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FLAT PLATE SOLAR COLLECTOR USING NANOFLUID

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Abstract- *Flat plate solar collector receives the sun's energy, and transfers that energy to a fluid contained in it, called nanofluid. Nanofluid is a fluid which contains nanoparticles. Nanofluid exhibits enhanced thermal conductivity and has larger convective heat transfer coefficient compared to the base fluid. The objective of this project was to increase the efficiency of a flat plate solar collector using nanofluid and observe the variation introduced in the efficiency of the collector using nanofluid over using solely water as the circulating fluid. The efficiency of flat plate solar collector using only water as circulating fluid was found 70% whereas the efficiency of flat plate solar collector using 10gm aluminum oxide in 1300gm circulating water was found 78%. Furthermore, when the amount of aluminum oxide was increased to 20gm within the same amount of water, the efficiency increased to 81%. It was observed that the efficiency of flat plate solar collector was increased by using nanofluid compared to using solely water as circulating fluid.*

Keywords: Flat plate solar collector, nanofluid, nanoparticle, thermal conductivity, efficiency

1.INTRODUCTION

The systems that convert solar radiant energy into thermal energy use special devices called solar collectors. There are different types of solar collectors. In this paper we use flat-plate solar collector. Flat-plate solar collector receives the sun's energy, transforms its radiation into heat, and finally transfers that heat to a fluid, especially water. Flat plate solar collectors are the most common solar collectors for solar-water heating systems in households and solar space heating. The main use of this is in residential buildings where the demand for hot water has a large impact on energy bills. There are different layers in flat plate solar collector. The upper part of the collector is called transparent cover. It is made from glass to permit penetration of solar beams. The absorber plate mostly a metal or plastic surface, mostly blacked in color. Insulation layer minimizes heat loss of the collector. A nanofluid is a fluid containing nanometer-seized particles, called nanoparticles. The nanoparticles used in nanofluid are typically made of metal, oxides, carbides, or carbon nanotubes. Common base fluid includes water, ethylene glycol and oil. Nanofluids have novel properties that make them potentially useful in many applications in heat transfer. They exhibit enhanced thermal conductivity and the convective heat transfer coefficient compared to the base fluid. Aluminum oxide is a chemical compound of aluminum and oxygen with the chemical formula Al_2O_3. It is the most commonly found among the several forms of aluminum oxides and is specially identified as aluminum (III) oxide, commonly called alumina. Aluminum oxide is an electrical insulator but has a relatively high thermal conductivity (30W/mK) for ceramic materials.

2. LITERATURE REVIEW

Amrutkar et al. (2012) [1] evaluated the performance of flat plate collector with different geometric absorber configuration. He measured the performance of solar collector with different absorber configuration. Alireza Hobbi et al. (2009) [2] performed an experiment to see the effect of heat enhancement devices on the collector performance. Four types of arrangement were analyzed: regular circular tube, regular tube with twisted strip tabulators, regular tube with coil spring wire and regular tube with conical ridges were installed in every 152mm.There were no significant effect on the performance of collector. Kumar (2014) [3] did an experiment to increase the performance of Solar Flat plate by using Semi-Circular Cross-Sectional Tube. When using semicircular type tube below the absorber plate, the area of intimate contact was increased between fluid and absorber plate and resistance due to adhesive was decreased. Due to this reason performance of solar flat plate collector was increased. Awasthi et al. (2014) [4] reported the thermal performance of double glazed flat plate solar collectors with different range of design variable on top heat loss coefficient. Z. Said et al. (2015) [5] studied the use of TiO_2 in water as nanofluid as a working fluid for enhancing the performance of a flat plate solar collector. The volume fraction of the nanoparticles was 0.1% and 0.3% respectively while the mass flow rates of the nanofluid varied from 0.5 to 1.5 kg/min, respectively. Thermo–physical properties and reduced sedimentation for TiO_2-nano fluid was obtained using PEG 400 dispersant. The results revealed the impact and importance of each of these parameters. Energy efficiency increased by 76.6% for 0.1% volume fraction and 0.5 kg/min flow rate, whereas the highest exergy efficiency achieved was 16.9 % for 0.1% volume fraction and 0.5 kg /min flow rate. Results showed that the pressure drop and pumping power of TiO_2 nanofluid was very close to the base fluid for the studied volume fractions. Gambo Buhari Abubakar and Gerry Egbo (2014) [6] studied the thermal performance of solar flat plate water heater (Model TE 39) in Bauchi weather conditions (lat.10.50° N, long. 10.00° E). Fluid was circulated through the imbedded copper tubes in the flat plate collector and inlet and outlet temperatures of the fluid were noted at intervals of five minutes.

3.EXPERIMENTAL SETUP

Fig.1: Flat Plate Solar Collector

The pictorial representation of the experimental domain (flat plate solar collector) used in this experiment.

Fig.2: Experimental setup

An experimental setup has been carried out to measure the performance of the flat plate solar collector using nanofluid. A transparent cover glass plate is used here having a length of 0.6858 m and width of 0.394 m. Copper tube used here which has a diameter of 0.015875 m. Black colored tin is used as absorber plate having a length of 0.64262 m and a width of 0.36322 m. The length of the wooden frame is 0.6858 m and width is 0.3937 m and height is 0.1016 m. The flat plate solar collector has been kept on a table. The copper pipe is jointed with rubber pipe with clamp screw. There are two gate valves in the setup to control the water flow in the flat plate solar collector. There is a bucket containing 3 litres of water. There is a copper coil inside the bucket which passes heat from circulating hot water inside it to the bucket water. There is a thermometer to measure the temperature of the bucket water. A water pump is used to circulate the water in the flat plate solar collector. A lux meter is used to measure the solar intensity incident on the flat plate solar collector. The amount of circulating water inside the tube is 1300 gm. Aluminum oxide nanoparticle which has an average diameter of 40-80 nm, is mixed with circulating water to make nanofluid. The solar beam is incident on the flat plate solar collector and the circulating fluid inside the copper tube absorbs the heat from the solar radiation. The circulating fluid then heats the water inside the bucket water while circulating inside the copper tube coil kept in the bucket.

4.MATHEMATICAL FORMULATION

The main equation to calculate the flat plate solar collector efficiency is,

$$\eta = \frac{Q_o}{Q_i} = \frac{mc_p(T-T_i)}{I.A.t} \quad (1)$$

Area of the absorber plate, A=0.2334 m^2
Mass of the water in bucket, m= 3 kg
Specific heat of water, Cp = 4200 $Jkg^{-1}K^{-1}$

5. RESULTS

The main purpose of this experiment is to observe the difference between efficiencies of the flat plate solar collector using water as working fluid and the efficiency of the collector while using water-based aluminum oxide nanofluid as working fluid. This is illustrated in the following graph.

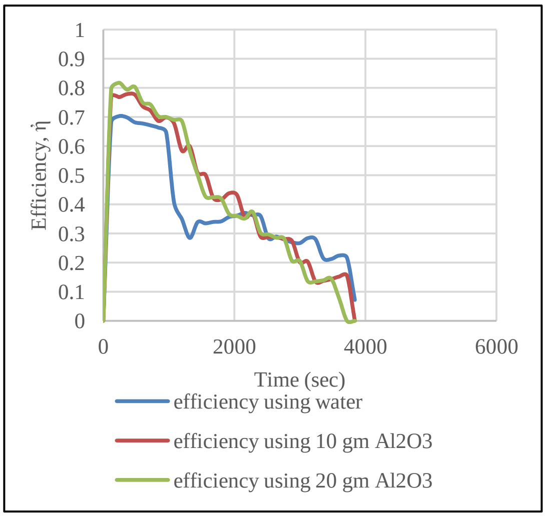

Fig.3: Comparison among efficiency of the collector using water, 10gm Al_2O_3 and 20 gm Al_2O_3 in circulating water.

The graphical representation shows the comparison among the efficiency of flat plate solar collector using water as working fluid, the efficiency of flat plate solar collector using 10 gm Al_2O_3 in 1300 gm circulating water as working fluid, and the efficiency of the flat plate solar collector using 20 gm Al_2O_3 in mixing with circulating water of 1300 gm as working fluid. The efficiency of the flat plate solar collector increased as the amount of Al_2O_3 in circulating water increased. The efficiency of the flat plate solar collector using water as working fluid is 70%. After using nanofluid as working fluid in amount of 10 gm Al_2O_3 in 1300gm circulating water, the efficiency increased to 78%. As the amount of Al_2O_3 in circulating water increased, the efficiency also increased. Using 20 gm Al_2O_3 in 1300gm circulating water brings about an efficiency of 81%.

6.CONCLUSION

The purpose of this research work is to check the efficiency of flat plate solar collector using water based aluminum oxide (Al_2O_3) nanofluid as working fluids.
Following are the conclusion drawn:
1.With water:
Using water as the working fluid in flat plate solar collector the efficiency is 70%.
2. With Aluminum oxide (Al_2O_3) nanofluid:
Using water based aluminum oxide (Al_2O_3) nanofluid the efficiency increased. The efficiency increased to 78% when there is 10 gm Al_2O_3 in 1300 gm circulating water. The efficiency of the flat plate solar collector is 81% when there is 20 gm Al_2O_3 in 1300gm circulating water.

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8.REFERENCES

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9. NOMENCLATURE

Symbol	Meaning	Unit
A	Collector area	(m^2)
I	Intensity of solar radiation	(W/m^2)
T_i	Initial fluid temperature	(K)
T	Fluid temperature after t time	(K)
Q_i	Collector heat input	(J)
Q_o	Collector heat output	(J)
m	Mass of water in bucket	(Kg)
t	Time of solar beam incident on the collector	(s)
η	efficiency	Dimensionless