

Improving the Effectiveness of Heat Pipe solar Connector by using Nano fluid

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Article History:

Submitted: 10-09-2022

Accepted: 11-09-2022

Published: 12-09-2022

Keywords:

Solar Energy; Nano fluid; Nano technology.

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ABSTRACT

This article provides a thorough analysis of current developments in the use of nano fluids in the sun collectors with heat pipes. Theoretical, numerical, and experimental papers that are current and relevant to the Applications of nanotechnology in this class of solar collectors. To provide a thorough overview of the effect of the nano fluid in enhancing heat pipe solar collectors, a large body of literature has been thoroughly researched and summarized. The effectiveness of heat pipe solar collectors can be significantly increased by using nano fluid, it was discovered certain tools.

INTRODUCTION

One of the most important sources of pure, free, and renewable energy today is solar energy. The energy that has less impact on the environment. Following the industrial revolution (1970s), energy use skyrocketed. Sharply, the danger of energy shortages spurred researchers to discover alternative energy sources. Solar power is widely used. All other renewable energy sources, it is thought to be the most sustainable type of energy. Renewable energy sources may account for 60% of the global electricity market and 40% of this by the middle of the twenty-first century. Fossil fuels are about to hit the market [1-2]. The definition of solar energy is energy that originates from the sun and can be transformed into heat and power. A natural outcome of electromagnetic radiation emitted by the sun is solar energy. The Sun by thermonuclear processes taking place inside its core. Energy has been produced by it over billions of years, therefore The use of solar energy has drawn a lot of attention, particularly in the last ten years [3–4]. For instance, some According to studies, solar energy can provide around 1000 times more energy than the world needs. However, just 0.02% of this energy being used at the moment [5]. The primary causes of this heightened interest in the Solar energy applications are necessary because of the rise in energy consumption, the depletion of fossil resources, and severe environmental issues are connected to them, particularly the carbon dioxide emissions. On the opposing side, the Massive population growth may be viewed as an especially dangerous issue [6]. In fact, the sun emits light. Huge amounts of energy are incident on the surface of the globe every day, and the hourly solar flux is higher than all of it combined. Energy used by people annually [7]. Despite the enormous amount of solar energy that is currently available, about Fossil fuels still account for a sizable portion of the world's energy consumption (80%) [8]. recently, one of the predictions for the future if we can develop and use the by 2050 to cut global carbon dioxide (CO₂) emissions to 75% of its 1985 level apparatus for using sun energy, like solar collectors.

LITERATURE REVIEW

Nano Fluid

Solid-liquid composite materials made of nanometer-sized solids are known as nanofluids. Various base fluids suspended with particles, fibres, rods, or tubes. Pure metals are an example of nanoparticles. Metal oxides (CuO, SiO₂, Al₂O₃, TiO₂, ZnO, Fe₃O₄), Carbides (SiC, TiC), Nitrides, and metals (Au, Ag, Cu, Fe), among others (AlN, SiN) and

other forms of carbon, including single- and multiwall carbon nanotubes, diamond, and graphite. traditional liquids, like Base fluids include things like engine oil, water, and ethylene glycol. Argonne National Laboratory employee Choi (9), The first individual to invent this fluid in the United States was in 1995. Using experiments, he discovered that the The basic fluid's thermal conductivity was improved by adding high thermal conductivity metallic and non-metallic nanoparticles. considerably increased the thermal conductivity of these fluids, improving their total capacity for heat transmission. For For instance, copper has a thermal conductivity that is approximately 700 times greater than that of water at ambient temperature. larger than motor oil by around 3000 times [10]. There are numerous industrial uses for nanofluid. Some solar absorption and energy harvesting, transportation, electrical energy, nuclear reactors, and biology and medicine [11–12]. The heat conductivity and radiation absorption of nanofluids are both excellent conductivity. For instance, the heat conductivity of individual multi-walled carbon fibres at ambient temperature MWCNTs nanotubes were discovered to have values higher than 3000 W/ m.K [13]. In addition, Assael et al. [14] demonstrated that adding roughly 1% volumetric fraction of MWCNT increased water's thermal conductivity 40%. When dispersing nanoparticles in a base fluid to create nanofluids, correct mixing and stabilisation of the particles are necessary. Nanoparticles have a very small size, ranging from 1 to 100 nm. It is really advised against introducing big solid particles (greater than 100 nm) into the base fluids for the following basic reasons:

Issues [15]:

1. The traditional millimeter- or micrometer-sized particles segregate rapidly in the fluid, generating a layer on the surface. The fluid's ability to transport heat is diminished by this fouling layer.
2. The cost goes up because huge solid particles demand a lot of pumping power.
3. Due to the significant rise in viscosity, the fluid's pressure drop increases significantly.
4. The traditional suspensions' huge particle sizes do not work with the newly-emerging "miniaturised" due to the possibility of clogging the minuscule passages of these devices.

As a result, nanofluid can be effectively employed to address these issues because it has a variety of properties, including:

1. High thermal conductivity effectively.
2. Due to its extremely small size, it fluidizes readily in base fluids and can move more quickly inside solid blocks the porous media, for instance.
3. A large specific surface area
4. The fluid maintains its Newtonian characteristics thanks to the small particle concentration.
5. Changing particle concentrations makes it simple to change the density, viscosity, specific heat, thermal conductivity, and other properties. to be appropriate for various engineering applications [16]. Low pumping power is six [17].
6. As the surface area for heat transfer between particles and fluids grows, the heat transmission increases With a high extinction coefficient, 8-Nanofluid (a function of the particle diameter and wave length of the light) as compared to the standard base fluid. It can therefore absorb more of the energy from incident light solar collectors are used in solar energy systems.
7. High stability of dispersion.
8. Due to the particles' modest size, prevent erosion or clogging from occurring.

Since nanoparticles can easily store a substantial amount of energy in their small volume,

9. Nanfluid has a high thermal capacity amount of heat. Naturally, this will reduce energy losses and improve system effectiveness [18].
10. Nanoparticles considerably improve the base fluid's optical characteristics [19].

However, the science that deals with nanofluids is known as nanotechnology, and it opens up a new field of study of investigation to address these novel fluids [20]. This innovation has the potential to fundamentally alter the techniques used to create processes and structures with recognisable and novel features that are lighter, stronger, and higher performing. The reader can get in-depth information regarding the uses and difficulties of nanofluids by visiting this website.

return to the analysis by Saidur et al. [21].

Sunlight Collector

A unique type of heat exchanger called a solar energy collector converts solar radiation energy into the internal energy of the transport medium. The solar collector is the main part of any solar system. It is an apparatus that gathers inbound solar energy, transforms it into heat, and transmits this heat to a fluid flowing through the collector (often air, water, or oil). The captured solar energy is transferred from the circulating fluid either directly to the hot water or space conditioning equipment, or to a thermal energy storage tank from which it can be pulled to be used at night or on overcast days. Improved output temperatures and higher collector efficiency in the power cycle result from greater heat transfer to fluid [22]. Therefore, the main issue is how to make this device more effective at converting solar energy into

thermal or electrical energy. Different domestic and small business uses for solar collectors include home water heating systems, solar space heating, solar desalination, sun drying equipment, energy generation, and tiny solar power plants. For solar thermal applications, the sun's energy is converted into heat by a solar collector, which is then passed on to the working fluid (air, water or oil). Domestic hot water/heating can be provided using the heat carried by the working fluid, or the heat can be stored in a thermal energy storage tank and used at a later time, such as at night or on overcast days. A PV module for photovoltaic applications creates a lot of waste heat in addition to directly converting solar irradiation into electricity [23]. This waste heat can be recovered for thermal use by connecting the PV board with recuperating tubes filled with carrier fluids. The working fluid's characteristics, which are employed to maximise solar energy absorption in the solar collector, have an impact on how well the solar collector performs. Solar water heaters, solar cookers, and solar ponds are a few examples of solar thermal collectors. Numerous researchers have access to literature reviews on solar collectors, including those by Kalogirou [24], Jaisankar et al. [25], and most recently Wang et al. [26].

Heat pipe for collecting Solar Light

A heat pipe is maintained inside a glass enclosure and is sometimes referred to as an evacuated tube solar collector (ETC) (Fig. This kind of collector was developed to address issues that cropped up with the more traditional flat-plate solar collectors. Since weather conditions have a considerable impact on the effectiveness of the latter collectors. In other words, they perform significantly worse on cold, overcast, and windy days [27]. In addition to the harsh weather, humidity and moisture both hasten the failure of internal pipe materials and lessen the effectiveness of the collector. Moreover, the forced circulation system because of the pump and the energy it consumes, the extra space needed for the natural circulation system because of the position restrictions, the night cooling because of the reverse flow of cooled water, the freezing of the water on cold nights, and pipe corrosion because of the use of water can all be thought of as additional issues. Use of the heat pipe solar collector, which is comprised of a heat pipe (a highly efficient thermal conductor) inside a vacuum-sealed tube, as shown in Fig. 2, can address all of the aforementioned drawbacks. The heat pipe solar collector offers significant advantages over the flat-plate solar collector in terms of heat loss. Single-walled glass heat pipes and Dewar tubes are the two main forms of heat pipe solar collectors that are now on the market. The two fundamental forms come in a variety of modifications, such as for The pipe, a sealed copper pipe, is joined to a black copper fin that fills the tube (absorber plate). Each tube has a metal tip sticking out of the top that is connected to the sealed pipe (condenser).

METHOD

Principles for use of (Heat Pipe Collector)

A tiny amount of fluid, such as methanol, water, or ethanol, is contained in the heat pipe and is utilized to transmit heat through an evaporating-condensing cycle, therefore capturing heat from solar radiation. In this cycle, the liquid is vaporized by solar radiation, and the vapor moves to the area of the heat sink where it condenses and releases its latent heat. The process is then repeated with the condensed fluid returning to the solar collector. The metal tips up when these tubes are installed into a heat exchanger (manifold), as seen in Fig. 2. Through the manifold, water or glycol flows while absorbing heat from the tubes. A process or water that is kept in a solar storage tank receives heat from the heated liquid as it passes through another heat exchanger.

RESULT AND DISCUSSION

Advantages of (Heat Pipe Collector).

1. HPC's vacuum envelope lowers convection and conduction losses, allowing it to function well at high temperatures.
2. They are highly effective at low incidence angles and capture both direct and indirect radiation.
3. When compared to other collectors, HPC has a high efficiency level. Since it transfers heat within the collector using liquid-vapour phase transition materials.
4. The HPC comes with a built-in defence against the freezing and overheating phenomena. Since, neither condensation nor evaporation takes place above the phase-change temperature. As a result, the HPC's internal temperature may be automatically managed.
5. In order to return the working fluid from the condenser to the evaporator, these collectors rely on the heat pipe technology, which operates under gravity with the condenser above the evaporator. As a result, they don't need external power or capillary action.
6. The use of heat pipe technology allows for the decrease of the solar collector's size, which also lowers the overall cost.
7. The HPC is ideal for extremely cold climates.

Uses of Nano Fluid

To achieve high fluid temperature, Lu et al. [30] created a unique open thermosyphon device that was used in an evacuated tubular solar collector. They used both deionized water and water-based CuO nanofluids as working fluids in the modified open thermosyphon, which had three basic sections: a tubular evaporator, a condenser box, and a condensing coil (Fig. 4). They came to the conclusion that, when compared to deionized water, the evaporator's thermal performance and evaporating heat transfer coefficients rose by roughly 30% at the optimal mass concentration of 1.2 wt%. Senthil Kumar et al. [31] produced two identical flat plate solar collectors. Effects of filling rate, type of base fluid, nanoparticle mass concentration, and operating temperature on the evaporating heat transfer coefficient in the open thermosyphon were also tested and discussed. Three identical wickless copper heat pipes with an outer diameter of 18 mm and a length of 620 mm were utilised in each collector. Pure water served as the working fluid in the first collection, whereas CNT-water nanofluid was used in the second. They came to the conclusion that the performance of the nanofluid collector was superior to the pure water collector in all test settings. The diameter of CNT nano particles was 10-12 nm, while their length was 0.1-10. In an experiment, Chougule et al. [32] examined the performance of two symmetrical collectors that were each connected by three wickless heat pipes. In the first collector, only pure water was utilised as the working fluid, whereas in the second, carbon nanotubes (CNT) were combined with water to create a nanofluid. It was discovered that under every test condition, the second collector performed better. TiO₂-water nanofluid was used by Moorthy et al. [33] to conduct an experimental study of the performance of evacuated tube solar collectors. It was discovered that employing nanofluid enhanced collector efficiency from 58% when using pure water to around 73%. In order to produce air with high and moderate temperatures, Liu et al. [34] designed and experimentally evaluated the thermal performance of a novel evacuated tubular solar air collector (Fig. 5) integrated with a streamlined CPC (compound parabolic concentrator) and open thermosyphon. They used a water-based CuO nanofluid. The air outlet temperature and collector efficiency employing nanofluid as the open thermosyphon's working fluid were both higher than those using water alone, according to experimental results. When the air volume rate was 7.6 m³/h in the winter, they noticed that the highest air outlet temperature was higher than 170 °C. Additionally, they came to the conclusion that the solar collector with nanofluid as the open thermosyphon's working fluid performed thermally significantly better than the collection with water alone. In studies conducted under outdoor test circumstances, Chougule et al. [35] investigated the thermal performance of two phase thermosyphon on flat-plate solar collectors employing both pure and nanofluids. It was discovered that the thermal performance of the nanofluid heat pipe solar collector was significantly better than the corresponding collector that used the pure water only. They used carbon nanotubes (CNT) particles with the pure water as a nanofluid for various concentrations (0.15%, 0.45%, 0.60%, and 1% by volume). Experimental research was done by Aruna et al. [36] to determine how the working fluid type affected the efficiency of the flat absorber plate solar water heater with thermosyphon (Fig.6). They employed a nanofluid made of propanol and (TiO₂ + DI water) in their test. The experimental set-up included a thermosyphon heat pipe, a flat absorber plate solar collector, and a water storage tank. Under the absorber plate, glass wool insulation was added to lessen conduction losses, and a thermo-cool insulator covered the sides of the absorber plate to lessen convection losses. It was discovered that the nanofluid displayed superior thermal behaviour over the pure fluid, including improved thermal conductivity and convection coefficient.

CONCLUSION

The current paper provides a thorough overview of recent developments in the use of nanofluid in heat pipe solar collectors. The following is a summary of some key findings:

1. Future research should focus on how fluid features, outside thermal conductivity, such as the optical characteristics of nanofluids, affect HPC performance.
2. In order to further lower the price of nanofluid-based solar collectors and to quickly fulfil commercial demands, future research must focus on developing non-toxic, inexpensive nanoparticles.
3. More research is required to determine whether employing nanofluids in HPC is reliable from an environmental and financial standpoint.
4. To improve the solar-weighted absorption and boost the effectiveness of the solar collector, nanoparticles must be evenly scattered in the base fluid.
5. To improve the functionality of the nanofluid collector, the volume fraction of nanoparticles must be carefully selected.
6. Using carbon nanohorns (CNHs) as nanoparticles to enhance the HPC's optical characteristics is advised. They have a lot of surface area and cavities, which accounts for this.
6. More work needs to be done to address a number of major obstacles in the field of nanotechnology and its application in solar collectors, such as Brownian motion of particles, particle migration, changing thermophysical properties with temperature, tendency of nanoparticles to aggregate, changing the properties of nanofluids by adding additives, and the stability of nanofluids.

7. The results of the publications that were studied showed that the system's other qualities and the characteristics of the nanofluid have a role in the HPC's overall performance.
8. In order to improve HPC efficiency, further research must be done on the use of mixtures of many nanoparticles.

REFERENCES

1. Al-Bahrani M, Bouaissi A, Cree A. Mechanical and electrical behaviors of self-sensing nanocomposite-based MWCNTs material when subjected to twist shear load. *Mechanics of Advanced Materials and Structures*. 2021 Jun 23;28(14):1488-97.
2. Javadi F., Saidur R. , Kamalisarvestani , M. Investigating performance improvement of solar collectors by using nanofluids . *Renewable and Sustainable Energy Reviews* 2013 ; 28 : 232-245.
3. Suman S., Khan M. , Pathak , M. Performance enhancement of solar collectors - A review .*Renewable and Sustainable Energy Reviews* 2015 ; 49 : 192–210.
4. Al-Bahrani M, Cree A. In situ detection of oil leakage by new self-sensing nanocomposite sensor containing MWCNTs. *Applied Nanoscience*. 2021 Sep;11(9):2433-45.
5. Xia X., Xia J. , Virkar A. Evaluation of potential for developing renewable sources of energy to facilitate development in developing countries. *Proceedings of the Asia-Pacific power and energy engineering conference 2010 Chengdu ,China* : 1-3.
6. Allamraju K. Materials used for renewable energy resources. *Advanced Materials Manufacturing and Characterization* 2013 ; 3 : 243-248.
7. Hussein A. Applications of nanotechnology in renewable energies - a comprehensive overview and understanding . *Renewable and Sustainable Energy Reviews* 2015 ; 42 : 460-476.
8. Thirugnanasambandam M., Iniyani S. , Goic , R. A review of solar thermal technologies. *Renewable and Sustainable Energy Reviews* 2010 ; 14 : 312-322.
9. Choi S. Enhancing thermal conductivity of fluids with nanoparticles. *Developments and Applications of NonNewtonian Flows, ASME FED, Vol. 231/MD-66* 1995 : 99-105.
10. Li Y. , Zhou J., Tung , S. , Schneider , E. , Xi , S. A review on development of nanofluid preparation and characterization . *Powder Technology* 2009 ; 196 : 89-101.
11. Bejan A., Kraus A. *Heat Transfer Handbook* . John Wiley and Sons 2003.
12. Faiz F., Zahir E. A comparative study of nanofluids for tuneable filter operation. *International Journal of Engineering Research* 2014 ; 3 : 9-12.
13. Hone J. Carbon nanotubes: thermal properties . In *Dekker Encyclopedia of Nanoscience and Nanotechnology* 2004.
14. Assael M., Chen C., Metaxa , N. , Wakeham , W. Thermal conductivity of suspensions of carbon nanotubes in water . *International Journal of Thermophysics* 2004 ; 25 : 971-985.
15. Al-Abboodi H, Fan H, Mhmood IA, Al-Bahrani M. The dry sliding wear rate of a Fe-based amorphous coating prepared on mild steel by HVOF thermal spraying. *Journal of Materials Research and Technology*. 2022 May 1;18:1682-91.
16. Adil A. , Gupta, S. , Ghosh , P. Numerical prediction of heat transfer characteristics of nanofluids in a minichannel flow. *Journal of Energy* 2014 ; Article ID 307520 : 1-7.
17. Chieruzzi M., Cerritelli G. , Miliozzi A. , Kenny J. Effect of nanoparticles on heat capacity of nanofluids based on molten salts as PCM for thermal energy storage . *Nanoscale Research Letters* 2013 ; 8 : 448-456.
18. Al-Bahrani M. *The Manufacture and Testing of Self-Sensing CNTs Nanocomposites for Damage Detecting Applications* (Doctoral dissertation, University of Plymouth).
19. Rashid F. , Dawood K., Hashim, A. Maximizing of solar absorption by (TiO₂-water) nanofluid with glass mixture . *International Journal of Research in Engineering & Technology* 2014 ; 2 : 87-90.
20. Saidur R. , Leong K. , Mohammad H. A review on applications and challenges of nanofluids . *Renewable and Sustainable Energy Reviews* 2011 ; 15 : 1646-1668.
21. Shukla R. , Sumathy , K. , Erickson , P. , Gong , J. Recent advances in the solar water heating systems: A review . *Renewable and Sustainable Energy Reviews* 2013 ; 19 : 173–190.
22. Al-Bahrani M, Majdi HS, Abed AM, Cree A. An innovated method to monitor the health condition of the thermoelectric cooling system using nanocomposite-based CNTs. *International Journal of Energy Research*. 2022 May;46(6):7519-28.

23. Kalogirou S. Solar thermal collectors and applications. *Progress in Energy and Combustion Science* 2004 ; 30 : 231-295.
24. Jaisankar S. , Ananth J. , Thulasi S. , Jayasuthakar S. , Sheeba K. A comprehensive review on solar water heaters . *Renewable and Sustainable Energy Reviews* 2011 ; 15 : 3045-3050.
25. Wang Z., Yang W., Qiu F. , Zhang X. , Zhao X. Solar water heating : from theory, application , marketing and research. *Renewable and Sustainable Energy Reviews* 2015 ; 41 : 68-84.
26. Mishra R. , Garg V. , Tiwari G. Thermal modeling and development of characteristic equations of evacuated tubular collector (ETC) . *Solar Energy* 2015 ; 116 : 165-176.
27. Yu W., Xie H. A review on nanofluids : preparation, stability mechanisms and applications . *Journal of Nanomaterials* 2012 ; Article ID 435873 : 1-17.
28. Du B., Hu E., Kolhe M. An experimental platform for heat pipe solar collector testing . *Renewable and Sustainable Energy Reviews* 2013 ; 17 : 119-125.
29. Lu L., Liu Z., Xiao H. Thermal performance of an open thermosyphon using nanofluids for high-temperature evacuated tubular solar collectors Part 1: Indoor experiment . *Solar Energy* 2011 ; 85 : 379-387.
30. Senthil Kumar R., Manimaran R. , Ramadoss K. , Shankar N. Experimental analysis of nano fluid-charged solar water heater by solar tracking system. *Archives of Applied Science Research* 2012 ; 4 : 2582-2590.
31. Chougule S., Pise A. , Madane A. Performance of nanofluid-charged solar water heater by solar tracking system. *International Conference on Advances in Engineering , Science and Management (ICAESM)* , Nagapattinam , Tamil Nadu 2012 ; 247-253.
32. Moorthy M., Chui L. , Sharma K., Anuar S. Performance evaluation of evacuated tube solar collector using water-based titanium oxide (TiO₂) nanofluid. *Journal of Mechanical Engineering and Sciences* 2012 ; 3 : 301-310. [34] Liu Z., Hu R. , Lu L., Zhao F. , Xiao H. Thermal performance of an open thermosyphon using nanofluid for evacuated tubular high temperature air solar collector . *Energy Conversion and Management* 2013 ; 73 : 135-143.
33. Chougule S., Sahu S. , Pise A. Thermal performance of two phase thermosyphon on flat-plate solar collectors using nanofluid. *Journal of Solar Energy Engineering* 2013 ; 136 : 1-5.
34. Aruna V., Channakaiah D., Murali , G. . A study on a flat plate type of solar water heater with an thermosyphon using different working fluid . *Singaporean Journal of Scientific Research* 2014 ; 6 : 132-135. [37] Saravanan M., Karunakaran N. Experimental analysis of heat pipe with V-trough solar collector. *International Journal of Research in Advent Technology* 2014 : 13-17.