Flat Plate Solar Collector Using Nanofluids

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ABSTRACT

Solar energy is one of the cleaner forms of renewable energy resources. The conventional solar collector is a well established technology which has various applications such as water heating, space heating and cooling. However, the thermal efficiency of these collectors is limited by the absorption properties of the working fluid, which is very poor for typical conventional solar flat plate collector. Recently usage of nano fluids, which is basically liquid- nano particle colloidal dispersion as a working fluid has been found to enhance solar flat plate collector thermal efficiency maximum by 30 percent. In this paper an effort has been made to present a comprehensive overview on thermal performance of solar flat plate collector for water heating using different nano fluids. Moreover, kgCO2/kWh at the site due to usage of nano fluid as a result of enhancement of thermal performance has also been discussed.

Keywords: colloidal dispersion, conventional solar collector, Thermal Efficiency

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INTRODUCTION

The fluids with nano sized solid particles suspended in them are called "nanofluids." The suspended metallic or nonmetallic nanoparticles change the transport properties and heat transfer characteristics of the base fluid. Nanofluids are the new generation heat transfer fluids for various industrial and automotive applications because of their excellent thermal performance and the word was which was coined at Argonne National Laboratory of USA by Choi in 1995, which showed that the conventional liquid thermal performance could be remarkably improved using nanoparticles. Nanofluids can be used for a wide variety of engineering applications like transportation, thermal management of electronics, medical, food, defense, nuclear, space, and manufacturing of many types. Heat transfer enhancement in solar devices is one of the key issues of energy saving and compact designs. Solar energy is widely used in applications such as electricity generation, chemical processing, and thermal heating due to its renewable and nonpolluting nature. Most solar water heating systems have two main parts: a solar collector and a storage tank. The most common collector is called a flat-plate collector but these suffer from relatively low efficiency. There are so many methods introduced to increase the efficiency of the solar water heater. But the novel approach is to introduce the nanofluids in solar collector instead of conventional heat transfer fluids (like water).One of the key feature for heat transfer enhancement is the thermal conductivity, the majority of the studies have discussed the thermal conductivity of nanofluids.Recently some studies were reported about using the nanofluids in solar collectors.

Natarajan has investigated the thermal conductivity enhancement of base fluids using carbon nanotubes and suggested if these fluids are used as a heat transport medium, it increases the efficiency of the conventional solar water heater. Tyagi et al. has studied theoretically the capability of using a non concentrating direct absorption solar collector and compared its performance with that of a conventional flat-plate collector. Otanicar has studied environmental and economic influence of using nanofluids to enhance solar collector efficiency in compare with conventional solar collectors. Otanicar has studied experimentally the effect of different nanofluids on the efficiency of the micro-solar- thermal-collector. He reported an efficiency improvement up to 5% in solar thermal collectors by utilizing the nanofluids as the absorption medium. Yousefi et al. experimentally investigated the effect of Al2O3 nanofluid in a flat-plate solar water heater and reported that using the surfactant the maximum enhanced efficiency is 15.63%. Yousefi et al. [19] experimentally investigated the effect of pH variation of MWCNT–H2O nanofluid on the efficiency of a flat-plate solar collector and showed that by the more differences between the pH of nanofluid and pH of iso electric point causes the more enhancements in the efficiency of collector. Very limited information is available flat-plate solar collectors using nanofluids which motivated this investigation. The major goal of the present study, theoretically investigates the performance of flat-plate solar collectors with Al2O3/water nanofluid. The effect of using Al2O3 nanofluid with different particle volume concentrations (0.5-2%) are investigated in this study.

THERMAL PERFORMANCE ANALYSIS

The Al2O3nanofluid based flat-plate solar collectors considered in present study. The physical dimensions and configuration of the flat-plate solar collector are listed in Table 1.

Table 1: Flat-plate solar collector geometry

Property	Value
Width x length	1x2 (m)
Glazing transmittance	0.90
Absorber absorptance	0.95
Absorber thickness	0.25 (mm)
Width of absorber fin	115 (mm)
Heat transfer fluid	Al2O3/water nanofluid

ASHRAE Standard suggests performing the tests in various inlet temperatures. The useful energy can be calculated using Eq. (1).

$Q_u = mc_p (T_{fo} - T_{fi}) \dots (1)$

Where, is the rate of useful energy gained, is the mass flow rate of fluid flow, Cp is the heat capacity of water or nanofluid and are the inlet and outlet fluid temperature of solar collector. The effective specific heat of the nanofluid can be calculated from Xuan and Roetzel relation [20] as:

$(\rho c_p)nf = (1-\text{ø})(\rho c_p)w + \text{ø}(\rho c_p)p \dots (2)$

Where refers to the heat capacity is the effective density of nanofluid, the subscripts p, w and nf refer to the nanoparticle, base fluid and the nanofluid, respectively and is the nanoparticle volume concentration. The density of nanofluid is calculated from Pak and Cho [21] using the following equation:

$\rho nf = \text{ø} \rho p + (1-\text{ø})\rho w \dots (3)$

Table 2: Efficiency parameter of the Flat-plate solar collector for water at various flow rates

Mass flow rates (Lit/min)	FR,UL	η
0.5	48.6	0.482
1.0	44.68	0.493
1.5	39.52	0.516
2.0	35.96	0.524

Table 3: Efficiency parameter of the Flat-plate solar collector for Al2O3nanofluid at various Concentrations

% Concentration	FRUL	η
0.5	49.23	0.549
1.0	45.19	0.649
1.5	42.36	0.726
2.0	36.29	0.639

By comparing the efficiencies of nanofluid with different concentrations, it can be seen that the efficiency at 1.5%

The instantaneous collector efficiency relates the useful energy to the total radiation incident on the collector surface by Eq. (6) or (7).

In a particular case of a solar collector where the temperature of the fluid entering the collector equals the ambient temperature i.e., results collector efficiency is at its maximum that is If the efficiency test is performed at near the normal incidence conditions so that FR is constant and both FR and UL are constant within the range of tested temperatures, a straight line will result when the efficiencies are obtained from averaged data is plotted against according to Eq. (7). The intersection of the line with the vertical efficiency axis equals to FR. The slope of the line is equal to FRUL. At the

intersection of the line with the horizontal axis collector efficiency is zero usually occurs when no fluid flows in the collector.

RESULTS AND DISCUSSIONS

The solar collector is modeled tested for various mass flow rates of 0.5, 1, 1.5 and 2 Lit/min. The experimental data has been taken from literature. The performance parameters are calculated for various input parameters. Due to lack of available experimental data on solar collector using nanofluid, the results has been tested with the design example and showed well matching. Table 2 show that the, value of the collector for 2 Lit/min is highest, and the FR, UL value in this mass flow rate is lowest. Therefore based comparison with the conventional SWHS (Solar water heating system).

CONCLUSION

The effect of using the Al2O3 nanofluid as absorbing medium in a flat-plate solar collector is investigated. The effect of mass flow rate and particle volume fraction on the efficiency of the collector is investigated. The results show that using the 1.5% (optimum) particle volume fraction of Al2O3 nanofluid increases the thermal efficiency as well as kgCO2/kWh saving in hybrid mode of solar collector in comparison with water as working fluid by 31.64%.

REFERENCES

[1] Choi SUS. Enhancing thermal conductivity of fluids with nanoparticles. ASME FED-Vol. 231/MD-Vol. 66 1995:99–103.
[2] Wong KV, Leon OD. Applications of nanofluids: current and future. Advances in Mechanical Engineering 2010(ID 519659):pp 11.
[3] Ho CD, Chen TC. The recycle effect on the collector efficiency improvement of double-pass
[4] Sheet-and-tube solar water heaters with external recycle. Renew Energy 2006; 31(7):953–970.
[5] Hussain AM. The performance of a cylindrical solar water heater. Renew Energy 2006; 31(11):1751–1763.
[6] Xiaowu W, Hua B. Energy analysis of domestic-scale solar water heaters. Renew Sustain Energy Rev 2005; 9(6):638–645.
[7] Xuesheng W, Ruzhu W, Jingyi W. Experimental investigation of a new-style double-tube heat exchanger for heating crude oil using solar hot water. In: Appl Therm Eng; 2005. p. 1753–1763.
[8] Xie H, Wang J, Xi T, Ai F. Thermal conductivity enhancement of suspensions containing nanosized alumina particles. Int. J. Appl. phys 2002; 91:4568–4572.