluid with different concentration ratios of (AL_2O_3 & CuO) nano fluids

II. EXPERIMENTAL ANALYSIS

In present investigation SFPC, pump and nano fluids ere used. AL_2O_3 & CuO nano particles were purchased from SIGMA – ALDRICH chemicals Pvt.Ltd, Bangalore.

Table 1 Specifications of AL_2O_3 nanoparticles

SI.	ITEM	DESCRIPTION
1	Product Name	Aluminum oxide, (Al_2O_3)
2	Particle shape	spherical
3	Average particle	<50 nm (TEM)
4	Specific surface	> 10m^2/g
5	Purity	> 99.8%
6	Appearance (Color)	White
7	Appearance (Form)	Powder

Distilled water was used as the base fluid throughout the preparation of the nanofluids.

Table 2 Specifications of CuO nanoparticles

SI. No	ITEM	DESCRIPTION
1	Product Name	Copperoxide, (CuO)
2	Particle shape	spherical
3	Average particle size	<50 nm (TEM)
4	Specific surface	> 10m^2/g
5	Purity	> 99.8%
6	Appearance (Color)	BLACK
7	Appearance (Form)	Powder

Distilled water was used as the base fluid during the preparation of the nanofluids.

S.No.	Volume Concentration, φ (%)	Weight of nanoparticles, (W_p) Grams
1	0.06	9.475
2	0.08	12.9

Table:3 Specifications of SFPC

SI. No	*ITEM*	*DESCRIPTION*
1	*Area of absorber plate*	*0.9576 ≈ 1m^2*
2	*Absorber Type*	*Tube and Sheet type*
3	*Thickness of Glass cover*	*4 mm*
4	*No. of Copper tubes*	*03*
5	*external Diameter of*	*Ø10 mm*
6	*inside Diameter of Copper tube*	*Ø09 mm*
7	*Bottom & Top Copper header*	*Ø25 mm*
8	*Insulation type*	*Mineral wool*
9	*Insulation thickness*	*50mm*
10	*Tilt Angle*	*15^o*

Estimation of nanoparticle volume concentration:
The amount of Al_2O_3 nanoparticles required for preparation of nanofluids is calculated using the law of mixture formula. A sensitive balance with a 0.1mg resolution [Fig.5] is used to weigh the Al_2O_3 nanoparticles [Fig.6] very accurately. The weight of the nanoparticles required for preparation of 2500 ml Al_2O_3 nanofluid of a particular volume concentration, using distilled water as base fluid is calculated by using the following relation

% volume concentration, $$\varphi = \frac{[W_p / \rho_p]}{[W_p / \rho_p] + [W_f / \rho_f]}$$

Where

W_p : Weight of Nano Particles, Grams

W_f : Weight of base fluid (water), Grams

ρ_p : Density of Al_2O_3 Nano Particles=3.9 gm/cm^3 (3900 kg/m^3)

ρ_f : Density of basefluid (water) = 995 kg/m^3

Volume concentrations of Al_2O_3 nanoparticle with corresponding weight

Volume concentrations of CuO nanoparticles with corresponding weight

III. EXPERIMENTAL PROCEDURE

The solar collector was experimentally investigated at G. Pulla Reddy Engineering College, Kurnool, Andhra Pradesh, India. Coordinates of the selected location are Latitude: 15° 50' N Longitude: 78° 05' E. According to the NREL (National Renewable Energy Laboratory), using a tilt angle of SFPC approximately equal to a site's latitude maximum yearly solar radiation can be achieved. For optimum performance of SFPC in winter, the collector shall be tilted 15° greater than the latitude and for best performance of SFPC in summer; the tilt shall be 15° less than the latitude. The most logical tilt angle for

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the fixed flat plate solar collector is to tilt the surface from horizontal by an angle equal to the latitude angle. So the selected SFPC tilt angle is 15°. Al_2O_3 & CuO nano particles of mean size, <50 nm and surface area were dispersed in distilled water as base fluid in different concentrations i.e. 0.06, 0.08. Surface tension exists between nano particles results in aggregation and deposits. The stability of the nano fluid is increased by using surfactants which creates air bubbles (foam) in it, results drop in collector efficiency. So it is better to use nano fluids without surfactants. The flow velocity of the nanofluid is restricted through the Rota meter. Small collector size (≈1 m^2) is used in order to decrease the quantity of nanofluid used. The ambient, inlet and outlet temperatures were calculated with the help of thermometer. The nanofluid was circulated by means of a pump Initially, the nano powder was added to distilled water and agitated by magnetic stirrer (Fig.8). Afterwards, the mixture was circulated in the system by means of pump. The inlet and outlet temperature readings were noted at 0.06% concentration at different flow rates 2ml/sec, 4ml/sec, 6ml/sec. The procedure is repeated for concentration 0.08%.

The useful heat gain by water (Qw) of the SFPC determined by the following equation

$$Q_w = mC_p(T_o - T_i) \quad (1)$$

Where m and C_p are mass flow rate and heat capacity of fluid, respectively

Koffi et al. (2008) used Equation 2 in order to calculate heat capacity of water:

$$C_{p,w} = 4226 - 3.244T_{fm} + 0.0575T_{fm}^{\ 2} \quad (2)$$

Heat capacity of nanofluid is also calculated by ;

$$C_{p,nf} = C_{p,np}(\varphi) + C_{p,w}(1-\varphi) \quad (4)$$

For each test, instantaneous efficiency (η_i) was determined from ratio of useful energy gain by water (Q_w) to incident radiation ($A_c.G_t$):

$$\eta_i = \frac{Q_w}{A_c.G_t} = \frac{m.C_p(T_o - T_i)}{A_c.G_t} \quad (5)$$

Where

Ac = surface area of the solar collector (m2)

Gt = global solar radiation ($\frac{w}{m^2 - k}$)

m= mass flow rate of fluid flow(ml/s)

$Cp,_{nf}$ = heat capacity of nano fluid (J/ Kg^0K)

$C_{p,np}$ = heat capacity of nano particles (AL_2O_3& CuO)

$C_{p,w}$ = Heat capacity of base fluid (water)(J/ Kg^0K)

Ti = inlet fluid temperature (^0C)

To = outlet fluid temperature of solar collector (^0C)

Energy balance on a flat plate collector under steady state condition is:

$$I_\tau A_c(\tau \alpha)_e = Q_u + Q_l$$

Where

I_τ = total solar radiation incident on the collector per unit area and time

A_c = aperture area of the absorber,

$(\tau \alpha)_e$ = effective transmittance – absorptance product,

$$(\tau \alpha)_e = \frac{\tau \alpha}{1-(1-\alpha)\rho d}$$

α = absorptance of the black absorber surface,

ρ_d = diffuse reflectance of the covers at 60^0 of incidence

τ = transmittance of the cover plate

Q_u = Rate of useful heat collected from the collector

Q_l = rate of heat lost from the collector,

Expression for useful heat from the collector:

$$Q_u = A_c[I\tau(\tau \alpha)_e - U_L(Tp-Ta)]$$

Where U_L = overall heat loss coefficient = $\frac{Ql}{(Tp-Ta)}$

Tp = average temperature of the absorber plate

Ta = ambient temperature

Overall loss coefficient (U_l) = $U_t + U_b + U_s$

(U_t) : Top loss co-efficient

(U_b) : Bottom loss coefficient

(Us) = Side loss coefficient

Heat loss from the collector (Q_l) = $U_l A_p (T_{p,m} - T_a)$

Useful amount of heat gain (Q_U) = $A_C[I_T(\tau\alpha)_e - U_l (T_p - T_a)]$

Actual heat absorbed by water (Q_w) = $m \times Cp \times (\Delta T)$

Heat loss from collector (Q_l) = (Q_U) – (Q_W)

Various results in the graphical form were plotted between efficiency vs mass flow rate, temperature difference vs time and efficiency vs time.

IV. EXPERIMENTAL SET UP

Fig .1 Experimental set up – SFPC

V. RESULTS & DISCUSSION

Variation of collector efficiency and temperature difference for AL_2O_3 based nano fluids at different volume concentrations @ mass flow rate 2ml/sec

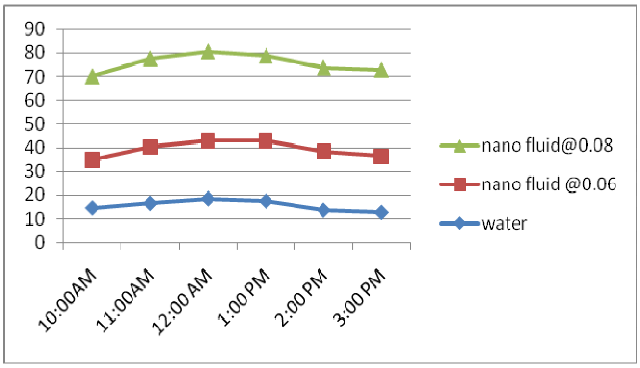

Fig .2 collector effeciency for AL2O3 nano fluids at different volume concentrations

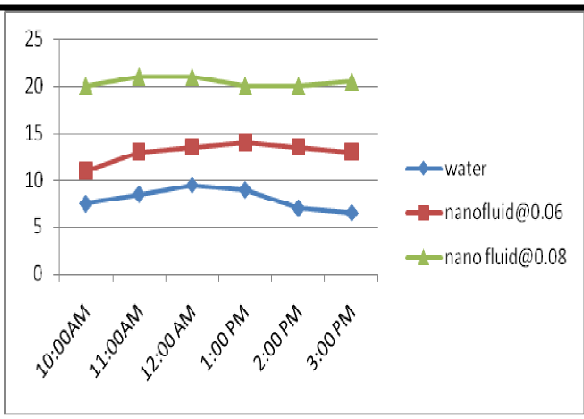

Fig .3 variation of temperature difference for AL_2O_3 - H_2O nano fluids at different volume concentrations

Variation of collector efficiency and temperature difference for AL_2O_3 based nano fluids at different volume concentrations @ mass flow rate 4 ml/sec

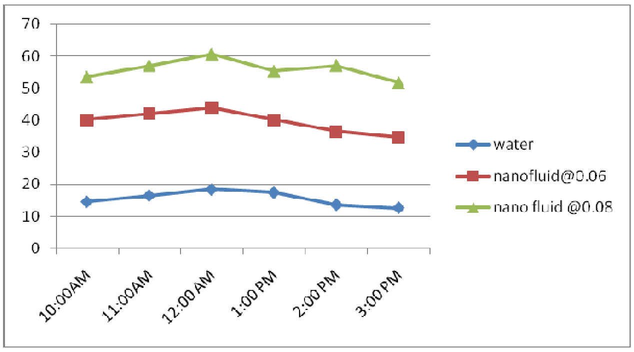

Fig .4 collector efficiency for AL_2O_3 nano fluids at different volume concentrations

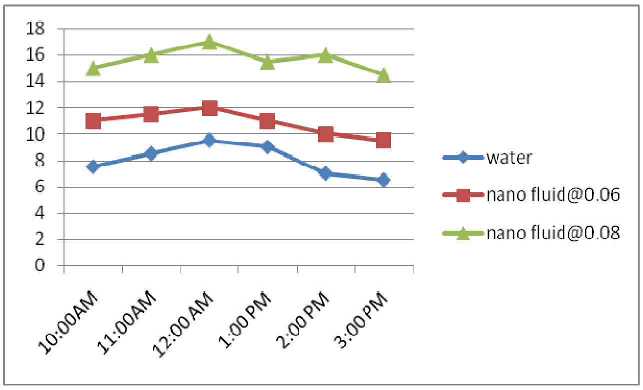

Fig .5 variation of temperature difference for AL_2O_3 - H_2O nano fluids at different volume concentrations

Variation of collector efficiency and temperature difference for AL_2O_3 based nano fluids at different volume concentrations @ mass flow rate 6 ml/sec

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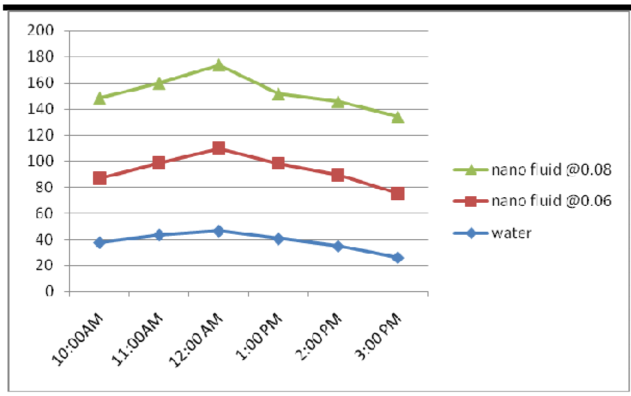

Fig .6 collector efficiency for AL_2O_3 nano fluids at different volume concentrations

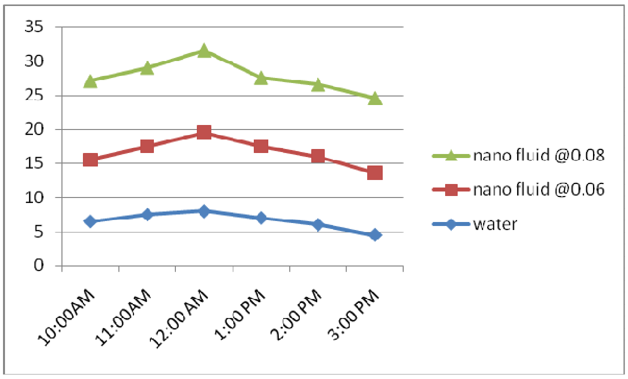

Fig .7 variation of temperature difference for AL_2O_3 -H_2O nano fluids at different volume concentrations

Variation of collector efficiency and temperature difference for CuO based nano fluids at different volume concentrations @ mass flow rate 2 ml/sec

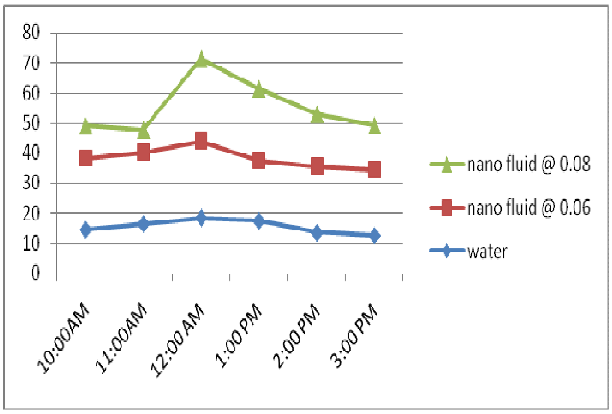

Fig 8 collector effeciency for CuO - H_2O nano fluids at different volume concentrations

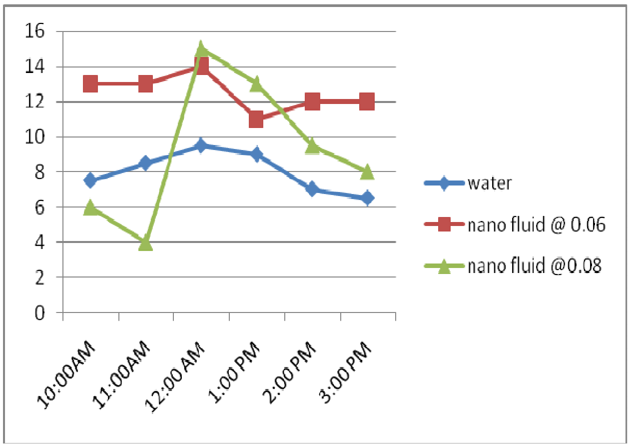

Fig . 9 variation of temperature difference for CuO- H_2O nano fluids at different volume concentrations

difference of collector efficiency and temperature difference for CuO based nano fluids at different volume concentrations @ mass flow rate 4 ml/sec

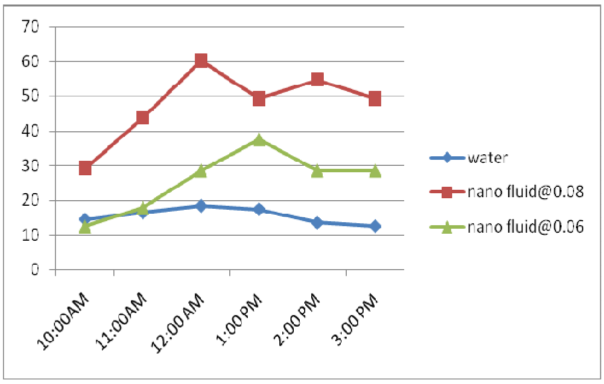

Fig .10 collector effeciency for CuO - H_2O nano fluids at different volume concentrations

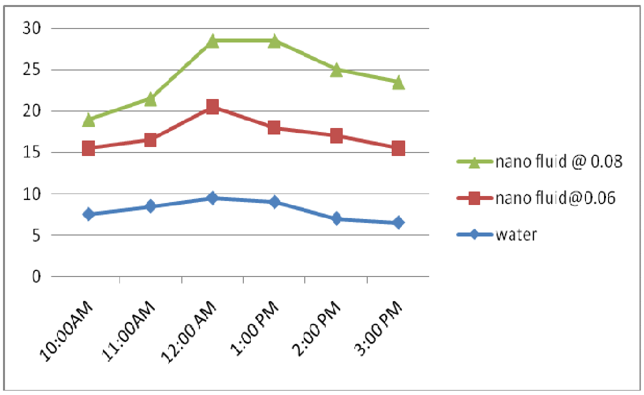

Fig 11 variation of temperature difference for CuO- H_2O nano fluids at different volume concentrations

Variation of collector efficiency and temperature variation for CuO based nano fluids at different volume concentrations @ mass flow rate 6 ml/sec

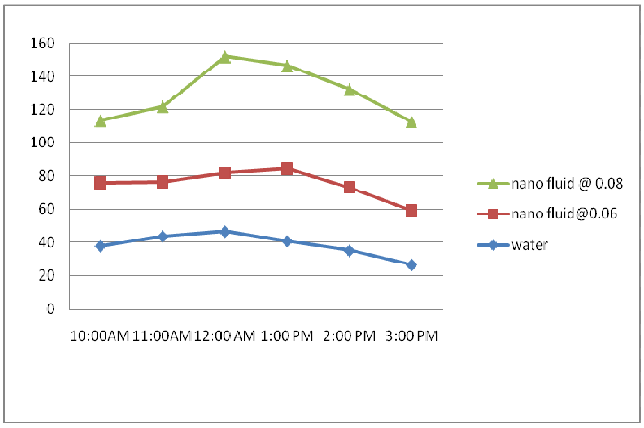

Fig .12 collector efficiency for CuO - H_2O nano fluids at different volume concentrations

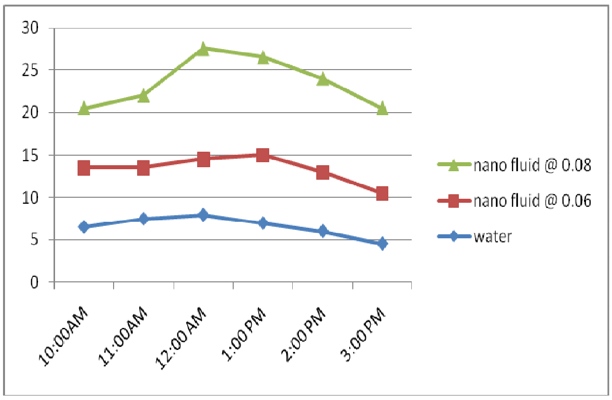

Fig 13 variation of temperature difference for CuO- H_2O nano fluids at different volume concentrations

From Fig 2-13, it has been observed that there is an raise in efficiency of the collector after using nano fluids. Efficiency is not constant with time. There is maximum increase in efficiency near at 01:00 pm due to high value of heat absorbed by water (Qw). It has been also experimental that as the mass flow rate of nano fluid increases the efficiency of SFPC also increases. Whereas, with the increase in mass flow rate the temperature difference will decreases. This is due to reason that with the lower the mass flow rate nano fluid has more time to absorb solar radiation and gain more heat.

CONCLUSION

The effect of different nano particle concentrations of CuO & AL_2O_3 / H_2O based nano fluids as working mediums on SFPC efficiency for different mass flow rates , nano particle mass fraction is studied . the results shows that there is an increasing in efficiency of SFPC by 17% with AL_2O_3 / H_2O nano fluid & 32% by CuO nano fluid. This will shoes there is a scope for improve the efficiency of a SFPC by using Nano fluids. It is recommended that higher efficiency of the collector can be obtained by minimize the losses and preventing the settling of the nanoparticles. The size, shape and volume fraction of the nanoparticles in the nanofluid affects directly the collector efficiency. Additional growth in the nanofluids properties and their related use in the solar energy harvest will leads to the more research in this field.

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