Uluslararası İleri Doğa Bilimleri ve Mühendislik Araştırmaları Dergisi
Sayı 8, S. 1-9, 2, 2024

Araştırma Makalesi

International Journal of Advanced Natural Sciences and Engineering Researches
Volume 8, pp. 1-9, 2, 2024

Research Article

https://as-proceeding.com/index.php/ijanser
ISSN: 2980-0811

Experimental Investigation of the Use of Al_2O_3 Nanofluid in the Heat Pipe for Passive Cooling of the Photovoltaic Panel

Ahmet Acar [1*], Lutfu Namli [2], Engin Ozbas[3]

[1,3] *Yesilyurt D.C. Vocational School, Ondokuz Mayis University, Samsun, Turkey*
[2] *Mechanical Engineering Department, Engineering Faculty, Ondokuz Mayis University, Samsun, Turkey*

Email of corresponding author: *ahmet.acar@omu.edu.tr

(Received: 27 February 2024, Accepted: 07 March 2024)

ATIF/REFERENCE: Acar, A., Namli, L. & Ozbas, E. (2024). Experimental Investigation of the Use of Al_2O_3 Nanofluid in the Heat Pipe for Passive Cooling of the Photovoltaic Panel. *International Journal of Advanced Natural Sciences and Engineering Researches, 8(2), 1-9.*

***Abstract* –** As the world population gradually increases, the energy needed also increases. Depending on this increasing need, it is necessary to diversify energy production and use existing energy resources more efficiently. Solar energy is one of the most significant energy conversion sources, which is electrical energy obtained by utilising solar energy in PV panels. In addition, some of the energy is lost and transformed into heat energy. Active and passive cooling applications are applied on the PV panel to reduce the lost heat energy. This study involved a passive cooling technique for the PV panel. A thermosyphon-type heat pipe was used as a passive cooler. In addition to the reference case, the effect of three different Al_2O_3 nanofluids at 1%, 2%, and 3% by weight, considered fluids in the heat pipe, was observed. In experiments conducted with solar simulation, the effect of passive cooling was examined for 120 minutes. Compared to the reference condition, front surface temperatures of approximately 17 °C, 13 °C and 11 °C lower were measured for AL1, AL2 and AL3, respectively. In terms of efficiency, an increase of approximately 7% in AL1, 5% in AL2, and 1% in AL3 compared to the reference situation was achieved. When the voltage amounts are compared, while 10.305 V is produced in the reference condition, the average voltage amounts produced for AL1, AL2 and AL3 are 9.805 V, 10.625 V and 10.485 V, respectively.

Key Words – Two-Phase Closed Thermosyphon, Nanofluid, Photovoltaic Panel, Passive Cooling.

I. INTRODUCTION

The need for energy has always existed throughout human history, and this need continues to increase with population growth. Depending on technological developments, different electricity production methods have emerged. In addition, various research is being carried out to use existing technologies more efficiently. Renewable energy sources are one of the energy sources used for electricity production. Different systems can be designed to produce electricity using renewable energy sources.

Systems that convert solar energy into electrical energy are called photovoltaic panels. Henri Becquerel introduced the discovery of electricity generation by the PV method in 1839 [1]. The PV panels have been preferred because they have no moving parts, do not cause noise and pollution, and are long-lasting. A typical PV panel consists of front glass, front encapsulant, solar cells, back encapsulant and back layers, as seen in Fig. 1[2].

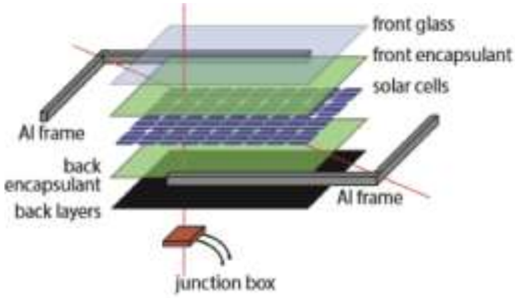

Fig. 1. PV panel components [2]

Nanofluids are an important option to increase the overall efficiency of solar energy systems with their thermophysical properties. Using nanofluids with high thermal conductivity makes it possible to achieve higher efficiency with the increased thermal change effect [3,4].

Cooling in PV panels can be provided in two ways: active and passive. Cooling systems that consume energy by including fans, pumps, and similar elements can be described as active [5], while cooling systems that do not consume energy can be characterised as passive [6].

This study experimentally examined electricity production obtained from PV panels using the sun as the energy source. Two-phase closed thermosyphons (TPCT) type heat pipes were preferred as the heat pipe (hp) to remove the heat occurring in the front region of the PV panel. As working fluid in the heat pipe, PV panel efficiencies were experimentally compared using Al_2O_3/pure water nanofluids at different weight percentage concentrations.

II. MATERIALS AND METHODS

A thermosyphon-type heat pipe was preferred in the passive cooling method for the PV panel. The working principle in Fig. 2 shows that the TPCT heat pipe consists of evaporator, adiabatic and condenser regions. When the moving working fluid in the heat pipe reaches the evaporator region, it overcomes the force of gravity due to the heat it draws from the outside and rises upwards. It then reaches the condenser region, passing the part where heat transfer is not experienced, called the adiabatic part. When the working fluid comes to the condenser region, it transfers the heat energy it carries to the external environment and turns into a liquid phase with the effect of condensation. Thus, its density increases and its transformation back to the evaporator region is achieved by the effect of gravity, thus completing the system cycle [7].

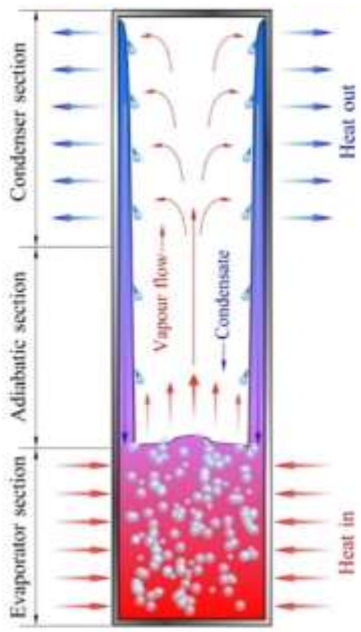

Fig. 2. Working principle of two-phase closed thermosyphon type heat pipe [8]

First of all, the photovoltaic panel was prepared to be used in the experimental setup. The initial state of the photovoltaic panel is shown in Fig. 3.

Fig. 3. Polycrystalline PV panel module front and back surfaces

The technical specifications and measurement information of the photovoltaic panel used are given in Table 1.

Table 1. Technical specifications of the polycrystalline PV module

Brand	Solar Energy
Model	TS5/36P
Maximum power	5 W
Open circuit voltage	24.62 V
Short circuit current	0.25 A
Maximum power voltage	20.84 V
Maximum power current	0.24 A
Dimensions	185*255*20 mm

An aluminium plate was added to the back surface to create a closed volume in the panel's interior. The plate is fixed using bolts. It is also sealed using silicone material. A thermocouple is connected to the middle part of the plate to detect the surface temperature value at the back of the panel. Then, foam material was added to the back surface of the plate to perform accurate measurements and cut off heat exchange with the environment. The rear part of the PV panel, ready for use in the experiment, is shown in Fig. 4.

Fig. 4 Rendered version of the back surface of the PV panel

The chemical and physical properties determined by the manufacturer for Al_2O_3 Nanofluid are presented in Table 2. Pure water was preferred as the base fluid, and Al_2O_3 nanofluid at different concentrations, 1%, 2% and 3% by weight was prepared for use in the heat pipe.

Table 2. Physical and chemical properties were provided by the manufacturer for Al_2O_3 (Aluminium oxide) nanoparticles [8].

Property	Value
Average Particle Size (nm)	78
Purity (%)	99.5
Specific Surface Area (m^2/g)	>20
Colour	White
Morphology	Nearly spherical
Crystallographic Structure	Rhombohedral
Grain size (nm)	27
Elemental Analysis (ppm)	V < 5, Ca < 20, Cl < 280, Mn < 5, Na < 30, Co < 5

Nanofluids must be stable to continuously demonstrate their thermal performance. To demonstrate this situation, Sodium dodecyl sulfate (SDS) surfactant was added to the Nanofluid. The mixture was prepared with the same ratio of Nanofluid in each mixture. For this reason, Al_2O_3 particles and SDS surfactant were mixed with deionised water using the SHIMADZU-TX4202L precision balance shown in Fig. 5. Subsequently, the nanoparticles were ultrasonically processed with an ISOLAB brand ultrasonic bath device for two hours to ensure stability. Fig. 6 shows the SDS surfactant, Al_2O_3 nanofluid, and ultrasonic bath device evaluated during the experimental preparation process.

Fig. 5 SHIMADZU-TX4202L model precision balance

Fig. 6 SDS surfactant, Al_2O_3 nanofluid and ultrasonic bath device

The experiments were carried out in "reference condition " and "heat pipe condition". Fig. 7 shows the reference PV panel experimental setup used in the first stage, called the "reference condition ".

Fig. 7. Reference condition

For the second stage of the experiments, TPCT-type heat pipes were created using copper pipes of 50 cm length and 8 mm inner diameter. Fig. 8 shows the copper pipe pairs used in heat pipe manufacturing.

Fig. 8. Copper pipe pairs

Fig. 9 shows the TPCT heat pipe added to the reference condition. For each percentage of the Al2O3 nanofluid experiment, the second stage was carried out by adding working fluid to half of the evaporator region of the heat pipe.

Fig. 9. Heat pipe condition

All experiments were carried out under laboratory conditions. The experiments used a Philips brand HPI-T PLUS model projector with 400W power for solar simulation. K-type thermocouples were preferred for temperature measurements. The amount of radiation incident on the system was measured with a Delta Ohm brand LP PYRA 02 model pyranometer. ORDEL UDL100 data logger and computer connection were used to create and transfer all temperature values and radiation amount (I) data. Fig. 10 shows the general view of the experimental setup.

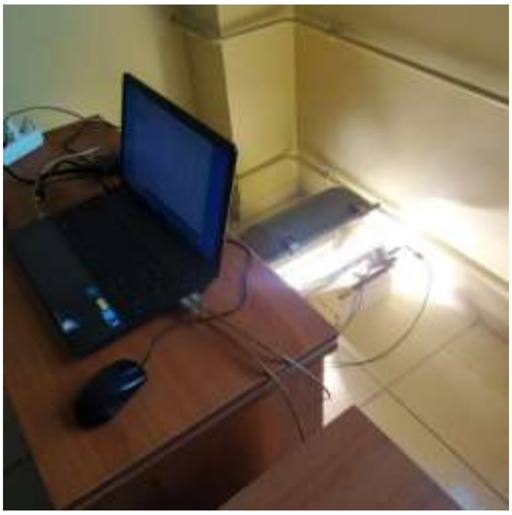

Fig. 10. Experimental setup

III. RESULTS

Experiments performed under laboratory conditions were repeated three times. The front and back surface temperatures of the photovoltaic panel, the amount of open voltage produced by the panel and the amount of radiation produced by the incandescent lamp were measured and automatically recorded on the computer with data collectors. The effect of using Al_2O_3 Nanofluid on the amount of open voltage produced in the panel in the reference condition and the heat pipe condition was examined experimentally. Experimental studies were conducted for four situations: REF, AL1, AL2 and AL3. These four different situations can be explained as follows:

- REF - Reference panel (passive cooling not achieved).
- AL1- passively cooled with a thermosyphon heat pipe with 1% Al_2O_3 nanofluid.

- AL2- passively cooled with a thermosyphon heat pipe with 2% Al_2O_3 nanofluid.
- AL3- passively cooled with a thermosyphon heat pipe with 3% Al_2O_3 nanofluid.

During the experimental measurements, the outdoor temperature was kept constant at 21°C. The time-dependent average radiation intensity distribution for all PV panels is shown in Fig. 11. When the graph was examined, it was seen that the average radiation intensity increased until the 25th minute and became stable, exceeding 840 W/m2 from that moment on.

Temperature distributions on the panel front surface depending on time for all PV panels are shown in Fig. 12. According to the data obtained, the surface temperature values occurring in the front region of the panels were calculated as 67.7 °C, 50.6 °C, 54.2 °C and 56.1 °C on average for REF, AL1, AL2 and AL3, respectively. As a result, approximately 17 °C, 13 °C and 11 °C lower front surface temperatures were measured for AL1, AL2 and AL3, respectively, compared to the panel in the reference experiment.

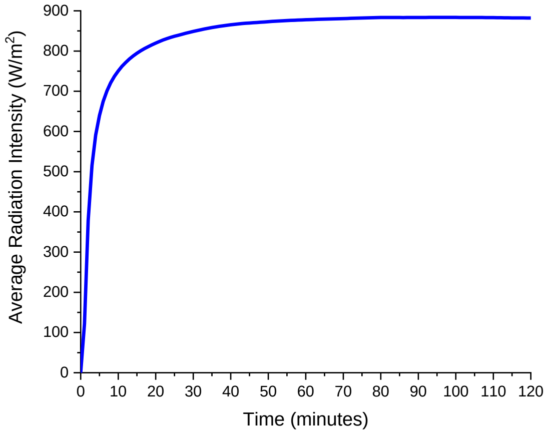

Fig. 11. Average radiation intensity distribution over time for all PV panels

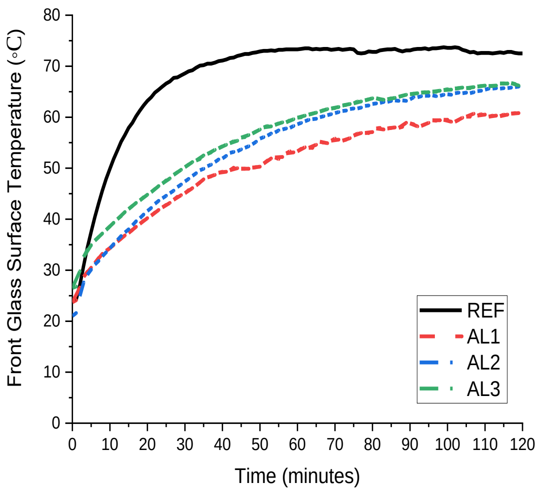

Fig. 12. Time-dependent front surface temperature distribution for all PV panels

Fig. 13 shows the distribution of voltage values recorded in all PV panels over time. Depending on the data obtained in the experiments; The average voltage amounts calculated for REF, AL1, AL2 and AL3 are 10.305 V, 9.805 V, 10.625 V and 10.485 V, respectively.

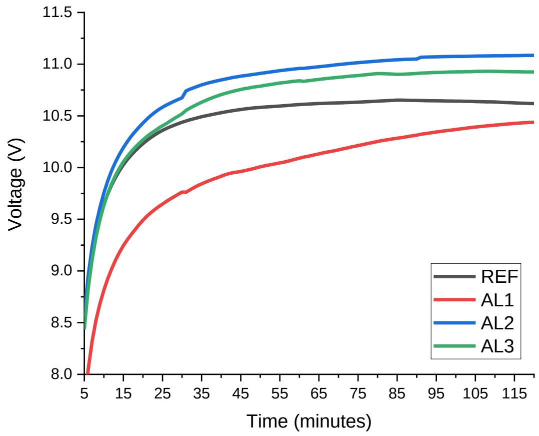

Fig.13. Voltage distribution over time for all PV panels

Fig. 14 shows the time-dependent back and thermosyphon heat pipe temperature distributions for all PV panels. T_b and T-T_s temperature values were not obtained since the cooling process was not performed in the REF experiment type.

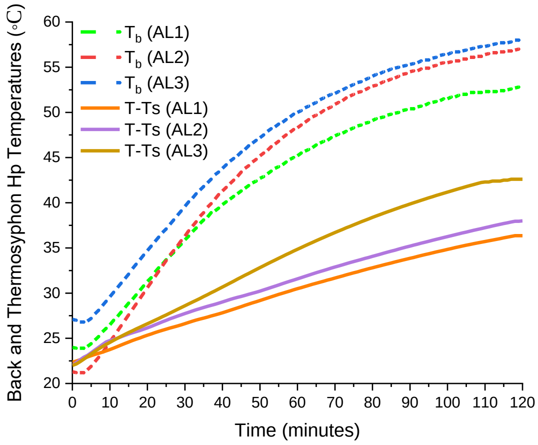

Fig. 14. Time-dependent back and thermosiphon heat pipe temperature distributions for all PV panels

Fig. 15 shows the efficiency change rates over time for all PV panels. Passive cooling in the reference panel and panels with heat pipes and nanofluids has clearly demonstrated its effect on efficiency. Average efficiency increases rates in AL1, AL2, and AL3 were calculated as 2.97%, 2.92%, and 2.82%, respectively. As seen in the graph, the highest efficiency increase was achieved in the panel with 1% nanofluidic heat pipe (AL1). When compared to the REF, the average change in yield increase rates was approximately 7% for AL1, 5% for AL2 and 1% for AL3, respectively.

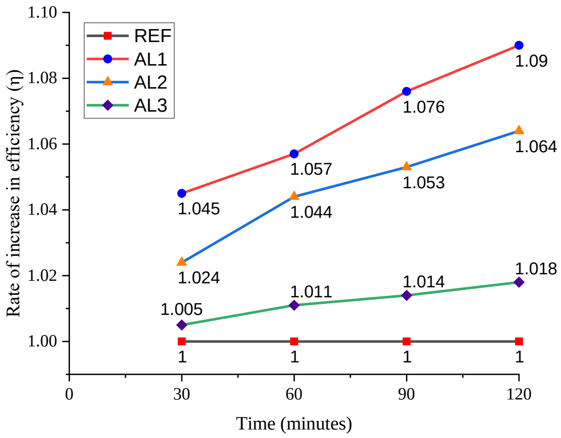

Fig. 15. Efficiency change rates over time for all PV panels

IV. DISCUSSION

In this study, an experimental study was carried out on the PV panel using a nanofluid in the heat pipe with a passive cooling method. Thermosyphon-type heat pipes can transfer heat depending on the temperature, density difference, and gravity's effect. The experimental study aimed to increase the electrical efficiency of the panel by reducing the surface temperature in the front region of the panel. It has been observed that the Al_2O_3 nanofluid used in TPCT increases the amount of open voltage produced. Contribution to the literature can be made by investigating the effects of different fluids on the PV panel in the designed passive cooler.

V. CONCLUSIONS

In the experimental study, passive cooler design and manufacturing was carried out. The effect of using Al_2O_3 Nanofluid as the coolant in TPCT used for passive cooling in PV panels was examined. Compared to the reference condition, it has been observed that in the cooling provided by Al_2O_3 nanofluid, the heat transfer from the front surface of the panel increases, the temperature decreases, and accordingly, the amount of voltage produced with the passive cooling effect also increases.

REFERENCES

[1] A. Goetzberger, V.U. Hoffmann, PV systems. Photovoltaic Solar Energy Generation. Springer, Freiburg.

[2] Bilen K., Erdoğan İ. 'Effects of cooling on performance of photovoltaic/thermal (PV/T) solar panels: A comprehensive review'. *Solar Energy*, 262, 11829, 2023.

[3] P.M.J. Stalin, T.V. Arjunan, M.M. Matheswaran, P.M. Kumar, N. Sadanandam. 'Investigations on thermal properties of CeO2/water nanofluids for heat transfer applications'. *Mater. Today*: Proc., 47, pp. 6815-6820, 2021.

[4] R. Sharma, P. Chauhan, A.K. Sharma, A. Katiyar, H.K. Singh, M.L. Rinawa, P.M. Kumar. 'Characterisation of ZnO/nanofluid for improving heat transfer in thermal systems'. Mater. Today: *Proc.* 62, pp. 1904-1908, 2022.

[5] S. Nižetić, E. Giama, A.M. Papadopoulos. 'Comprehensive analysis and general economic-environmental evaluation of cooling techniques for photovoltaic panels, Part II: Active cooling techniques'. *Energy Conversion and Management*,155, pp. 301-323, 2018.

[6] Ramkiran, B., Sundarabalan C.K., Sudhakar, K.'Sustainable passive cooling strategy for PV module: A comparative analysis'. *Case Studies in Thermal Engineering*, 27, 101317, 2021.

[7] Acar, A., Namli, L. & Ozbas, E. An experimental investigation on passive cooling of the photovoltaic panel using CuO nanofluid in a two-phase closed thermosyphon. *J Therm Anal Calorim* 148, 9609–9618 (2023). https://doi.org/10.1007/s10973-023-12343-6

[8] Kaya, M. 'An experimental investigation on thermal efficiency of two-phase closed thermosyphon (TPCT) filled with CuO/water nanofluid'. *Engineering Science and Technology, an International Journal*, 23, pp 812-820, 2020.

[9] (2023) [Online] Available: https://nanografi.com/nanoparticles/aluminum-oxide-al2o3-nanopowder-nanoparticles-alpha-purity-99-5-size-78-nm-hydrophilic/