Application of nanofluids to improve performance of a Flat plate solar collector: A Review

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Abstract - *Innovative cooling strategies being explored for the sake of effective dissipation of low grade thermal energy in majority of power product applications. Enormous amount of research work has been contributed in order to enhance the effectiveness of solar powered heat exchanger by the incorporation of various value added techniques. Few among them are dispersion of nano particles into base fluids, incorporation of inserts, increasing surface area, and decreasing the hydraulic diameter of heat exchanger setup. The present review summarizes the contributions of research community concerning nano fluid applications in order to improve the performance of solar collectors.*

Key Words: Flat plate solar collectors, nanofluids, Heat transfer coefficient, Efficiency, Exergy

1. INTRODUCTION

Nano Technology has got promising application in both industrial as well as bio medical fields due to their inherent advantages. A great deal of interest focused on nano fluids in energy sector. This can play crucial role in different areas of energy sector namely energy transformation, energy storage, energy saving etc. Recent advancement in nano science leads to the development of nano fluids produced by dispersing nano particles (size between 10-50nm) into base fluids. The nano fluids possess high potential to enhance heat transfer rates in different applications such as nuclear reactors, solar energy conservation, industrial cooling purposes, automotive cooling, MEMs, NEMs and various bio medical applications.

1.1Literature Survey

Ehsan et al [1] have investigated the novel method of increasing the performance of solar based heat exchangers. Comparison between numerical and experimental approaches has been conducted with TiO_2/water based nano fluid allowing through uniformly heated tube. The study conducted that HTC of nano fluids got enhanced with the increase in Reynolds number, nano particle concentration as well as thermal conductivity. However particle diameter observed to cause negative influence on heat transfer coefficient. Finally, maximum enhancement of 21% in average HTC, with the dispersion of TiO_2 nano particles at low concentration of 2.3vol% has been reported.

[2] Hemanth Kumar gupta Et al have experimentally investigated the efficiency of direct absorption solar collector of 1.4m2 gross area. Influence of Al_2O_3 – H_2O nano fluid on collector efficiency have been studied with a volume fraction of 0.005% at three different flow rates of 1.5,2 and 2.5litre/minute. Experimental results have proven that higher temperature rise of the fluid with very low flow rates due to its high residence time in the collector. However, higher emissive losses reported at lower velocities which resulted in drop in the efficiency of the collector at 8.1% & 4.1% respectively.

[3] M.Faizal Et al carried out studies on saving in the material for fabrication of solar collector as well as energy consumption for each collector fabrication. The study reported that 21.5%, 22.1%, 21.6% & 25.6% reduction in collector area achieved by using Al_2O_3,SiO_2 & CuO respectively. It was reported that 8618,8625,8857 & 10,239 kg total weight for 1000 units of solar collectors can be saved for Al_3O_2, SiO_2, TiO_2 & CuO nano fluids respectively along with a reduction of 170Kg less emissions of Co_2 in comparison to a conventional collector.

[4] Gianpiero colangelo Et al summarized their experimental results on sedimentation phenomenon due to lower velocity of fluid dlow at the tube surface than that at the centre line. Sedimentation could be able to overcome by keeping mean velocity constant in headers. This could be achieved by the incorporation of a special shaped element in the headers. It is reported that an enhancement in thermal conductivity at the rate of 6.7% and enhancement in convective heat transfer coefficient value by 25%with 3% volume concentration of Al_2O_3.

[5] Tooraj Yousefi Et al focused on the effect of Multiwall Carbon Nanotube based nano fluid working as absorbing medium on the performance of a flat plate solar collector by diluting surfactant. Their experimental results revealed that at the lower ranges of temperature difference the efficiency observed to move n increasing manner with respect to mass flow rate. Surprisingly, the trend got reversed for higher temperature difference values.

[6] E.Shojaeizadeh Et al examined the influence of propylene glycol concentration in water based nano fluid with five different volume fractions of 0%,25%,50%,75%,100% respectively on the efficiency of solar collector. The results revealed that there

was a drop in maximum efficiency of the flat plate collector in comparison to the respective value at for 0% propylene glycol i.e. pure water by 15.68% in 0.0167Kg/sec mass flow rate. However, the collector efficiency observed to increase from 25% volume concentration to 75%. But the value of the same observed to get decrease by 8.3% for a concentration ranges from 75% to 100%. Although, the electricity consumption was observed to increase with higher PG concentrations, but this burden was very much lower than the gain obtained in the heat transfer enhancement.

[7] Tehereh B.Gorji Et al investigated thermal and exergy efficiency of flat plate solar collector with graphite, magnetic and silver nano particles of different operating parameters namely volume fraction of nano particle dispersion (range $5<\rho_v<40$ppm), different volumetric flow rates (range 5<Q<10ml/min) using box-behnken experimental design approach. The RSM analysis results revealed that magnetic nano particles have gained highest thermal as well as exergy efficiency followed by graphite which is followed by silver nano particles. Beyond 25-30ppm concentration there is no significant gain in efficiencies. The rise in incident radiation flux observed to cause reduction in thermal efficiency. However it has positive influence on exergy efficiency of the solar collector. While increasing the nano fluid flow rate caused beneficial effect on thermal efficiency, at the same time it was observed to cause adverse effect on exergy efficiency.

[8] M.A.Alim Et al conducted theoretical study to analyze the consequences on entropy generation, capability of heat transfer enhancement as well as pressure drop with different types of nano fluids namely Al2O3, CuO, SiO2, TiO2 with water as fluid at various flow rates in a flat plate solar collector. The investigation has drawn remarkable results of enhanced heat transfer by 22.15% along with reduction in entropy generation by 4.34% as compared to pure water as working fluid. There was little penalty in pumping power by 1.58%.

[9] Z.Said Et al investigated theoretically the entropy generation, heat transfer rate and pressure drop characteristics of a flat plate solar collector operated with Single walled carbon nano tube based nano fluids. The study was restricted to laminar flow region only. Based on the study, SWCNT based nano fluids exhibited optimum thermal properties which lead to enhanced thermal as well as exergetic efficiencies than metal oxide nano fluids. It was observed that entropy generation could reduce by 4.34% and heat transfer coefficient got increased by 15.33%. There is no penalty in pumping power as well as pressure drop.

[10] Alireza Ahmadi Et al carried out experimental investigation to study the influence of graphene based nano fluid on thermal performance of a flat plate solar collector. The results reveal that with 0.01 and 0.02% dispersion rates of graphene nano platelets into deionized water reported zero heat loss efficiency of 12.19% & 18.87% respectively. Thermal conductivity of the working fluid also observed to increase up to 13% with 0.02wt% of graphene nano particles. It was concluded that the water heater outlet temperature reached to 67.5^0C and 71^0C for 0.01 and 0.02wt% graphene nano particles respectively.

[11] Tooraj Yousefi Et al investigated thermal efficiency of flat plate solar collectors with Al_2O_3/water nano fluid as base fluid. Experimental results revealed that enhancement of thermal efficiency by 28.3% with 0.2wt% Al_2O_3 particle suspension and a maximum enhanced efficiency of 15.63% by the use of Triton-X -100 as surfactant.

[12] Tooraj Yousefi Et al studied experimentally the effect of MWCNT based nano fluids on the performance of solar flat plate collector. Experimental observations conclude that for 0.2% MWCNT nano fluid decreased the efficiency of the collector. However, for 0.4% MWCNT nano fluid the efficiency was increased. Surfactant of Triton-X-100 addition also observed to cause enhancement in the collector efficiency.

[13] Amiehossein Zamzamian Et al investigated the effect of Cu/EG nano fluid of average diameter 10nm on the efficiency of flat plate solar collector. The experimental study reported that with increasing the weight fraction of Cu nano particles the collector efficiency was increased. Absorbed energy parameter of the solar collector was increased and highest value obtained for a flow rate of 1.5Lit/min. Optimum point for solar collector efficiency could be attained for 0.3wt% Cu/EG nano fluid at 1.5Lit/min flow rate.

[14] Hossein Chaji Et al fabricated and studied the efficiency of a small flat plate solar collector with TiO_2/H_2O nano fluid for three different flow rates (36, 72 and 108Lit/m^2.hr) and four concentration ratios (0, 0.1, 0.2 and 0.3Wt %) respectively. Experimental findings revealed that the initial efficiency ranging between 3.5 to 10.5% and the index of collector efficiency between 2.6 to 7% relative to pure water as working fluid. Results also indicate that for volume flow rates of 36, 72, and 108 Lit/m^2.hr the initial efficiency was 0.471, 0.4998 and 0.5457 respectively, which reveals that an enhancement of 6.1 and 15.8% in the later cases in comparison to first case i.e. 36Lit/m^2.hr.

[15] Ali Jabari Moghadam Et al carried out investigation to study the effect of CuO-H_2O nano fluid as working fluid with a volume fraction of 0.4% and mean particle diameter of 40nm. The experimental results concluded that the collector efficiency enhanced by 16.7% for optimum flow rate in comparison to pure water.

[16] Ehsan Shojaeizadeh Et al have studied the exergy efficiency of a flat plate solar collector using Al_2O_3-H_2O nano fluid as base fluid. Interior-point technique has been applied for constrained optimization of different parameters namely nano particle

volume concentration, flow rate of fluid, collector inlet temperature of fluid in order to attain optimum exergy delivery. Analytical results indicate that with actual constraints, for both nano fluid as well as pure water as working fluids, the optimized exergy efficiency enhanced with solar radiation intensity. The maximum collector exergitic efficiency got enhanced by about 0.72% with nano particles. The corresponding mass flow rate and fluid inlet temperatures observed to get decreased by about 67.8% and 1.9% respectively.

[17] Sujit Kumar Verma Et al conducted experimental investigation on a flat plate solar collector with wide variety of nano fluids with regarding to various parameters in respect of energy and exergy efficiency. Experimental results concluded that approximately 0.75vol% concentration at a mass flow rate of 0.025Kg/sec could lead optimum exergy efficiency. Among the different nano fluids considered for investigation MWCNT reported maximum enhancement of the order of 29.32%, followed by 21.46%, 16.67%, 10.86%, 6.97% and 5.74% respectively for Graphene/water, CuO/H_2O, Al_2O_3/H_2O and SiO_2/H_2O respectively instead of pure water as working fluid. Entropy generation also recorded to be minimum with MWCNT/H2O, which is the highest among all the nano fluids under study, establishing a fact that the system becomes more compact and more efficient

2. Methodology

During latest years, alternate renewable energy sources have attained prominent importance due to the lasting fossil fuel reserves. Alarming climatic changes due to rapidly raising green house gases and global warming effect has lead to the importance of solar energy conservation because of its eco friendly nature. Most simplest and direct ways for harnessing solar energy is by solar thermal conversion method. Solar thermal power can use only beam radiation (or) Direct Normal Insolation, which is the fraction of sun light that is not deviated by clouds, fumes, or dust in the atmosphere and that reaches earth in parallel beams for concentration.

Solar energy can be transformed to thermal energy with the aid of a specially designed heat exchanger known as solar collector. Solar collectors can be categorized into two types. They are i). Non-concentrating type and ii).Concentrating type. Non-concentrating type are the mechanically simpler in which the collector area is the same as the absorber area which can attain temperatures of 60^0 to 250^0C , where as in concentrating type various types of mirrors, reflectors & concentrators are used to collect solar energy hence they can provide higher temperatures in the range of 400^0 to 1000^0C than non-concentrating type.

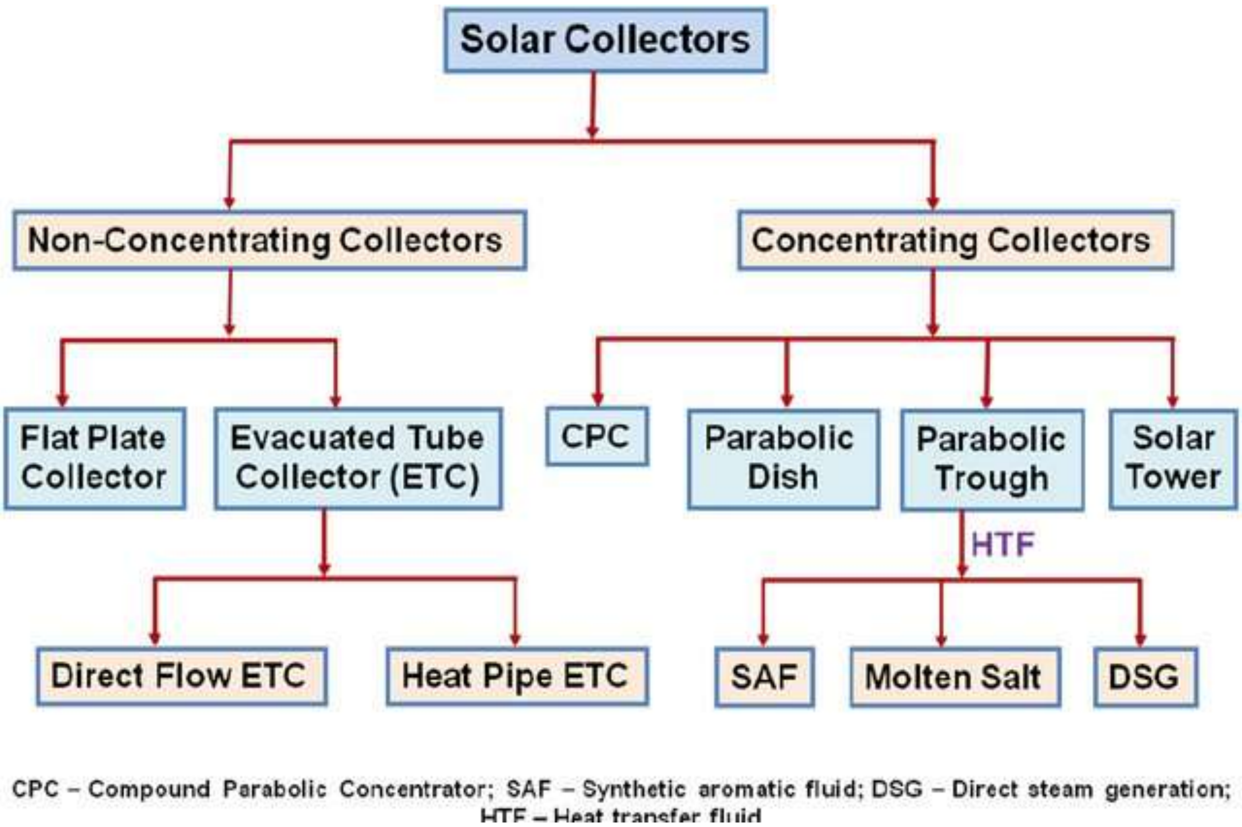

Figure (1)

Classification of solar Classification of solar Collectors

The schematic diagram of a typical flat-plate solar collector is shown in Figure 2.

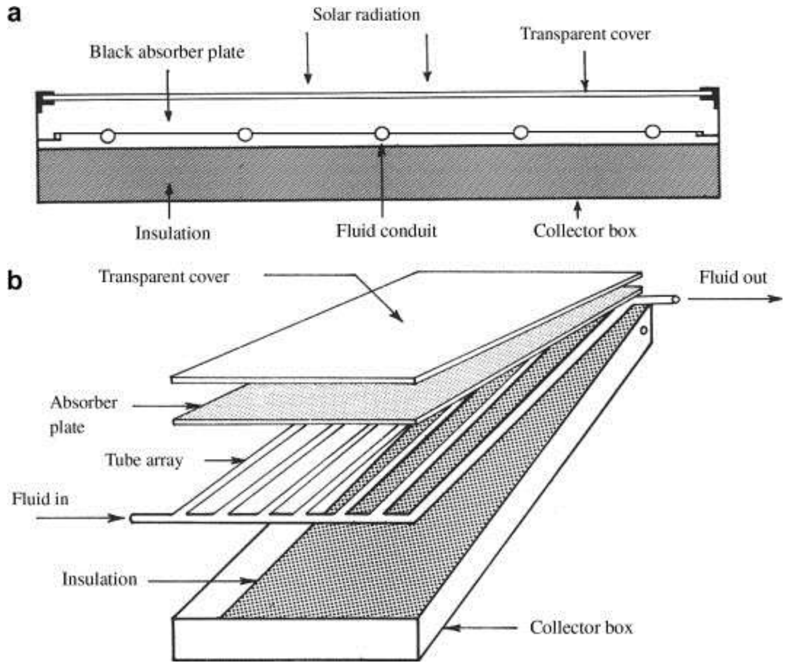

Figure (2).

A flat-plate collector consists of: (1) an absorber, (2) a transparent cover (3) a heat-transport fluid (water, air, etc.) (4) Housing or casing and (5) insulation. The absorber consists of a solar selective coating deposited on top of a thin absorber sheet of steel or copper. A low iron solar safety glass is used as a transparent cover. Solar radiation enters the collector through the transparent cover and reaches the absorber. The absorber converts the absorbed radiation into thermal energy. In the case of a flat-plate solar water collector, good thermal conductivity is required to transfer the collected heat from the absorber sheet to the absorber pipes. The housing ensures safety and protects the absorber and insulation from the environmental impacts. Generally, rock wool or mineral wool is used as an insulation material in order to reduce the thermal losses on the back side of the absorber [3]. The efficiency of standard liquid flat-plate collectors can be improved by reducing the optical and thermal losses. This can be achieved by: (i) multiple glazing with anti-reflective glass, (ii) filling a hermetically sealed flat plate collector with a noble gas or (iii) evacuating a hermetically sealed flat plate collector. These improved flat plate collectors can be used for solar industrial process heat (SHIP) applications.

The efficiency of a solar thermal collector depends on the effectiveness of absorbing incident solar radiation and heat transfer from the absorber to the carrier, which is normally fluid. Due to surface heat absorption and indirect transfer of heat to working fluid, the conversion of sunlight into thermal energy suffers from relatively low efficiencies. In order to improve the efficiency of solar thermal collector, researchers proposed the concept of directly absorbing the solar energy within the fluid volume in the 1970s called Direct Absorption Solar Collector (DASC). However, the efficiency of direct absorption collector is limited by the absorption properties of the conventional working fluid, which is very poor over the range of wavelength in solar spectrum. In the beginning, black liquids containing millimeter to micrometer sized particles were also used as working fluid in direct absorption solar collectors to enhance the absorption of solar radiation that had showed efficiency improvement. The applications of micron-sized particles into the base fluid for DASCs lead to pipe blockage, erosion, abrasion and poor stability. Particle sedimentation from the suspensions resulted in clogged channels. Advance material synthesis technologies provide us an opportunity to produce the nano-size materials (nanoparticles), when suspended in conventional fluids considered as nanofluids. The use of nanofluid has a dramatic improvement on the liquid thermo physical properties such as thermal conductivity.

The present paper summarizes the contribution of researcher community to enhance the performance of flat plate solar collector in order to achieve higher heat transfer coefficient.

3. CONCLUSION

Rising global population concerns over climate change, secure and safe low carbon energy supplies. Over the next 40 years, in order to sustain life we must develop deep solutions for massively scaling terawatts of affordable sustainable energy and develop means to reduce on CO_2 emissions. A pivotal future research should be determining the energy transport mechanism and green energy (solar thermal) in nanofluids. The solar thermal based engineering as well as many other industries has specific needs to increase heat transfer rates under a variety of constraints. Nanofluids have to satisfy many such needs and constraints. For solar thermal applications, the important features of nanofluids are the high transfer coefficients for liquids with high boiling points and medium pressures. Increased heat transfer rates in solar collectors could reduce the pumping power needs. However, ideal or even optimized nanofluids for solar thermal applications do not exist yet. The above review shows that the application of nanofluids in solar energy applications is still in its early stages so far, theoretical investigations have been reported on parabolic trough collectors; subsequently experimental studies can be performed. Practical implications of nanofluids are influenced by major factors such as production cost, synthesis methods, physical & chemical parameters. The evolvement of nanotechnology in future may overcome these factors.

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