Performance Analysis of FPSC using hybrid nanofluid of Aluminum oxide and Titanium oxide

Gaurav Bharadwaj
Department of Mechanical Engineering, GLA University, Mathura-281406 (INDIA)
Email id: gauravmech2211@gmail.com

Abstract. An experimental study was conducted to see the effect of using Aluminum oxide and Titanium oxide hybrid nano fluid on FPSC results. Experimentation was carried out by using nano fluid of size 30-50 nm and particle volume concentration at 0.25, 0.5, 0.75 and 1%. It has been found that by using nanofluid optimum efficiency is obtained at 0.75% concentration of nano fluid maximum 62%.

1. Introduction
With the growth of the world's population, energy demand is rising day by day. Demand of energy can be fulfilled by using convention energy sources as well as non-conventional energy sources. Our conventional sources are limited like fossil fuels, etc. So, by using them continuously they will get finished and they also create a lot of population with their use which in turn disturb the life on the planet Earth. Other than conventional sources, many non conventional sources are present which can be used in place of conventional energy sources to fulfill the demand of energy. These energy sources are available free of cost as well as they donot create any hazardous to the planet Earth [1]. Of all the non-conventional sources of energy, solar energy is a promising one. Thermal systems such as solar collectors in which solar energy is absorbed through the absorber plate will harness solar energy and this absorbed solar energy is transferred by a working fluid for further use such as space heating, water heating, etc [2]. Water is used as a working fluid in the case of water solar heaters to transmit the solar energy absorbed by the absorber plate. The efficiency of the water solar air heater is poor and this efficiency can be enhanced by using other working fluids combined with water. Vary first time Choi [3] introduced the use of nano fluid to increase the heat transportation capacity and heat absorption capacity of the working fluid.

In order to see the implications of using SWCNT nanofluid in FPSC, Said et. al. [4] conducted a theoretical analysis. They found that the use of SWCNT as a coefficient of nanofluid heat transfer increased by 15.33 percent and decreased the production of entropy by 4.43 percent. In order to see the impact of using CuO-based nanofluid on FPSC results, He et. al. [5] performed an experimental study. They found that by using CuO BASED nanofluid with 25 nm nanoparticle size and 140 l/h mass flow rate, the efficiency of FPSC is enhanced by 23.83 percent. In order to see the effect of using MgO-based nano fluid on FPSC efficiency, Vema et. al. [6] performed an experimental study. They observed that at a flow rate of 1.5 lpm, the thermal efficiency of FPSC was improved by 9.34 percent at 0.75 percent volume concentration. Many other researcher have also working on same area [7-10] The present study shows the use of hybrid nanofluid to see the consequences of it on the thermal efficiency of FPSC.
2. Experimental Setup

2.1. Details and Specifications

The experimental configuration line diagram is shown in Fig. 1. The experimental setup consists of a solar collector that can absorb the heat of infrared lamps from the solar panel. This solar panel consists of 8 infrared lamps each having a power of 500 W and with the help of this solar panel an artificial solar environment is created. The setup contains a tank for nanofluid and demineralized water which has been used for cooling and heating arrangements. There is a chiller unit which is provided for the heating and cooling of the tank of nanofluid and demineralized water. Human interaction machine and programmable logic controller have been used to record the heat transfer. Pumps were used to ensure the correct circulation of the system's nanofluid and demineralized water. To maintain the mass flow rate, the Rotameter was used and a three-way valve was supplied to maintain the pressure of nanofluid and demineralized water. Table 1 includes a specification of the experimental setup.

![Figure 1: Line Diagram of Experimental Setup](image)

| Specification       | Dimensions       |
|---------------------|------------------|
| Absorber area       | 0.375 cm²        |
| No. of Glazing      | 1                |
| Glazing thickness   | 4 mm             |
3. Methods for performance analysis of FPSC

3.1. Thermal Performance Evaluation

As stated by Duffie and Beckman, Hottel and Woertz were the first to evaluate the thermal efficiency of the flat plate solar collector in terms of heat removal factor (Fr) [11]. Useful energy gain (Qu) as a function of the fluid inlet temperature (Ti) and the ambient temperature (Ta) is given as follows: as stated by Duffie and Beckman [11]

Useful energy gain

\[ Q_u = F_r A_p [I(\tau \alpha) - U_L (T_o - T_i)] \]  

(1)

Useful energy gain can also be reflected in terms of increasing air enthalpy by collecting.

Useful energy gain

\[ Q_u = mC_p (T_o - T_i) \]  

(2)

By comparing eq. (1) and eq. (2), heat removal factor can be written as,

\[ F_r = \frac{mC_p (T_o - T_i)}{A_p [I(\tau \alpha) - U_L (T_i - T_a)]} \]  

(3)

The ratio of useful energy gain to solar irradiance is the thermal efficiency of SAH, and can be given as Duffie and Beckmen [11].

\[ \eta_{sh} = \frac{Q_u}{A_p I} = F_r \left[ (\tau \alpha) - U_L \left( \frac{T_i - T_a}{I} \right) \right] \]  

(4)

3.2. Exergy Evaluation

One of the important methods for evaluating the efficiency of the thermal system is the measurement of energy. This method helps to assess the usable performance of energy and the pumping power needed. The net flow of energy (En) can be reported as,

\[ E_n = IA_p \eta_{sh} \eta_C - P_m (1 - \eta_C) \]  

(5)

The term \( IA_p \eta_{sh} \eta_C \) is the exergy of the solar energy drawn up by the working fluid and the term \( P_m (1 - \eta_C) \) is the loss of exergy because of friction.

The exergy penetration because of the solar irradiance (I) on the absorber plate of the solar collector is expressed as,

\[ E_s = IA_p \left( 1 - \frac{T_o}{T_{sun}} \right) \]  

(6)

Hence, \( \eta_{II} \) is written as,

\[ \eta_{II} = \frac{E_n}{E_s} \]  

(7)
4. Result and Discussion

An experiment has been carried out to do the analysis of FPSC. Experiment has been carried out at different concentration ratio of nanofluid and mass flow rate to determine optimum thermal efficiency of the FPSC.

Fig. 2. shows the variation of thermal efficiency with mass flow rate graphically. It can be easily seen from the graph that thermal efficiency gradually increases with the increase in mass flow rate. The maximum efficiency occurs at a volume concentration of 0.75% for the same value of mass flow rate. The maximum thermal efficiency occurs at 1.25 lpm of mass flow rate. The augmentation in the thermal efficiency found to be 8.25%.

Out of Fig. 2. It is also very clear that thermal efficiency tends to increase with an increase in concentration of up to 0.75 percent and decreases in thermal efficiency after rising concentration. This is so happens because with the increasing concentration the Brownian motion between the nanoparticle and base fluid particle get slowed down because of decreases in heat transfer coefficient and hence thermal efficiency decreases.

Fig. 2. Shows the variation of thermal efficiency with temperature parameter rise. Experimentation has been carried out at constant mass flow rate of 1 lpm and radiation intensity of 800 W/m². The profile of each thermal efficiency with respect to temperature parameter rise is almost linear as eq. 4. Show the linear variation as it is almost equation of line.

**Figure. 2.** Variation of thermal efficiency with mass flow rate at various concentrations
Figure. 3. Variation of thermal efficiency with Temperature parameter rise at various concentrations

5. Conclusions
The present study demonstrates the use of hybrid nanofluid to boost FPSC's thermal efficiency. In the above analysis, the findings are as follows:
1. The thermal output can be improved with the use of hybrid nanofluid.
2. Maximum thermal efficiency occur at volume concentration of 0.75% and then decreases with the increase in volume concentration.
3. Maximum thermal efficiency occur at mass flow rate of 1.25lpm.
4. The augmentation in the thermal efficiency found to be 8.25% as compared to demineralised water.

References
[1] energyquest. Energy Quest; 2007. www.energyquest.ca.gov/story/chapter14. html.
[2] S. Kolagirau. Solar Thermal Collectors and applications. Progress in energy and combustion science. (2004) 231-95.
[3] Choi SUS. Enhanced thermal conductivity of fluids with nanoparticle. ASME FED-66. 231/MD 66 (1995) 99-103.
[4] Said Z, Saidur R, Rahim NA, Alim MA. Analyses of exergy efficiency and pumping power for a conventional flat plate solar collector using SWCNTs based nanofluid, Energy and Buildings, Volume 78, 2014, Pages 1-9.
[5] He Q, Zeng S, Wang S. Experimental investigation on the efficiency of flat-plate solar collectors with nanofluids, Applied Thermal Engineering, Volume 88, 2015, Pages 165-171.
[6] Verma SK, Tiwari AK, Chauhan DS. Experimental evaluation of flat plate solar collector using nanofluids, Energy Conversion and Management, Volume 134, 2017, Pages 103-115.
[7] Kumar A, Sharma K, Dixit, AR. Carbon nanotube- and graphene-reinforced multiphase polymeric composites: review on their properties and applications. J Mater Sci 55, 2682–2724 (2020). https://doi.org/10.1007/s10853-019-04196-y
[8] Kumar A, Sharma K, Dixit, AR. A review of the mechanical and thermal properties of graphene and its hybrid polymer nanocomposites for structural applications. J Mater Sci 54, 5992–6026 (2019). https://doi.org/10.1007/s10853-018-03244-3.
[9] Kumar A, Sharma K, Dixit AR (2020) A review on the mechanical and thermal properties of graphene and graphene-based polymer nanocomposites: understanding of modelling and MD simulation, Molecular Simulation, 46:2, 136-154, DOI: 10.1080/08927022.2019.1680844
[10] Shukla MK, Sharma K, Effect of Carbon Nanofillers on the Mechanical and Interfacial Properties of Epoxy Based Nanocomposites: A Review. Polym. Sci. Ser. A 61, 439–460 (2019). https://doi.org/10.1134/S0965545X19040096

[11] Duffie, JA, Beckman, WA, 1980. In: Solar Engineering of Thermal Processes, third ed. Wiley Inter science publications, New York.