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A Review: Nanofluid Effect on Performance of Solar Collectors

Prashant. G. Hukare[1], Amit A. Gavhad[2], Rupeshkumar D. Suryawanshi[3]
Assistant Professor
Department of Mechanical Engineering
G. H. Raisoni Academy of Engineering and Technology, Nagpur (M.S), India

Abstract:
Solar energy is a very large, inexhaustible source of energy with two main distinct advantages as follows; the first one is unlike fossil fuels and nuclear power, it is an environmentally clean source of energy and secondly it is free and available in lump in almost all the parts of world. Reducing the devices and energy efficiency are two major factors to find new materials and improving the designs of solar collectors. Nanofluides are innovative fluids getting worldwide attention due to their inherent characteristics. Nanofluides exhibits enhanced thermal conductivity and heat transport ability goes to nanoparticle suspension in based fluids. Nanofluides are nanoparticles suspended in base fluids. These nanofluides are now being used as working fluids to absorb solar radiation and transfer it to another fluid at higher rate as reported by many researchers and nano research labs all over the world. Our intention behind writing this review is to comprehensively and thoroughly investigate the research work done for improvement of efficiency in Direct Absorbing Solar Collectors using Nanofluides. Review of previous works based on experimental and theoretical studies have established that nanofluides have great potential to increase thermal efficiency of Direct Absorption Solar Collector. Recent trends also encourage towards applications of nanofluides on conventional solar flat plat collectors and concentrating collectors to increase overall efficiency of solar energy conversion.

Keywords: Solar Energy, DASC, Nanofluides, Thermal Efficiency

1. INTRODUCTION

Limited availability of fossil fuels and environmental problems associated with them has emphasized the need for new sustainable energy supply options that use renewable energy. Everyday sun radiates enormous amount of energy and the hourly solar flux incident on the earth's surface is greater than all of human consumption of energy in a year [1]. So, problem lies in efficiently collecting and converting this energy into some useful form. The conversion of solar energy into heat is done with the help of solar collectors. Most commonly used collectors are simple in construction and are flat plate type collectors. New classes of collectors which are used to increase the efficiency of the collectors are direct absorption solar collector (DASC) [2]. The DASC's were firstly proposed in the mid 1970's but the major problem faced by these collectors was the poor absorption properties of conventional fluids used in these collectors. By the development of new class of fluids known as nanofluides [3] which show improved properties over the conventional fluids, these type of collectors can gain importance.

In conventional type of flat plate solar collectors they are encountered with three resistances whereas in case of direct absorption type solar collector (DASC), these three resistances are reduced to one. The major problem associated with conventional collectors using micro or millimetre sized particles is Nanofluides are new class of fluids in which nanometer sized (1– 100 nm) particles of metal/non-metals/metal oxides, etc. are dispersed in conventional fluids. As we move towards the nanometer scale, it has been found that the properties of the suspension get changed drastically. Volume % of nanoparticles in base fluid remains very small still impact in terms of thermal efficiency observed is very significant. Addition of nanoparticle into base fluid can significantly enhances thermo physical, mass diffusivity and radioactive heat transfer properties of fluid. Due to these inherent characteristics, Nanofluides are getting increasing attention among scientific, academic and engineers to develop improved systems and devices which are based on Nanofluides as a heat transporting and absorbing medium. Presently many types of nanoparticles are used to prepare Nanofluides.

These are:

- Oxide ceramics (Al_2O_3, CuO, ZnO)
- Metal carbides (SiC, AlC)
- Nitrides (AlN. SiN)
- Metals (Al, Cu, Ag, Au, Mg, Zn)
- Nonmetals (Graphite, Carbon Nanotubes, Fullerenes)
- Layered (Al+ Al_2O_3, Cu+C, Cu+CNT)
- Functionalized Nanoparicles.

1.1 Materials for base fluids

- Water
- Ethylene glycol and other coolants
- Oil and other lubricants
- Bio-fluids
- Polymer based solutions

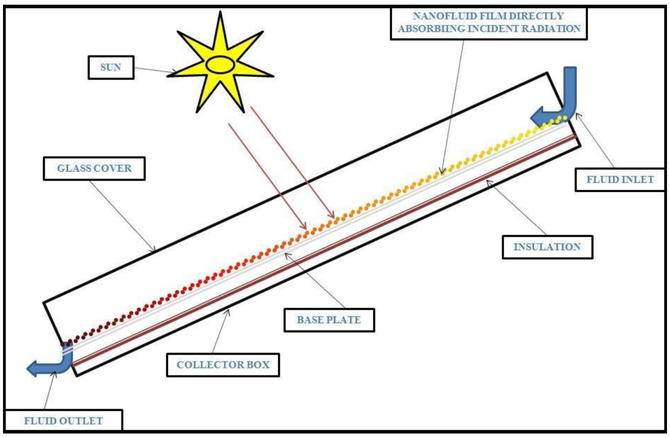

Figure.1. Working principle of Nanofluides on Direct Absorption Solar Collector

2. LITERATURE REVIEW

2.1 CONCENTRATION OF NANOFLUIDE

Gupta *et al* [4] studied the thermal performance of direct absorption solar collector using nanofluides of three different concentrations 10 ppm, 50 ppm and 100 ppm with 20 nm alumina nanoparticles in distilled. They found the collector efficiency increased for all three concentrations of nanofluid than pure water. Collector efficiency enhancement of 39.6% and 22.1% is noticed for 50 ppm and 10 ppm respectively. Enhancement in efficiency with nanoparticle concentrations beyond 50 ppm is found to be lower as compared to other concentrations.

2.2 EFFECT OF NANOFLUIDES ON FLAT PLATE SOLAR COLLECTORS

Meibodi *et al* [5] conducted the experimental study and determine the characteristic curves of a flat plate solar collector where the working fluid is SiO_2/EG–water nanofluid. The tests were performed for volume fractions of 0, 0.5%, 0.75%, and 1% at three mass flow rates, including 0.018, 0.032, and 0.045 kg/s. The results elucidated that despite the low thermal conductivity of SiO_2 nanoparticles, they make a noticeable enhancement in thermal efficiency when are suspended in EG/water. Findings showed that when the heat loss parameter limits to zero, an increase in nanofluid concentration from 0 to 1% results in an efficiency enhancement approximately between 4 and 8%. It was observed that the thermal efficiencies associated with concentrations of 0.75% and 1% are very close. Hence, it is better to use lower volume fraction to reduce the preparation cost and instability problems. The experimental data demonstrated that removed energy parameter decreases with an increase in the mass flow rate of nanofluid. Moghadam *et al* [6] conducted the experiment on the flat-plate solar collector using CuO-H_2O nanofluid as the absorbing medium. The experiments are carried out in Mashhad, Iran (latitude 36.19^0N and longitude 59.37^0E). The influence of the mass flow rate on the solar collector efficiency has also been investigated. The working fluid mass flow rate has been selected in the range of 1–3 kg/min. The volume fraction of nanoparticles is set to 0.4%; the particle dimension is 40 nm. The results demonstrate that using CuO–H_2O nanofluid increases the solar collector efficiency in comparison with that of water by 16.7% (especially in the optimum mass flow rate). The experimental results also prove that the highest heat absorption by the collector occurs at different mass flow rates for water and nanofluid. The optimum mass flow rate depends on the working fluid thermal characteristics. Zeng *et al* [7] performed the experiment to investigate the effect of Cu-H_2O nanofluides on the efficiency of flat-plate solar collectors. The experimental results show that their collecting efficiencies are all superior to that of water. The efficiency of Cu-H_2O nanofluides (Cu:25 nm, 0.1 wt%) is increase up to 23.83%. when the mass fraction gets to 0.2 wt%, the efficiency of Cu-H_2O nanofluides is less than that of CueH2O nanofluides (0.1 wt%). It illustrates that the nanoparticle concentration cannot be too much. Nanoparticle size also has a major effect on the efficiency of flat-plate solar collectors with nanofluides. In allusion to the temperature and heat gain of water in the water tank, the highest temperature and highest heat gain of water in the nanofluid (25 nm, 0.1 wt%) tank can increased up to 12.24% and 24.52% compared with that of water tank, respectively. On the other hand, the frictional resistance coefficient of nanofluides has a slight increase compared to water. In the compatibility aspect, nanofluides has no corrosion on stainless steel and silicone rubber but has a little corrosion on brass. The corrosion problem can be solved by adding some corrosion inhibitor. In conclusion, the solar energy absorbing experiments show that Cu-H_2O nanofluides have good absorption ability for solar energy, and can effectively enhance the efficiency of flat-plate solar collectors. Thus, Cu-H_2O nanofluides can be hopeful to apply in solar thermal energy system. Chaji *et al* [8] studied the effects of different nano particle concentrations of TiO_2 in water as base fluid on a flat plate solar collector. They use three flow rates (i.e. 36, 72 and 108 lit/m^2.hr) and four particles concentration ratios (i.e. 0, 0.1, 0.2 and 0.3 % wt). Adding nano particles to water brought about an improvement of initial efficiency of flat plate solar collector between 3.5 and 10.5% and the index of collector total efficiency between 2.6 and 7% relative to base fluid. Also the results indicate that the initial efficiency (η_0) for 36, 72 and 108 lit/m^2.hr flow rates of water as base fluid were 0.4712, 0.4998 and 0.5457, respectively which reveals the increase of 6.1 and 15.8% of it in the two latter cases in comparison with the first case, 36 lit/m^2.hr flow rate. In addition, the index of collector total efficiency of 72 and 108 lit/m^2.hr mass flow rates has increased by 6.7 and 15.7%, respectively in comparison with 36 lit/ m^2.hr mass flow rate. Roy *et al* [9] conducted an experiment to investigate the heat transfer characteristics of silver/water nanofluid in a solar flat plate collector. The solar radiation heat flux varies between 800 W/m^2 and 1000W/m^2, and the particle concentration varies between 0.01%, 0.03%, and 0.04%. The fluid Reynolds number varies from 5000 to 25000. The influence of radiation heat flux, mass flow rate of nanofluid, inlet temperature into the solar collector, and volume concentration of the particle on the convective heat transfer coefficient and the collector efficiency are studied. Both parameters increase with increase in the particle volume concentration and flow rate. The maximum percentage increase obtained in the convective heat transfer coefficient is 18.4% for the 0.04% volume concentration at a Reynolds number of 25000. An increase in the performance of nanofluid is also witnessed when compared to the base fluid, which has a strong dependency on volume concentration and mass flow rate.

2.3 DASC INSTEAD OF FLAT PLATE SOLAR COLLECTOR

Gupta *et al* [10] conducts an experiment to investigate the effect of using Al_2O_3– water nanofluid on the direct absorption solar collector efficiency with three different flow rates 1.5, 2, 2.5lpm. The volume fraction of nanoparticles has been selected as 0.005%. The collector efficiency increased with nanofluid than pure water for all flow rates. Collector efficiency enhancement of 8.1% and 4.2% has been observed for 1.5 and 2lpm flow rate of nanofluid respectively. The experimental results prove that the optimum flow rate for maximum collector efficiency occurs at different flow rate for water and nanofluid i.e. 2.5 and 2 lpm respectively in this study. Otanicar *et al* [11] experimentally studied the effect of nanofluides on a DASC and demonstrated some unique advantages over conventional collectors:

• Heating within the fluid volume, limiting the need for a hot surface, which only transfers heat to a small area of fluid, and allowing the peak temperature to be located away from surfaces losing heat to the environment.

• Variability of the size, shape, material, and volume fraction of the nanoparticles allows for tuning to maximize spectral absorption of solar energy throughout the fluid volume.

• Enhancement in the thermal conductivity can lead to efficiency improvements, although small, via more effective fluid heat transfer.

• Vast enhancements in surface area due to the extremely small particle size, which makes nanofluid, based solar systems attractive for thermo chemical and photocatalytic processes.In the study they use geometry 30 nm diameter particles at 1% volume fraction have 300 times more surface area than the bottom of the channel itself. Further improvements to the efficiency could be achieved by taking advantage of particle size and shape distributions to make the volumetric absorber more selective. In addition by determining the optimum profile of volumetric absorption, potentially such that the maximum temperature is closer to the centre of the fluid, one could minimize heat loss and further enhance the efficiency. Luo *et al* [12] studied the simulation model was proposed by combining the radiative heat transfer in particulate media with conduction and convection heat transfer in the DAC collector to predict the photo thermal efficiency. They used TiO_2, Al_2O_3, Ag, Cu, SiO_2, graphite nanoparticles, and carbon nanotubes as nanofluides, whose transmittances and testing performances were reported. These results are used to validate the simulation model.

- The conductivity of the nanofluides decreased as the temperature increased, similar to that in the matrix, and the conductivity increased with the increase of nanoparticle loadings. The radiative properties of the nanofluides were related to the depth of the layer, and low loadings can efficiently enhance the absorption of 200–2000 nm radiation.
- The predictions of the model were in accordance with the experimental results. The predictions showed that the nanofluides improved the outlet temperature and the efficiency by 30–100 K and by 2–25% than the base oil, respectively. Except for TiO_2, the nanoparticles (C, Ag, SiO_2, Al_2O_3, and Cu) have acceptable performances to improve the efficiency of the DAC. According to the efficiency value, the order of nanofluides could be given as follows: C ~ Ag ~ Al_2O_3 > SiO_2 ~ 0.01%Cu > 0.025%Cu > TiO_2.
- The radiative heat flux was absorbed by the body of nanofluides in the DAC collectors instead of by the top surface for coating ones. The photo thermal efficiencies of nanofluides of 0.01 volume% graphite and 0.5 volume% Al_2O_3 are 122.7% (0.01 volume% graphite) or and 117.5% (0.5 volume% Al_2O_3) of that of the coating absorbing collector, respectively.

3. CONCLUSIONS

From the above review it can be concluded that:-

• The thermal efficiency of solar collector is improved when we use certain amount of nanoparticles with base fluid.

• The efficiency of conventional solar flat plate collector is less as compared to that of direct absorption solar collector when we use the nanofluides on both.

• As the flow rate of nanofluides increases the efficiency of collector also increases, up to certain value, but if flow rate is more than the optimum flow rate, then the effect of nanoparticles does not occur.

• The concentration of the nanoparticles in the base fluid also plays an important role in thermal efficiency enhancement.

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