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A Review of Studies on Performance of solar collectors with nanofluids

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Abstract

Nanofluids are dilute colloidal suspensions of nanoparticlesin a base fluid that exhibit thermal properties superior than that of the conventional fluid. The application of nanofluids is to achieve the highest possible thermal properties at the smallest possible concentrations, by homogeneous dispersion and stable suspension of nanoparticles in the host fluids. Nanofluids plays vital role in various thermal applications such as automotive industries, heat exchangers, solar power generation etc. Mostly heat transfer augmentation in solar collectors is one of the key issues in energy saving, compact designs and different operational temperatures. In this paper, a comprehensive literature on thermo physical properties of nanofluids and the application of solar collector with nanofluids have been compiled and reviewed. Recent literatures indicate the conventional heat transfer using nanofluids and their specific applications in the solar collector.

1. Introduction

World's energy demand is growing fast because of population explosion and technological advancements. It is therefore important to go for reliable, cost effective and everlasting renewable energy source for energy demand arising in future. Solar energy, among other renewable sources of energy, is a promising and freely available energy source for managing long term issues in energy crisis. Solar industry is developing steadily all over the world because of the high demand for energy while major energy source, fossil fuel, is limited and other sources are expensive. Solar energy is most exclusively used because of its ease of availability and least impact on the Environment.It is estimatedthat the amount of solar energy falling on earth per hour canmeet world energy demand for the whole year. However the acceptanceof solar energy as an alternate source of energy is not so clearbecause of its high operation cost and low efficiency and various researchwas done in this regard. Solar collector is one of suchdevice which converts solar energy into thermal energy using a heatexchanging fluid as absorber fluid. The enhanced thermal conductivity of an absorber fluid may translate into higher performance and loweroperating costs.

In recent years, many researchers have investigated the effects of nanofluids on the enhancement of heat transfer in thermal engineering devices, both experimentally and theoretically. Researchers have also applied a variety of preparation methods, characteristics, and different models used for the calculation ofthermophysical properties of nanofluids (i.e., thermal conductivity, viscosity, density, specific heat capacity). Some investigators have also summarized the effects of nanofluids on flow and heat transfer in natural and forced convection in different systems. The enhanced thermal behavior of nanofluids could provide a basis for an enormous innovation for heat transfer intensification, which is of major importance to a thermal therapy for cancer treatment, chemical and metallurgical sectors, as well as heating, cooling, ventilation and air-conditioning. Nanofluids are also important for the production of nanostructured materials for the engineering of complex fluids as well as for cleaning oil from surfaces due to their excellent wetting and spreading behavior (Ding et al. [20]). Another application of the nanofluid flow is in the delivery of nano-drug as suggested by Kleinstreuer et al. [21].

Saidur et al. [13] reviewed the potential of nanofluids in theimprovement of heat transfer in refrigeration systems. The authorsconcluded that more studies are required to find the reasons behindthe considerable improvements in heat transfer whereas aninsignificant increase in pressure occurs. Thomas and Sobhan[14] Presented experimental studies on nanofluids, with emphasison the techniques of measuring the effective thermal conductivity.Escher et al. [15] investigated the applications of nanofluids incooling electronics. Recently, applications of computer simulationsand computational fluid dynamics (CFD) used to model systemsemploying nanofluids were reviewed and analysed by Aboualiand Ahmadi [16] and Kamyar et al. [17]. Ahn and Kim [18] alsopublished a review on the critical heat flux of nanofluids for bothconvective flow boiling and pool boiling applications. In anotherpublication, Saidur et al. [19] reviewed the general applicationsof nanofluids in some fields such as cooling of electronics, heatexchangers, medical applications, fuel cells, nuclear reactors, andmany more. They also mentioned briefly the applications of nanofluidsin solar water heaters. They investigated challenges in usingnanofluids, including an increased pressure drop and pumpingpower, long-term stability of nanoparticles dispersion, and thehigh cost of nanofluids.

2. Applications of nanofluids in solar energy

Initially, the application of nanofluids in collectors and waterheaters are investigated from the efficiency, economic, and environmentalaspects. Some studies conducted on thermal conductivityand optical properties of nanofluids are also briefly reviewed,because these parameters can determine the capability of nanofluidsto enhance the performance of solar systems.

2.Solar Collectors

Solar collectors are particular kind of heat exchangers that transform solar radiation energy into internal energy of the transport medium. These devices absorb the incoming solar radiation, convert it into heat, and transfer the heat to a fluid (usually air, water, or oil) flowing through the collector. The energy collected is carried from the working fluid, either directly to the hot water or space conditioning equipment or to a thermal energy storage tank, from which it can be drawn for use at night or on cloudy days. Solar water heaters are the most popular devices in the field of solar energy. As mentioned in the introduction, the nanofluidbased solar collectors are investigated in two aspects. In the first, these devices are studied from the efficiency viewpoint, and in the second, from economic and environmental viewpoints.

ISSN 2515-8260 Volume 08, Issue 03, 2021

Studies on performance of nano-fluid based solar collectors

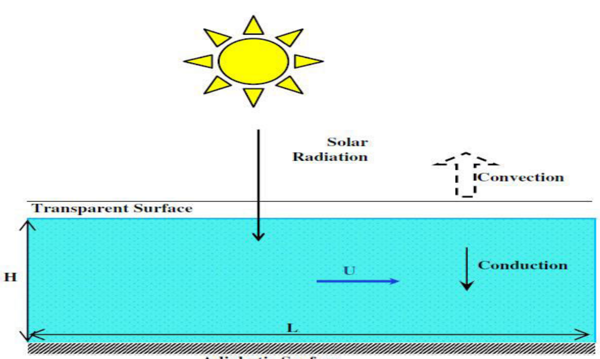
Tyagi et al. [1] investigated theoretically the effects of different parameters on the efficiency of a low-temperature nanofluid-based direct absorption solar collector (DAC) where the working fluid is a mixture of water and aluminum nanoparticles. A schematic of the direct absorption collector is shown in Fig. 1. The upper side of this collector is covered by a glass while the lower side is well insulated, so it is adiabatic. *Otanicar et al.*[2] investigated both experimentally and numerically the effects of different nanofluids (carbon nanotubes, graphite, and silver) on the performance of a micro scale direct absorption solar collector (DASC). The schematic of the experimental set up showing also the dimensions of the collector is presentedinFig. 2.

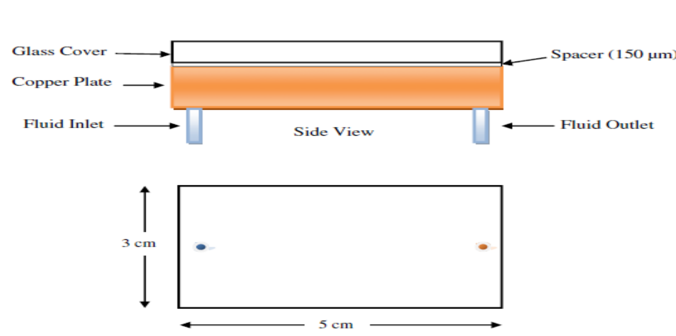
Fig. 1. Schematic of the nanofluid-based direct absorption solar collector thermal collector

Fig. 2. Experimental schematic of the microsolar

Taylor et al.[3] compared a nanofluid-based concentrating solar thermal system with a conventional one. Their results show that the use of a nanofluid in the receiver can improve theefficiency by 10%.Y.He et al. [22] investigated the light-heat conversion characteristicsof two nanofluids, water–TiO_2 and water–carbon nanotube(CNT), in a vacuum tube solar collector under sunny and cloudyweather conditions. The experimental results show a very goodlight heat conversion characteristic of the CNT–H_2O nanofluid withthe weight concentration of 0.5%. Because of the better light-heatconversion characteristics of the CNT–H_2O nanofluid compared tothe TiO_2–H_2O nanofluid, the temperature of the CNT–H_2O nanofluidis higher than that of the TiO2–H2O one. This means thatthe CNT–H2O nanofluid is more suitable than the TiO2–H_2O to beutilized in a vacuum tube solar collector.

*Patrick E. Phelan, et al.*they did experimental study onNanofluid-Based Direct Absorption Solar Collector. Theydemonstrate efficiency improvement up to 5% in solarthermal collectors using nanofluids as an absorptionmechanism. And they also compare experimental data withthe numerical model of a solar collector with directabsorption nanofluids. They conclude that experimental andnumerical results show an initial rapid increase in efficiencywith volume fraction, followed by a levelling off in efficiencyas volume fraction continues to increase. They conclude thatusing nanofluids as a direct absorption solar collector wasdemonstrated to offer





unique advantages over conventionalcollectors are:

ISSN 2515-8260 Volume 08, Issue 03, 2021

1. Heating within the fluid volume, limiting the need fora hot surface, which only transfers heat to a small area offluid, and allowing the peak temperature to be located awayfrom surfaces losing heat to the environment.

2. Variability in the size, shape, material, and volumefraction of the nanoparticles allow for tuning to maximizespectral absorption of solar energy throughout the fluidvolume.

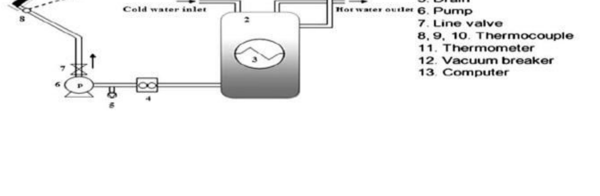
3. It enhance the thermal conductivity can lead toefficiency improvement, and more effective fluid heattransfer.

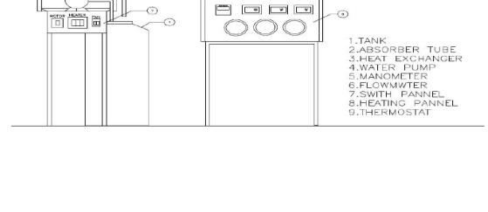
4. Greater enhancements in surface area due to theextremely small particle size, which makes nanofluid-basedsolar systems attractive for thermo chemical and photocatalytic processes.

T. Yousefi et al., [3] they performed an experimentalinvestigation (Fig 3) on the effect of Al2O3 and H2O nanofluid on theefficiency of flat-plate solar collectors. Experiment wasperformed with and without Triton X-100 as surfactant. Theyconclude with results, comparison with water as absorptionmedium using the nanofluids as working fluid whichincreases the efficiency i.e. for 0.2 wt % the increasedefficiency was 28.3%. From the results it was concluded thatthe surfactant causes an enhancement 15.63% in heat transfer.*DnyaneshwarR.Waghole, et al.*, [4]they did experimentalinvestigations (fig.4) on heat transfer, friction factor of silvernanofluid in absorber or receiver of parabolic trough collectorwith twisted tape inserts. They made experiment withReynolds number range 500 to 6000 with twisted tape insertsof different twist ratios in the range $0.577 \leq H/D \leq 1.732$.They concluded that when twisted tape inserts are used theresult shows great enchantment of heat transfer rate inabsorber and the heat transfer coefficient and friction factorof $0 \leq \Phi \leq 0.1$ % volume concentration of silver nanofluidare higher as compared to flow of water in absorber.

Fig:3 Shows experimental setup **Fig. 4. Shows Experimental Setup**

HimanshuTyagi et al., [1] they studied and theoretically investigate the feasibility by using a non-concentrating direct absorption solar collector and compare its performance with typical flat-plate collector. They used nanofluid as a mixture of water/ aluminium nanoparticles. The direct absorption solar collector was modelled numerically with two dimensional heat transfer analysis. They studied on various parameters, such as nanoparticles size and volume fraction, and collector geometry on the collector efficiency, and finally the performance of this collector was compared with that of a conventional flat-plate type collector. The collector efficiency was found to increase with particle volume fraction, glass cover transmissivity, and the collector height. However the direct absorption solar collector used nanofluids as the working fluid performs better as compare to flat plate collector. They observed that with the presence of nanoparticles increasing the absorption of incident radiation with more than nine times as compare to that of pure water. As from the results they obtained from study, under similar operating conditions, the





efficiency of a direct absorption solar collector used nanofluid as a working fluid is found to be 10% higher than that of a flat-plate collector.

P.Selvakumar, P.Somasundaram, P.Thangavel, [8] hadexperimentally investigated on Evacuated Tube SolarCollector using Therminol D-12 as Heat Transfer Fluid whichwas coupled with Parabolic Trough. They studied theevacuated tube solar collector with therminol D-12 as theheat transfer fluid which was coupled with parabolic trough.They used water as a heat transfer fluid for theexperimentation. They conclude that problems in using wateras heat transfer fluid was described in detail in this paper. Thetemperature characteristics of heat transfer fluid and water inthe storage tank and the heating efficiency are determinedunder various conditions. The results shows that efficiency oftherminol based evacuated tube collector which coupled withparabolic trough is 40% more as compare to water basedevacuated tube collector coupled in parabolic trough.

Kapil Sharma, LalKundan, [9] they performed experimental study nanofluid based concentrating parabolic solar collector with new alternatives. They did the experimental investigation on parabolic solar collector by studying the effect of alumina and copper oxide nanoparticles in water, as working fluid. The mass flow rates are 20, 40 & 60 l/hr andNanoparticles volume concentrations of 0.01% had been examined, and the size of nano-particle is 20 to 30 nm. Comparison of water/alumina nanofluid is done with copper oxide nanofluid and they observed that using CuOnanofluid as a working fluid the thermal efficiency has been improved.

LalKundan, Prashant Sharma [10] they performedEvaluation on nanofluid (i.e. CuO/H2O) based Low FluxSolar Collector. In our research work the CuO-water basednanofluid has been tested in the solar collector and theirperformance is investigated. They concluded that using CuOnanofluids in direct absorption solar collector the efficiencyincreases in the order of 4 to 6 %, which compared to water.And CuOnanofluid with 0.005% volume fraction gain from 2to 2.5 % efficiency than 0.05% volume fraction. They alsoconclude that for getting higher efficiency due to very smallsize particle which increases the absorption capacity ofnanofluid which improves the efficiencies. It has been foundthat efficiency if the solar collector is increased by 4-6%compared to water.

Vikrant Khullar, HimanshuTyagi [11] this paper containsnanofluid as working fluid in linear parabolic solar collectorshad analyzed by mathematically modelling, its heat transferand flow aspects. The collector had modelled as 2-dimensional steady state system, and finite difference methodis used numerically solve the equations. The 2-dimensionaltemperature field, optical, thermal efficiencies and averageoutlet temperatures was experimentally evaluated andcompared for the conventional parabolic collectors andnanofluid based collectors respectively. After evaluation theeffects of various parameters such as concentration ratio,volume fraction of nanoparticles, absorber length, and fluidvelocity was studied. After analysis they concluded that thenanofluid based collector performed better as compared toconventional collector with similar working conditions andalso they seen that improved in thermal, optical efficiencies
and maximum outlet temperatures.

Budi Kristiawan et al., [12] experimental investigation hadperformed to study thermal performance of TiO2/distilledwater nanofluid in evacuated tube absorber model with TiO2nanoparticles volume concentration of 0.1%. In this paperwork, the uniform heat flux is generated by variactransformer for a fix magnitude instead of daily solarradiation. This investigation shows that the applied heat fluxhad just affected on outlet temperatures of nanofluids but itdoes not depend on Nusselt number and result also shows thatthe friction factor of the observed nanofluid is greater thanthe base fluid. They concluded that the thermal

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performanceand the average Nusselt number increased between nonevacuatedand evacuated condition with yields of 17.9% and21.7% for water and nanofluid respectively. They alsoconcluded that the evacuated receiver tube increases thethermal performance of Nano fluids is more efficient thanthat of non-evacuated absorber tube.

kumarsunil, et al., [5] experimental study conducted toinvestigate the performance of a parabolic solar collectorusing SiO2-H2O based nanofluid. They decide volumeconcentration of 0.01% and 0.05% was used to prepare thenanofluid. They employed different volume flow rates in theexperiment i.e. 20 l/h, 40 l/h and 60 l/h. The surfactants arenot used when preparing the nanofluids. The sonication wasdone by using ultra bath sonicator for enhancing the stabilityand dispersion of nanoparticles with water. From the resultsthey conclude that, SiO2-H2O based nanofluid wascomparatively higher efficiency at higher volume flow rates.

S. E. Ghasemi1, GH. R. MehdizadehAhangar [6] theystudied Numerical analysis solar parabolic trough collectorwith Cu-Water nanofluid.They evaluate the temperaturefield, thermal efficiency, and mean-outlet temperatures andcompare for the conventional parabolic collectors withnanofluid based collectors, and simultaneously investigatesthe effect of various parameters such as fluid velocity,volume fraction of nanoparticles, concentration ratio andreceiver length. They concluded that in addition of trace theamount of copper nanoparticles inside the base fluidconsiderably improves its heat gain capacity. Thus they hadseen during analysis the thermal, optical efficiencies canimproved and higher outlet temperatures also, the effect ofconcentration ratio, volume fraction of nanoparticles andlength of collector was studied. This concludes that thenanofluid based parabolic concentrator has higher efficiencyas compare to the conventional collector.

CONCLUSION

This paper presents overview about nanofluid with solar collector applications, an existing emerging class of heat transfer fluid, in terms of barriers, future research and environmental challenges. Nanofluids are used to increase the performance of many thermal engineering systems. The use of nanofluids in the solar collectors may raise the effectiveness of the collectors using both experimental and theoretical investigations subjected to certain limitations. Experimental works encountered the major limitations, such as particle agglomeration, stability, erosion and corrosion of the heat transfer equipment's. Numerical simulations requires more exact models such as two phase mixture models need to be done for various solar collector applications. Based on the recent investigations, it was observed that the volumefraction and particle size plays a major role in determining the effectiveness. Further the nanofluids concentration by weight percentage, volume percentage and also pH plays a vital role in the performance of the solar collector. Future studies are exposed widely on the application of nanofluids for high temperature applications and energy storage devices by having experimental andtheoretical investigations. The nanofluids for any real applications can be made viable practically by undergoing study under different environment, geographical conditions testing its viscosity, fluid properties and thermo-physical properties on different thermal applications. Researchers on using the nanofluids on solar collector applications are at its fundamental level. Using the solar fuel with nanotechnologies in solar collector application have enormous potential in the future and is under global focus to attain clean and green energy.

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