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Review on Investigation on Efficiency of Flat Plate Collector with Nano-Fluid

#1D.D. Barale, #2R.R. Arakerimath, #3C. Limbadri

#1Department of Mechanical Engineering, G.H. Raisoni College of Engg.& Management,pune.

#2HOD, Department of Mechanical Engineering, G.H. Raisoni College of Engg.& Management,pune.

#3Faculty of Department of Mechanical Engineering, G.H. Raisoni College of Engg.& Management, pune.

ABSTRACT

Application of nanofluids in thermal energy devices such as solar collectors is developing day by day. This paper reports the results of investigation on a flat plate solar collector where the working fluid is nanofluids.In this study, nanofluids with different mass fraction and size were prepared through two-step method. Its thermal conductivities and the effect of nanofluids on the efficiency of a flat-plate solar collector was investigated. Meanwhile, the water temperature, heat gain of the flat plate solar water heater and the frictional resistance coefficient of working fluid were also investigated.The experimental results reveal that utilizing the nanofluid increases the collector efficiency in comparison to water as an absorbing medium. The nanofluid with mass flow rate of 1 kg/min increases the collector efficiency about 21.8%. For any particular working fluid, there is an optimum mass flow rate which maximizes the collector efficiency. Adding nano particles to a base fluid produces a nanofluid which has enhanced thermal characteristics compared with its base fluid.

Keyword: **Online social network, Machine Learning, Filtering Rules, Short text classification, Blacklist, Whitelist.**

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I. INTRODUCTION

Solar thermal energy is by far the largest exploitable resource. It is a very convenient source of heating. It can be used free of charge, and does not need to be transported. The critical problem for solar thermal utilization is how to improve the efficiency of the solar collector. It can be performed with optimizing the structure of collector or developing a new type of working medium. Currently, water as a medium in solar thermal energy system is used widely. Butthe thermal conductivity of water is not high. With the development of nanotechnology, an innovative heat transfer fluid arises. Nanofluid based solar collector where nano partical in liquid medium can scatter and absorb solar radiation. They have recently received interest to efficiency distribute solar energy. they have more efficiency as compared to conventional solar collector.

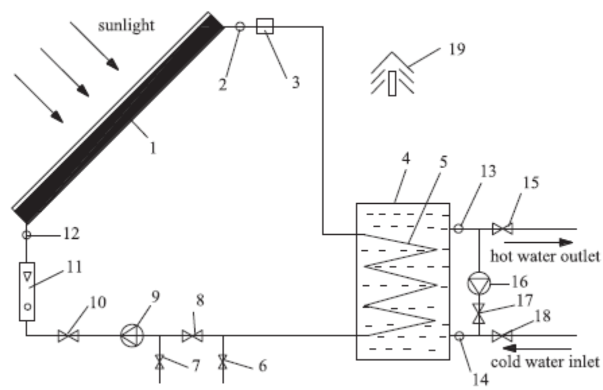
Nanofluids have been considered as a new-type heat transfer fluid because of their enhanced thermal conductivities. In the past decade, many researchers have evaluated the role of nanofluids in heat transfer enhancement of thermal engineering equipment. Recently some researchers have put forward to use the nanofluid as the working fluid for the solar collectors.Tyagi et al.[1] have investigated theoretically the feasibility of using a non-concentrating direct absorption solar collector (DAC) and compared its performance with that of a conventional flat plate collector. The AleH2O nanofluid was used as the absorbing medium.
They concluded that the absorption of incident radiation of nanofluids by more than nine times over that of pure water and the efficiency of a DAC using nanofluid as the working fluid is up to 10% higher than that of a flat-plate collector.

Otanicar et al.[2]performed the experiments of photothermal properties for nanofluids made from a variety of nano particles (carbon nanotubes, graphite, and silver). They presented an efficiency improvement up to 5% in solar thermal collectors by utilizing the nanofluids as the absorption medium. Taylor et al.[3] have studied the nanofluid optical property characterization. In Taylor's research, the nanofluids that mixed water and graphite, aluminum, copper, silver, titanium dioxide nanoparticles were used as the absorbing medium. According to the results of Taylor's study, over 95% of incoming sunlight can be absorbed with the nanoparticle volume fractions less.Yousefi et al.[4] performed the experiments of efficiency of a flat-plate solar collector with Al2O3eH2O and MWCNT-H2O nanofluids as the working fluid respectively. The results show that the efficiency of solar collector can be enhanced by 28.3% with 0.2 wt% Al2O3 nanofluid than that of pure water. The dose of surfactants in MWCNT-H2O nanofluids can affect the efficiency of solar collector. The more differences between the pH of nanofluids and pH of isoelectric point cause the more enhancements in the efficiency of collector.Mao et al. [5] performed the experiments of efficiency of a direct absorption solar collectors used carbon-coated copper water-based nanofluids. The results show that the efficiency of solar collector is reach to 74.69%.Mercatelli et al. [6] investigated the absorption and scattering properties of nanofluids consisting in aqueous and glycol suspensions with single-wall carbon nano horns. The results show that SWCNHs-based nanofluids have considerably higher sunlight absorption ability with respect to the pure base fluids. The fraction of the power stored in SWCNHswaternanofluids is higher than that of SWCNHs-glycol nanofluids with the same volume fraction.

II. NANOFLUID

Nanofluid based solar collector where nano partical in liquid medium can scatter and absorb solar radiation. They have recently received interest to efficiency distribute solar energy. they have more efficiency as compared to conventional solar collector. The CuH2O nanofluids was prepared through two-step method (Cu nanoparticle, the average diameter is about 25 nm and 50 nm, supplied by Shanghai ChaoWei Nanotechnology Co.Ltd., China; the base fluid is deionized water). A certain amount of nano powders were blended with deionized water, and some dispersing agents (SDBS) were added, The suspensions were stirred 30 min by magnetic stirring apparatus and oscillated 40 min through ultrasonic oscillation apparatus at 90 W The particle size was measured by Scanning Electron Microscope (Nova Nano SEM 430), There are a few larger particles, which are likely aggregates of the smaller ones, but the whole distribution of the particles is relatively well- dispersed. The particles are basically spherical or near spherical, the mean diameter is about 25 nm and 50 nm.The schematic diagram of the solar collector system is shown in Fig. 1. The two solar water heater systems have a tank for absorbing the heat energy, respectively. The capacity of the tank is about 100 Lit. In the nanofluids solar cycle, one heat exchanger was used inside the tank. So the nanofluids can transmit the heat load of the solar cycle to the water. While in the water solar cycle system, the tank has no heat exchanger. Two glass rotameters were used to measure the mass flow rate of working fluid in the solar system.Two thermocouples (Type K) were used to measure the fluid temperatures in the inlet and outlet of solar collector. The test precision of thermocouples is ±0.2 _C, and they were calibrated by a precision thermometer. All thermocouples were connected to thedata acquisition system Agilent 34970A. The interval time of data acquisition is 20 s. The air temperaturewas measured by a platinum resistance thermometer with a cover for solar radiation protection. The total solar radiationwas recorded by a TBQ-2 solar meter which using a calibrated reference solar meter with a valid calibration certificate. The platinum resistance thermometer and solar meter were connected to the solar data logger system.

III. EXPERIMENTAL SETUP AND DATA PROCESSING



1 flat plate collector 2, 12, 13, 14 Thermocouple 3 vent valve 4 water tank 5 Heat exchanger 6, 7, 8, 10, 15, 17 valve 11 Flow meter 9, 16 water pump 19 platinum resistance thermometer

Fig.1. Schematic diagram of solar thermal energy measuring system.

The thermal performance of the flat-plate collectors were evaluated by the ASHRAE Standard 86-93. The collecting efficiency, water temperature and heat gain were compared in the same solar irradiation. The tests have performed from 9:00 to 16:00. The volume flow rate of wokingfluids is 140 L/h. The heat gain of fluids can be calculated using Eq. (1). The heat gain of fluids can also be in terms of the energy absorbed by the absorber and the energy lost from the absorber as given by Eq. (2)

$$Q = mC_p(t_o - t_i) \qquad (1)$$

$$Q = A_c F_R[G(\tau\alpha) - U_L(t_i - t_a)] \qquad (2)$$

where Q is the heat gain of fluids, W; m is the mass flow rate, kg/s; Cp is the heat capacity of water or nanofluid, J/(kg K); to is the outlet fluid temperature, _C; tiis the inlet fluid temperature, _C; ta is the environment temperature, _C; Ac is the surface area of solar collector, m2; FR is the heat removal factor; G is the solar radiation, W/ m2; ta is the absorptance-transmittance product; UL is the overall loss coefficient of solar collector, W/(m2 K);

The heat capacity of nanofluids can be calculated by Eq. (3)

$$c_{pn} = c_{pp}\varphi + c_{pb}(1-\varphi) \qquad (3)$$

whereCp,n, Cp,p, Cp,bis the heat capacity of nanofluids, nanoparticle and base fluid, respectively, J/(Kg K); 4 is the volume fraction of Cu nanoparticle; The heat capacity of Cu and water is 390 J/(kg K) and 4182 J/(kg K), respectively.The instantaneous collector efficiency, hi, can be given by Eq. (4)

or Eq. (5)

$$\eta_i = F_R(\tau\alpha) - F_R U_L \frac{t_i - t_a}{G} \qquad (5)$$

Nanofluid preparation:

In this research, SiO2 nano particles with an average size of 40 nm are

Suspended in a mixture of EG and water (50:50 vol.%) with the

$$\eta_i = \frac{Q}{A_c G} = \frac{mC_p}{A_c}\frac{t_0 - t_i}{G} \qquad (4)$$

Following instruction. Depending on the desired concentration, thespecified quantity of nanoparticles is added gradually to the mixture of EG/water and simultaneously the suspension is well stirred by a stirrer. Next, the suspension is inserted in an ultrasonic bath for about 2 h to break down the agglomeration between nanoparticles and minimizing the sedimentation. No sedimentation was observed for at least two weeks with naked eyes. Nanofluids in three different volume concentration including 0.5%, 0.75%, and 1% are . Fig. 1 displays a photograph of the prepared nanofluid as well as the base fluid.

IV. RESULTS AND DISCUSSION

4.1. Thermal conductivity

In order to investigate the effect of mass fraction andnanoparticle size on the enhancement of the thermal conductivity. The thermal conductivity of CuH2O nanofluids with five different mass fraction (0.01 wt%, 0.02 wt.%, 0.04 wt%, 0.1 wt%, 0.2 wt%) and different nanopaticle size were measured by Hot Disk instrument.

Fig.shows the enhanced thermal conductivity as a function of mass fraction of Cu suspended into deionized water. knand kb stand for the thermal conductivity of the nanofluids and deionized water, respectively. The data indicates that the thermal conductivity of nanofluid increases nonlinearly with mass fraction of the nanoparticles. The enhancement rate is more and more slowly with the mass fraction increases. When the mass fraction is 0.01 wt% and 0.1 wt%, thermal conductivity is increased up to 17.01% and 23.58% at 70 _C, respectively. It indicates that the nanoparticle concentration has a major influence on thermal conductivity.

Fig. 3 shows the enhanced thermal conductivity as a function of nanoparticle size of Cu(0.1 wt%). As can be seen from the data, the thermal conductivity of 25 nm CueH2O nanofluids is larger than that of 50 nm CueH2O nanofluids. There are two possible explanations to this phenomenon. On the one hand, in the same mass fraction, the quantity of small particle is more than that of large particle. It lead to the former has a larger interfacial area between iquid and particles. Hence, the heat transfer is turned to more quick and high efficiency. On the other hand, due to the small size effect of nanoparticles, the nanoparticles in suspension will random walk. The micro movement of nanoparticles makes the microconvection phenomena exists between particles and liquid. This kind of microconvection enhances the energy transfer process between the particles and liquid, which increased the thermal conductivity of nanofluids. Most important of all, in the particle movement also with the migration of energy at the same time. This part of the energy transfer is closely related to the movement intensity of the particles. The scale of the particle is smaller, the greater the intensity of micromotion, the more frequently the nanoparticles move. It will lead to the nanofluids internal energy transfer rate faster, which make the thermal conductivity of nanofluids greater.

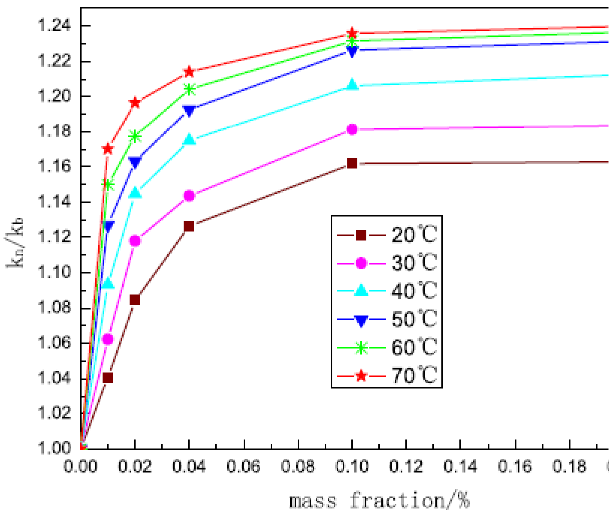


Fig. 2. Thermal conductivity ratio (kn/kb) as a function of temperature at different mass fraction of Cu(Cu:25 nm).

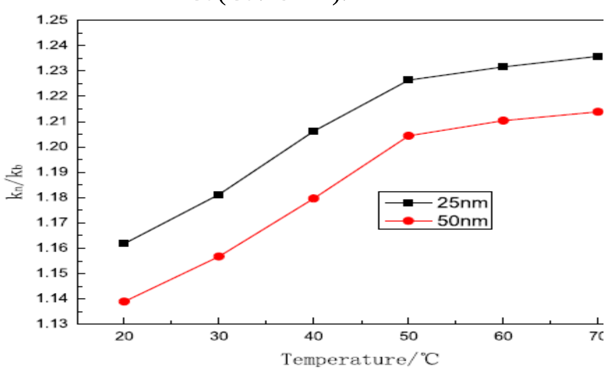


Fig. 3. Thermal conductivity ratio (kn/kb) as a function of particle size at differenttemperature (mass fraction is 0.1%).

4.2 The effect of mass fraction

In order to study the performance of nanofluids as the working fluids in the solar collector system, each experiment was performed four times and the good data were chosed to analyze. Fig 4 shows an example of typical recorded data for water and nanofluids (Cu:25 nm, 0.1 wt%) at 140 L/h in one of the test days. The inlet fluid temperature is almost remain unchanged, the outlet fluid temperature is the critical parameter. As can be seen from Fig. 4, before 180 min (12:00), the outlet temperature of nanofliuds is higher than that of water. With the solar radiation decline (12:00e15:00), the temperature difference of the outlet between nanofluids and water is reduce gradually. In the end, the outlet temperature of nanofliuds and water is almost equal. There is a possible explanation to this phenomenon. During the high solar radiation, the heat loss is very little compared with the solar thermal energy absorbed by the fluids. The temperature of nanofluids enhanced faster than that of water because of the superior heat transfer performance.

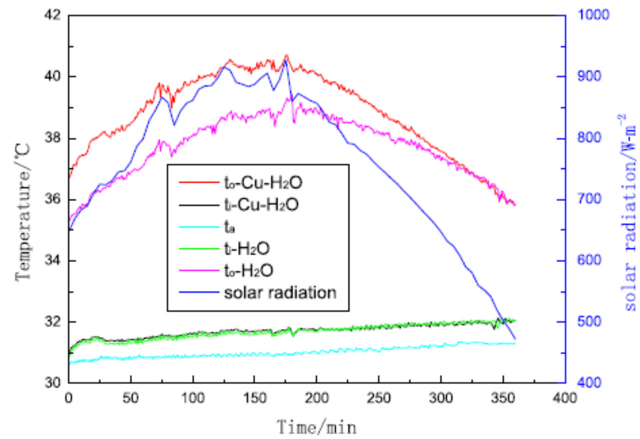


Fig. 4.Temperature curve of CueH2O and water (Cu:25 nm, 0.1 wt%, ta is the ambient air temperature).

Fig. 5 shows the effect of mass fraction of nanofluids on the efficiency of solar collector. As shown in Fig. 5 the efficiency of flatplate solar collector with Cu nanofluid is higher than that of water. The maximum efficiency (ti¼ta) of flat-plate solar collector with 0.1 wt% CueH2O nanofluid is increased up to 23.83% compared with tap water. But with the mass fraction increasing, the efficiency declined instead. For example, the maximum efficiency at 0.2 wt% is decreased up to 5.97% compared with 0.1 wt% CueH2O nanofluid. There are two possible explanations to this result. On the one hand, according to previous works [27], nanoparticles in base fluid at higher concentration tend to be agglomerated and the stability of homogenous solutions will be reduced. On the other hand, the viscosity of nanofluids is enhanced with the mass fraction increasing. It lead to the boundary layer thickness increasing. Hence, the heat transfer rate reduces. The experimental data are fitted with linear equations to provide the characteristic parameters of the flatplate solar collector in order to compare the effect of different mas fraction. The specific fitting parameters are shown in Table 1.

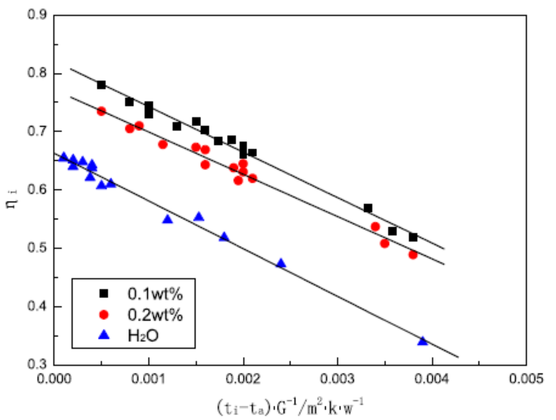


Fig. 5.The efficiency of the flat-plate solar collector with CueH2O nanofluids andwater as the absorbing medium (Cu:25 nm).

4.3 The effect of nanoparticle size

Table 1
Fitting parameters of collection efficiency curves for CueH2O and water.

Working fluid	$F_R(\tau\alpha)$	FrUl	R^2
CueH2O(25 nm, 0.1 wt%)	0.821	78.021	0.986
CueH2O(25 nm, 0.2 wt%)	0.772	72.506	0.979
H2O	0.663	81.831	0.988

4.4. Temperature and heat gain of water in the tank

The temperature curves of water in the two tanks are shown in Fig. 6. As can be seen from the data, the water temperature in system the nanofluids as working fluid increases more quickly than that of system water as working fluid. Before 300 min (about 14:00), the water temperature rises faster.

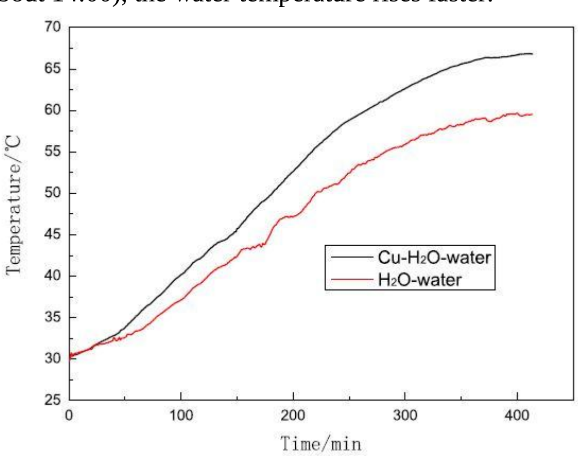


Fig. 6.Temperature curve of water in the tank of the flat-plate solar water heater

(Cu:25 nm, 0.1 wt%).

With the solar radiation decline, the water temperature increased more and more slowly. In the end, it reaches the maximum value. The highest temperature of water in CueH2O nanofluid (Cu:25 nm, 0.1 wt%) system is increased up to 12.24% compared with water system. Fig. 11 shows the heat gain of water in the tank. The maximum heat gain of water in CueH2O nanofluid (Cu:25 nm, 0.1 wt%) system is increased up to 24.52% compared with water system.

4.5 The frictional resistance coefficient

The viscosity of base fluid will increase dues to the nanoparticles suspend into water. Hence, the frictional resistance coefficients of

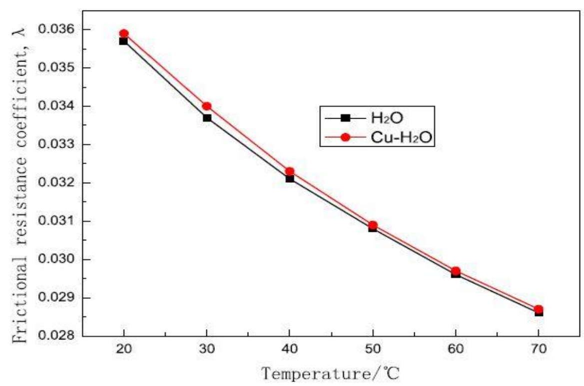


Fig. 7.The frictional resistance coefficient with different temperature (Cu:25 nm, 0.1 wt%).

nanofluidsflowing in the tube are necessary calculated. In this experiment, the viscosity of nanofluids (Cu:25 nm, 0.1 wt%) was measured by viscometer (Brookfield-DV2T). The Reynolds number of fluid in the tube is 4000 <Re <105, which belongs to the turbulent.

The frictional resistance coefficient can be calculated by Eq.(6) [29].

$$\lambda = 0.3164 / Re^{0.25} \quad (6)$$

Fig. 7 shows the frictional resistance coefficient of water and CueH2O nanofluids (Cu:25 nm, 0.1 wt%) with different temperature.It can be seen from Fig.7, the increment rate of the frictional resistance coefficient is less than 1% in the whole working temperature area. It indicates that the nanofluids has a little effect on the pump power, it is suitable for solar thermal energy systems.

V. COMPARISION OF VARIOUS NANOFLUIDS

5.1 SiO2/EG–water nanofluid

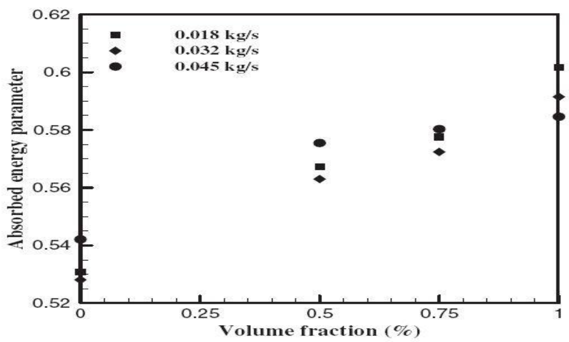


Fig. 8.Variations of absorbed energy parameter with the volume fraction.

5.2 CuO/water nanofluid

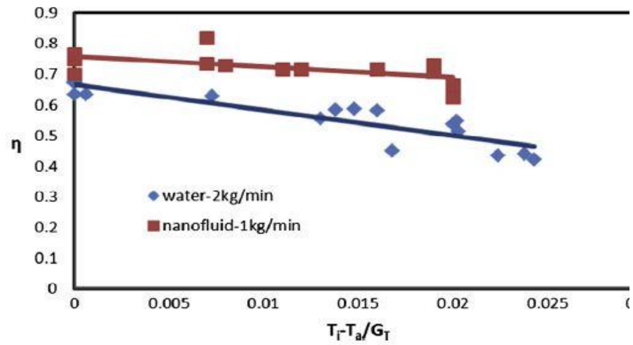


Fig. 9.The flat-plate solar collector efficiency for water and nanofluid at their optimum mass flow rates.

VI.CONCLUSION

Adding nano particle to pure water can increase the thermal conductivity of water. Nano particle size also has a major effect on the efficiency of flat-plate solar collectors with nanofluids In conclusion, the solar energy absorbing experiments show that CueH2O nanofluids have good absorption ability for solar energy, and can effectively enhance the efficiency of flat-plate solar collectors. Thus, CueH2O nanofluids can be hopeful to apply in solar thermal energy system.

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