Paper ID 46

A review on performance of nanofluids in solar collector

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Abstract

In this era, solar energy is a remarkable energy source. This review paper will investigate on nanofluids use in solar collector. For better efficiency, nowadays nanofluids are used for heat transferring. Nanometer sized nanoparticle inclusion is very efficient in this aspect. Optimization of volume fraction for getting better efficiency is reviewed in this paper. Besides, nanoparticle size is also an important fact. This review paper will analysis all this matter. The main goal of this review paper is to emphasize on getting better and better efficiency using nanofluids in solar collector. Environmental viability and economical consideration are also discussed in this review paper.

INTRODUCTION

Base fluids such as water, ethylene glycol and heat transfer oil plays an important role in many industrial processes such as power generation, heating or cooling processes, chemical processes, fuel cells and pharmaceutical process. By inserting ultra-fine solid particles as suspension into some base fluids a new particle comes in study, which is namely "Nanofluid". The solid particles are nanometer sized, specifically of 1-100 nm. It's obviously far better than a liquid operating alone for heat transferring. Choi first used the term "nanofluid" in 1995[1]. Water, ethylene glycol and heat transfer oil are used as base fluids. On the other hand, metal oxides, carbides and carbon nanotubes are used as solid particles for their high heat conductivity property. Nanofluids show better stability, rheological properties and higher thermal conductivity than the suspensions with particles of millimeter-or-micrometer size.

Straightly, nanofluids are used for better heat transferring. In recent years, many researchers have investigated theoretically and experimentally the effects of nanofluids on the enhancement of heat transfer in thermal engineering devices. Research has been done on nanofluids preparation and characterization by Le, Zhou, Tung and Shneider[2]. Lee, Lee, Choi, Zang and Choi[3] has researched on nanofluids conductivity, mechanics and models. Ghadimi, Saidur and Metselaar[4] has researched on nanofluids stability properties and characterization in stationary conditions. A critical review of heat transfer characteristics of nanofluids has been done by Trisaksri and Wongwises[5].

Solar energy is a remarkable energy source nowadays. Environmental consideration and shortage of fossil fuels made us move for solar energy as an alternative energy source. The increasing price of fossil fuels is another reason. For better efficiency we use nanofluids as working fluid in consuming solar energy. In this review paper we will investigate on performance of nanofluids in increasing the efficiency of solar collector. Different types of solar collector will be investigated. Finally, economical consideration and environmental viability of using nanofluids will be discussed.

NANOFLUIDS

So far, different nanofluids have been taken for both experimental and numerical study. Different metallic and non-metallic nanofluids have been investigated. Some of the metallic nanofluids are Cu-water, Au-water, Ag-water, Cu-ethylene glycol and many others. Some of the non-metallic nanofluids are Al_2O_3-water, SiC-water, CuO-water and many others.

SOLAR COLLECTOR AND PERFORMANCE OF NANOFLUIDS IN SOLAR COLLECTOR

Solar collectors are heat exchangers which transforms solar radiation energy into internal energy. First, solar collector absorbs solar radiation energy and then that is converted into heat and then that heat is transferred to some fluids. Basically these fluids are oil, air or water. The energy collected is carried from the fluid either directly to the hot water or to space conditioning equipment or to a thermal energy storage tank from which it can be drawn for use on cloudy days or at night. Initially flat plate solar collector was used in collecting solar energy. Flat plate solar collector is shown in Fig. 1.

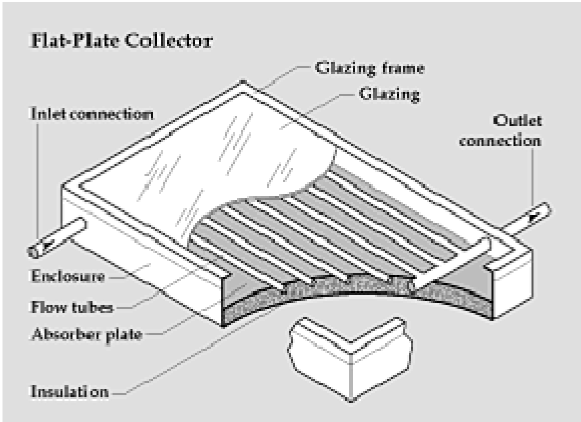

Fig. 1. Schematic diagram of a flat plate solar collector.

In this review paper we will be focusing on enhancement of efficiency of solar collector using nanofluids. Direct absorption solar collector (DASC) is a nanofluids based solar collector. Initially, we used flat plate solar collector. But, that was not highly efficient. That forced us to collect solar energy by DASC. The schematic of a DASC is shown in fig. 2.

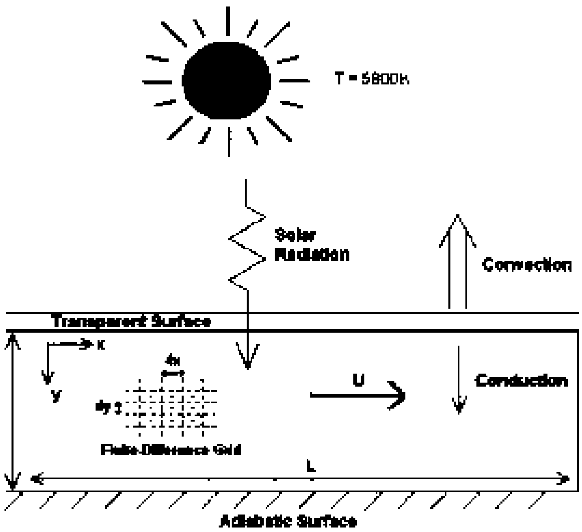

Fig. 2. Schematic of direct absorption solar collector.

The upper part of the collector is covered by a glass while the lower is insulated, so it is adiabatic. The efficiency is given by the equation.

$$\eta = \frac{\text{useful gain}}{\text{available energy}} \qquad (1)$$

Tyagi, Phelan and Prasher[6] plotted the variation of collector efficiency as a function of volume fraction(%), where the volume fraction varies from 0.1% to 5%. Their result showed that efficiency increases for lower volume fraction. Numerically from 0.1% to 2%. After 2% efficiency remains constant. They attributed the increase of collector efficiency to the increase in attenuation of sunlight passing through the collector due to the nanoparticles addition that leads to increase of collector efficiency. The graph is shown in fig. 3. Tyagi, Phelan and Prasher [6] also plotted collector efficiency as a function of nanoparticle size at volume fraction 0.8%. Their result revealed that collector efficiency increases with a slight increase of nanoparticle size. The graph in shown in fig. 3. Otanicar, Phelan, Prasher, Rosengarten and Taylor [7] investigated experimentally and numerically the effects of different nanofluids (carbon nanotubes, graphite and silver) on the performance of a micro scale direct absorption solar collector. The main difference in the steady-state efficiency between the nanofluids occurs in silver particles, when the size is between 20 to 40 nm. When the size is having from 40 to 20 nm the efficiency is found to increase about 6%. The collector efficiency for silver particles is shown in fig. 4.Unlike the result obtained by Tyagi, Phelan and Prasher[6], with increase of nanoparticle size, efficiency of collector decreases.

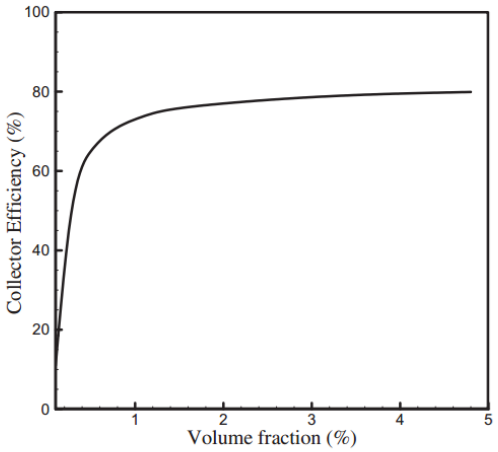

Fig. 3: DASC efficiency vs. volume fraction.

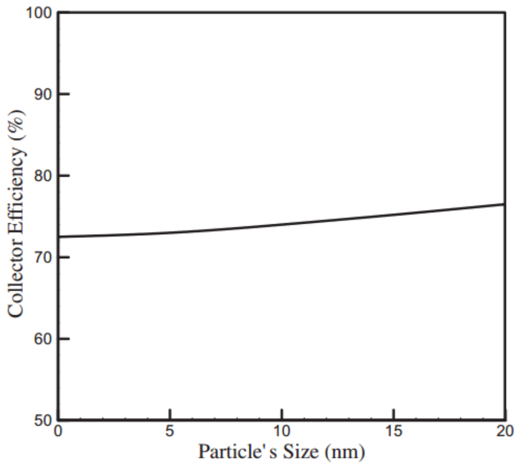

Fig. 4. DASC efficiency vs. particle size at 0.8% volume fraction.

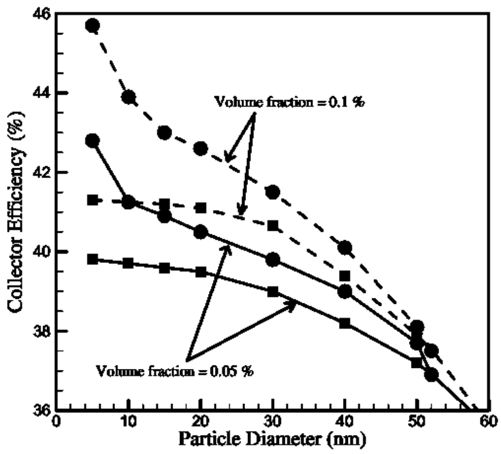

Fig. 5. Collector efficiency vs. particle diameter for silver particle in micro scale direct absorption solar collector.

Nanoparticle inclusion increases thermal conductivity. The increase in thermal conductivity is a big factor in solar collector efficiency enhancement. Different nanoparticles, their base fluids, nanoparticles and enhanced thermal conductivity is given in table 1.

ENVIRONMENTAL VIABILITY

Nanofluids application in solar energy is beneficial to reduce the environmental problems. It has no bad impact on environment.

DISCUSSIONS

Different nanofluids have been taken for use in solar collector. Among all the nanofluids CNT nanofluids are more efficient for use. For micro scale direct absorption solar collector silver nanoparticle use was more efficient.

ECONOMICAL CONSIDERATION

High cost in nanofluid production is the biggest impediment in nanofluid application. Nanofluids can be produced either by one step or two step methods.

But both require advanced equipment. Lee and Mudawar[13] and Pantzali, Mouza and Paras[14] stressed that high cost of nanofluids is among the drawback of nanofluid applications.

CONCLUSION

Nanofluids are used to increase system efficiency. This paper reviewed on nanofluids application to enhance solar collector efficiency. Nanoparticle inclusion is helpful and a larger volume fraction is not the best option. So, it is suggested that nanofluids in different volume fraction must be tested to find the optimum value. Particle size is also a big fact in collector. It is also worthy to carry out experimental work on size effect of nanoparticles. From economical point of view the use of nanofluids in collecting solar energy was found costly. That is a huge drawback in this aspect. Nanofluids use is helpful for environment.

Table 1: Thermal conductivity of different nanofluids.

Reference	Type	Particle	Base fluid	Particle size	Thermal conductivity enhancement	Volume fraction
[8]	Metallic	Fe	Ethylene glycol	10 nm	18%	0.55%
[9]	Metallic	Ag	Water	60-80 nm	17%	0.001%
[10]	Non-metallic	Al_2O_3	Water	13 nm	30%	4.3%
[11]	Non-metallic	MWCNT	Synthesis oil	25 nm in diameter and 50 µm in length	150%	1%
[12]	Non-metallic	CuO	Water	50 nm	17%	0.4%

ACKNOWLEDGMENTS

We are thankful to MMMRN group of BUET for their support. We are also thankful to ICEAB authority for organizing the conference.

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