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A Review of Flat Plate Solar Collector Using Nanofluids

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ABSTRACT

In most recent couple of years, nanoparticles with measurements under 100nm have pulled in the consideration of numerous specialists because of their amazing properties. Scientists in the field of thermal science additionally used nanoparticles to improve the proficiency of thermal frameworks through presenting another age of working liquids which are designated "nanofluids". Nanofluids containing strong nanoparticles have indicated shocking consequences for the productivity upgrade of thermal frameworks. Flat plate solar collectors are a gathering of thermal gear which nanofluids may improve their proficiency amazingly. Flat plate solar collector is most generally utilized solar collector yet is less productive. The utilization of nanofluid (liquid acquired by blending nanoparticle in base liquid) instead of base liquid has improved impact on thermophysical properties, for example, thermal conductivity. The utilization of nanofluid on flat plate solar collector (FPSC) can be distinguished as a compelling method to upgrade the presentation of solar collector.

1. INTRODUCTION

Solar collectors are special type of heat exchangers that convert solar energy to thermal energy. Various types of solar collectors have been utilized to gather solar energy. The flat-plate solar collector (FPSC) is the most widely recognized type, and it changes over solar energy to thermal energy utilizing a solid surface called an "absorber plate". The surface of the absorber plate is generally dark matte painted or specifically covered frightfully to accomplish high absorptivity of the solar range with low emissivity (Duffie and Beckman, 1980; Bogaerts and Lampert, 1983).

The got solar radiation is consumed by the collector's absorber plate, and afterward, it is changed into heat and transferred to the heat transfer medium that is moving through the collector's tubes. The real part of the incident solar radiation going through the FPSC's straightforward spread is consumed by the absorber plate. The base and sides of the collector's absorber plate are completely protected to limit heat losses by conduction. The collector's glass spread lessens heat losses by convection by means of control of an air layer and by radiation in that it is straightforward to the sun's shortwave solar radiation yet for all intents and purposes non-straightforward to the long-wave thermal radiation emitted by the absorber plate (nursery impact) (Kalogirou, 2009).

Water, engine oil, and ethylene glycol are basic working fluids in different engineering forms and mechanical equipment, for example, cooling or heating applications, control age, concoction procedures, microelectronics, and a wide assortment of heat trade gadgets. By the by, due to the relatively low thermal conductivity of these heat transfer fluids, they can't achieve high rates of heat transfer in thermal applications (Daungthongsuk and Wongwises, 2007). By creating heat transfer fluids with improved heat transfer properties, mechanical equipment having higher minimization and proficiency can be planned with the resulting investment funds in capital and working expenses.

2.1 Nanofluids

A nanofluid can be defined as the fluid containing nano-sized particles (1–100 nm). These fluids consist of nanoparticles mixed in the base fluid. The nanoparticles employed in nanofluids are generally made from metals, oxides, carbides, or carbon nanotubes. Common base fluids consist of water, ethylene glycol and oil. Nanofluids have special properties that create them helpful in several applications in phenomenon involving heat transfer for ex. electronics, fuel cells, medical field, hybrid-powered engines, engine thermal management, domestic white goods, in grinding, machining etc. They exhibit increased thermal and physical properties when compared to conventional fluid.

2.2 Reasons for Choosing Nanofluid

1) Thermal conductivity: The abnormal rise in thermal conductivity is observed when using nanofluid.

2) Thermal diffusivity: Thermal diffusivity increases when using nanofluid thus increasing heat transfer rate.

3) Viscosity: Increase in viscosity due to the addition of nanoparticle leads to enhanced thermal properties.

4) Convective heat transfer coefficient: The convective heat transfer coefficient enhances when using nanofluid.

5) optical absorption: Due to the addition of metallic nanoparticle optical absorption properties gets enhanced.

6) Environmental aspect: Use of nanofluid in solar collector cuts CO2 emission and saves annual electricity and fuels.

7) Surface area to volume ratio: Nanoparticles usually have large surface area to volume ratio that increases heat transfer between the base fluid and solid particle.

8) Overall cost and size reduction of the solar collector when using nanofluid.

9) High absorption coefficient: This is achieved when using nanofluid in place of conventional fluid such as water

10) Reduction in losses: When using nanofluid the radiative and convective losses reduce due to increasing in heat transfer between absorber plate and nanofluid.

3. REVIEW OF FLAT PLATE SOLAR COLLECTOR USING NANOFLUIDS

Nanofluids using in different experiments are WO3/H2O nanofluid, Al2O3/H2O with or without longitudinal strip inserts, TiO2/H2O nanofluid, CeO2/H2O nanofluids. Sharafeldin et al {1} experiment deals with the effects of using WO_3/water nanofluids on the efficiency of a flat plate solar collector which operates under weather conditions of Budapest, Hungary. First, water based nanofluids containing WO_3 nanoparticles (with a mean size of ninety nm) at 3 totally different volume fractions together with .0167%, 0.0333%, and .0666% have been synthesized. The stability of nanofluids has been evaluated through zeta potential tests that unveiled the ready suspensions have high stability.

After that, the thermal performance of the flat plate solar collector using nanofluids is investigated at different mass flux rates including .0156, 0.0183, and 0.0195 kg/ s.m2. The results showed that adding WO_3 nanoparticles to water increases the efficiency of the solar collector. The experiment results reveal that the maximum enhancement in efficiency of the collector at zero value of [(Ti–Ta)/GT] was 13.48% for volume fraction of .0666% and mass flux rate of .0195 kg/s.m2 compared to water, which clearly shows the high potential of WO_3 nanoparticles for solar energy applications. Thermal efficiency raised by 4.25%, 10%and 13.48% for volume fraction φ .0167, 0.0333% and .0666%, respectively.

Sharafeldin2 et al. {5} performed the experiment to study the effect of using CeO_2- water on the efficiency of flat-plate solar collector by three different volume fractions of CeO2 nanoparticles of .0167%, 0.0333% and .0666%, while the mean particle dimension was kept constant at 25 nm. An ultrasonic process was used for maintaining the steadiness of the CO_2-water nanofluid. The working fluid mass flux rates were .015, 0.018 and 0.019 kg/s m2. The experiments were carried out in Budapest, Hungary on the latitude of 47°28′N and longitude of 19°03′E.

Higher collector's efficiency was achieved when using CeO_2-water nanofluid compared to results achieved with water application. Based on the data, the efficiency of the collector is directly proportional with the mass flux rate and with the volume fraction in the ranges of the present study. Experiments indicate that the maximum rise in efficiency of the collector at zero value of [(Ti – Ta)/GT] is 10.74%, for volume fraction (φ) 0.066%, and for mass flux rate of 0.019 kg/s m2 compared to water.

Farajzadeh et al. {8} investigated the effect of using nanofluids on the thermal efficiency of a flat plate solar collector (FPSC) numerically and experimentally. The results of numerical studies conducted by the open source Computational Fluid Dynamics (CFD) software have good agreement with the experimental results. The studied nanofluids were $Al2O_3$-H_2O (20nm 0.1wt %), TiO_2-H_2O (15nm 0.1wt %), and their mixture with equal ratio. The nanofluids were prepared based on two-step method and cetyltrimethyl ammonium bromide (CTAB) was used as a surfactant. Volume flow rates were 1.5 l/min, 2.0 l/min and 2.5 l/min. by using $Al2O_3$ (0.1wt%), TiO_2 (0.1wt%) and the mixture of these two nanofluids, the thermal efficiency will enhance about 19%, 21% and 26%, respectively (compared with water as a working fluid). A mixture of the 2 nanofluids attains the most effective thermal performance compared to the 2 different nanofluids. Since TiO_2 is costlier than $Al2O_3$ Nanopowder, using the mixture of them is more economical with better thermal efficiency. Increasing the concentration of the nanofluid mixture from 0.1 wt% to 0.2 wt% will result in approximately 5% improvement in the thermal efficiency of the solar collector. Also, the thermal efficiency are intensified by volume flow rate.

Kilic et al. {10} has investigated experimentally the effect of using of titanium dioxide-water (TiO_2/water) nanofluid on the performance of the flat plate solar collector (FPSC]. The nanofluid was obtained by mixed with a 2 wt% TiO_2/pure water mixture. In order to take care of the stability of the prepared nanofluid suspension and to eliminate the matter of agglomeration over time, 0.2 wt% Triton X-100 surfactant was added into the mixture.

The nanofluid was mixed in continuous pulsing for 8 h in ultrasonic bath. In the experiments done in accordance with EN ISO 9806 standard, the highest instantaneous enhancements for pure water and nanofluid were determined. In the experimental setup of flat plate solar collector, the highest instantaneous efficiency was obtained to be 48.67% for TiO_2/water nanofluid, whereas the highest instantaneous efficiency was 36.200% for pure water. The performance increase in collector instantaneous efficiency is between 34.430% and 1.680% and in useful heat being drawn from collector is between 30.060% and 20.300%.

Vakili et al. [13] carried out experimental investigation of grapheme nanoplatelets nanofluid-based volumetric solar collector for domestic hot water systems. The experiment was performed for the temperature range of 35–40 °C for four different nanofluid including one base fluid. The experiment was conducted for various weight fraction of 0.0005, 0.001 and 0.005 and various mass flow rate of 0.0075, 0.015 and 0.225 kg/s. The efficiency was found to increase with increase in mass flow rate from 0.0075 kg/s to 0.015 kg/s but it was found to be decreasing when mass flow rate increased further from 0.015 kg/s to 0.225 kg/s because of the higher loss at the boundary. The highest collector efficiency was noted for the mass flow rate of 0.015 kg/s for both nanofluid and basefluid. The efficiency was found to be initially increasing with increasing weight fraction but on further increase in weight fraction, the efficiency was found to be decreasing because of enhancement in zero loss efficiency.

Natarajan and Sathish [14] experimentally investigated the heat transfer properties of MWCNT-$H2$ O nanofluid and compared it with water as the conventional heat transfer fluid. sodium dodecyl sulfate (SDS) was used as a surfactant (1.0 wt %) for the preparation of a stabilized nanofluid. The thermal conductivity enhancement of MWCNT nanofluid was seen up to 41% for a volume fraction of 1.0%. The thermal conductivity enhancement was found to be depending upon the volume fraction of the particle, the thermal conductivity of the particle and base fluid. Nanofluid was found to be more effective for a working fluid having lower thermal conductivity. Thus MWCNT-$H2$O was found to be a suitable candidate for the performance enhancement of a solar collector.

Mahian et al. [17] studied analytically the entropy generation and heat transfer due to A$l2O3$/water nanofluid flow in a flat plate solar collector. The particle size considered was 25, 50, 75 and 100 nm volume concentration was varied up to 4% and mass flow rate was varied from 0.1 to 0.8 kg/s. Effect of tube roughness, particle size and various thermophysical properties on nusselt number,heat transfer coefficient, entropy generation, outlet temperature and Bejan number were studied. The effects of solar radiation and ambient temperature on entropy generation were also studied. Nusselt number was found to decrease with increase in volume fraction and was found to increase with the increase in nanoparticle size. Heat transfer coefficient had an opposite trend in comparison to the nusselt number for different particle size and volume fraction. With the increase in volume fraction of nanoparticle entropy generation reduces and outlet temperature rises. The importance of roughness was more prominent when the solar radiation and ambient temperature decreases.

Table 1 *Comparison of different nanofluids considering in this review paper*

Research	**Nanofluid**	**Volume/ weight fraction**	**Size of nanofluid (nm)avg**	**remarks**
Sharfeldin et al.[1]	WO3/water	Volume fraction of .0167% .0333%	90	The experiment results reveal that the maximum enhancement in efficiency of the collector at zero value of [(Ti–Ta)/GT] was 13.48% for volume fraction of 0.0666% and mass flux

		.0666%		rate of 0.0195 kg/s.m2 compared to water. Thermal efficiency raised by 4.25%, 10%and 13.48% for volume fraction φ 0.0167, 0.0333% and 0.0666%, respectively
Sharfeldin2 et al.[5]	CeO2/water	Volume fraction of .0167 .0333 .0666	25	The highest rise in efficiency of the collector at zero value of [(Ti – Ta)/GT] is 10.74%, for volume fraction (φ) 0.066%, and for mass flux rate of 0.019 kg/s m2 compared to water.
Farajzadeh et al. {8}	Al2O3-H2O TiO2-H2O Their mixture with equal ratio.	.1wt% .1wt%	20 15	Efficiency will enhance about 19%, 21% and 26%, respectively (compared with water as a working fluid note:. Increasing the concentration of the nanofluid mixture from 0.1 wt% to 0.2 wt% will result in approximately 5% improvement in the thermal efficiency of the solar collector. Also, the thermal efficiency will be intensified by volume flow rate.
Kilic et al. {10}	(TiO2/water)	2wt%	44	The highest instantaneous efficiency was obtained to be 48.67% for TiO2/water nanofluid, whereas the highest instantaneous efficiency was 36.20% for pure water. The performance increase in collector instantaneous efficiency is between 34.43% and 1.68% and in useful heat being drawn from collector is between 30.06% and 20.3%. Note: surfacant, 0.2 wt% Triton X-100 was added into the mixture for stability of nanofluid
Vakili et al. [13]	grapheme nanoplatelets base fluid deionized	Wt% 0.0005, 0.001 and 0.005 and mass flow rate of 0.0075,	Dia. = 2 μm Thickness =	The efficiency was found to increase with increase in mass flow rate from 0.0075 kg/s to 0.015 kg/s but it was found to be decreasing when mass flow rate increased further from

	water	0.015 and 0.225 kg/s	2 nm	0.015 kg/s to 0.225 kg/s because of the higher loss at the boundary. The highest collector efficiency was noted for the mass flow rate of 0.015 kg/s for both nanofluid and basefluid
Natarajan and Sathish [14]	MWCNT-H_2O	Vol fraction of 1.0%	-	CNT dispersion prepared with SDS was found to be very stable. The thermal conductivity enhanced up to 41%for a volume fraction of 1%. Nanofluid was found more effective for a working fluid with lower thermal conductivity
Mahian et al. [17]	Al_2O_3/water	Vol fraction 4% and mass flow rate of .1to.8 kg/s	25, 50, 75 and 100 nm	Nusselt number was found to decrease with increasing volume fraction and increase with nanoparticle size. Entropy generation decreases with increase in volume fraction. The impact of tube roughness on entropy generation increases with increase in mass flow rate

4. CONCLUSION

The present review paper comprehensively analyzed the recent development in solar technology namely FPSC (Flat plate solar collector). The use of nanofluid as an absorber fluid showed the promising increase in collector's efficiency. The major challenge still lies in cost reduction of the solar collector so that it can be used effectively for both domestic and industrial use.

As discussed in the review paper the efficiency of solar collector increases by using nanofluid as absorber fluid and nano fluid was found more effective for a working fluid with lower thermal conductivity. There are variation in thermal efficiency by variate the mass flow rate and volume fraction of nanofluid as discussed above. This is a review paper so only result and important consideration is taken from different research paper.

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