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COMPUTATIONAL EXAMINATION OF PV SOLAR PANEL COOLING USING FINNED HEAT PIPE TECHNOLOGY

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Research Article

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ABSTRACT

There are several solar energy methods, each with a unique application method for producing electricity. Due to their comparatively high prices and poor efficiency, photovoltaic (PV) modules have been widely used in these technologies. As the operational temperature rises, PV panel efficiency falls. This is caused by heat absorption from the opposite half of the spectrum, reflection from the top surface, and heat absorption by components other than the cell. The cell temperature may sometimes rise to 700C, which reduces the PV module's output power by up to 0.65%/K and efficiency to 0.5%/K above the working temperature. Cooling is thus crucial, and a 200C drop will result in a 10% boost in efficiency. In this project, a finned heat pipe has been used to cool the panel in an effort to lower its working temperature. The fins and solar panel with finned heat pipe assembly were designed and modeled using computational fluid dynamics (CFD). A maximum drop of 20K was shown by the CFD study.

Keywords: Heat pipes, CFD, PV modules, and finned heat pipes.

INTRODUCTION

Fossil fuels now provide 80% of the world's energy. Massive exploitation is causing these resources to run out and presents a serious danger to the ecosystem, which is most seen in the acidity of the water cycle and global warming. Fossil fuels are distributed equally unevenly around the planet. Over half of the world's oil reserves are found in the Middle East. This reality causes global economic instability that has an impact on the whole geopolitical system. It is impossible to sustain the current system for more than two generations. Alternatives should be used in light of the aforementioned and the rapid depletion of oil. One of the most potential solutions to the aforementioned issues is renewable energy. In instance, photovoltaic panels may be a useful way to generate clean power. The scientist Edmund Becquerel made the first discovery of the photovoltaic phenomenon in 1839. In spite of this, this technology is regarded as relatively new. With an efficiency of 1%, the first cell that could be classified as PV was built in 1941. Cooling is crucial in circumstances with high light, such as concentrating systems or hot, muggy weather, since photovoltaic cells lose efficiency as the temperature rises. The cell temperature may rise to 800 C in the summer, when the average temperature may reach up to 42 0C, which reduces the output power. Therefore, there is a need for a passive cooling system for PV modules that may be produced at a reasonable cost. This study examines the effectiveness of a finned heat pipe configuration for cooling a typical photovoltaic module using computational fluid dynamics (CFD).

LITERATURE REVIEW

An experimental study on the features of a novel PV/T system was conducted by Qianyan Liu [1]. The conventional PV/T system was altered in this work, and a hierarchical structure—that is, the separation of solar panels and heat-absorbing plates—was suggested. This allowed cooling water to pass through solar panels on the rear before absorbing heat and then entering the collector. This increased the export of refrigerant collector quality while also significantly increasing the efficiency of solar panels for power production. It has been shown that in order to enhance power production, the water flow rate should be between 10 and 30 liters per hour.

A study on the performance of photovoltaic solar cells at high temperatures was conducted by David Meneses-Rodrıguez [8]. In order to boost the overall efficiency of solar energy usage, their research looked at the alternative of making a cell operate at a pretty high temperature (about 100–200 0C) and using the extra heat in some kind of hybrid system. Considering the various carrier transport modes and recombination characteristics of the cell material, they investigated the temperature dependence of the solar cell parameters both theoretically and empirically for the basic cells with p–n junction and the Schottky barrier. Additionally, the potential for using the focused sunlight was considered. A two-stage solar-to-electric energy converter with a high-temperature second stage and an overall conversion efficiency of 30–40% might be built, according to the computed data from the tests, which were carried out in the temperature range of 25–170 0C.

An experiment on solar panel cooling using a new micro heat pipe array was conducted by Xiao Tang [2]. This research examined the utilization of water-cooling and air-cooling techniques. The findings showed that lowering the temperature under cooling conditions may successfully raise the solar panel's photoelectric conversion efficiency.

1) On a day when the maximum air temperature and wind speed are 360C and 5.32 m/s, respectively, and the daily global radiation is 26.3 MJ, the temperature of the air-cooled solar panel decreases by 4.70C, the output power increases by 8.4%, and the efficiency difference is 2.6%.

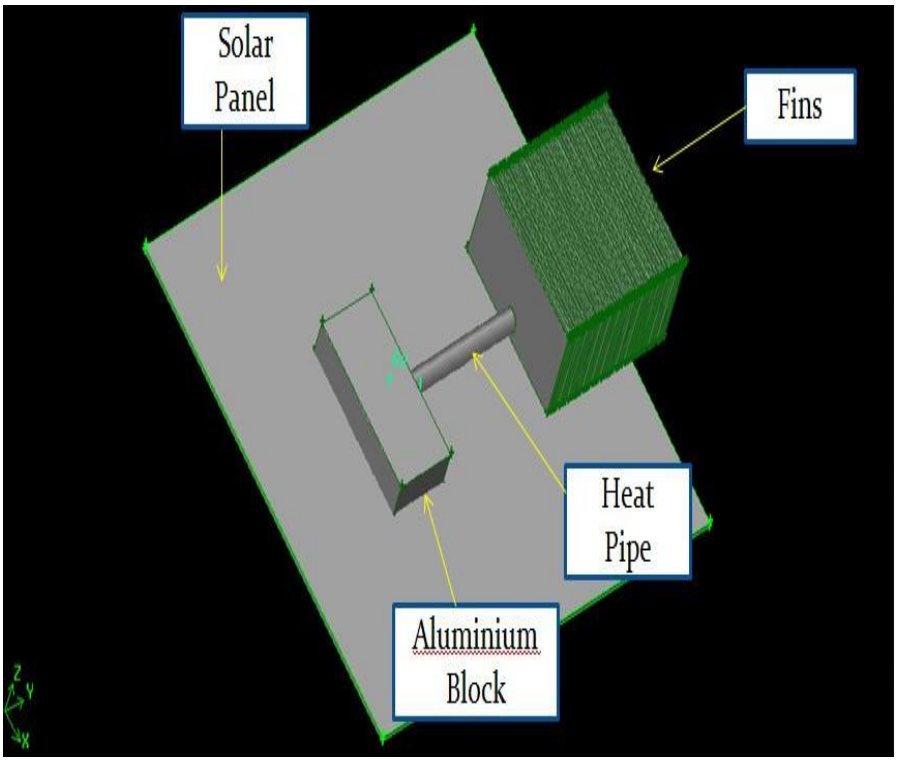
2) The solar panel with water cooling has a maximum temperature reduction of 8°C, a maximum output power gain of 13.9%, and a 3% efficiency difference when compared to the solar panel with air cooling. On that day, the highest air temperature and wind speed are 35°C and 4.72 m/s, respectively, while the daily global radiation is 21.9 MJ, allowing for a maximum efficiency of 13.5%.

OBJECTIVE

The purpose of this research on the finned heat pipe cooling system for PV panels is to decrease the operating temperatures of the PV panels by considering low cost techniques that can decrease the and enhance its power output. The present paper focuses on the performance of a finned heat pipe assembled onto the rear of a PV panel analyzed using CFD.

COMPUTATIONAL STUDY

The 3D Profile of my proposed finned heat Pipe is shown below. The CAD geometry has been drawn in GAMBIT 2.4.



3D model of finned heat pipe Specification of the Solar Panel

The Specification of the solar panel for which the experiment has to be carried out is listed below:

Dimension - 33cm x 30cm x 0.3cm
Number of cells - 36
Type of cell - Mono crystalline
Open Circuit Voltage of 1 cell - 0.6V
Short circuit Current of 1 cell - 0.23A
Open circuit Voltage of solar panel - 21.6V
Short circuit current of solar panel - 0.23A
Maximum Power of the solar panel - 4.968W

Theoretical calculation of the net heat that has to be removed (Q_{waste})

It is assumed that the average heat flux receiving from sun is 500 W/m^2 (Q_{total}). Therefore, the heat input to the solar panel is

$Q_{solarpanel}=Q_{total}xA_s$ A_s - Surface area

= 500 x 33x 30

$Q_{solar\ panel}$ = 49.5W

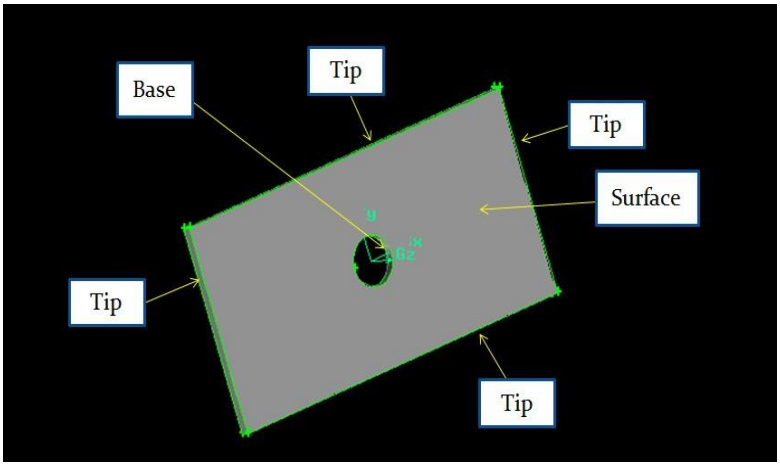
The amount of Q_{total} that is converted to electricity is 5W (Q_{used}). The net heat that has to be removed is

Q_{waste} = $Q_{soalr\ panel}$ - Q_{used}
= 49.5 - 5
Q_{waste} = 44.5W

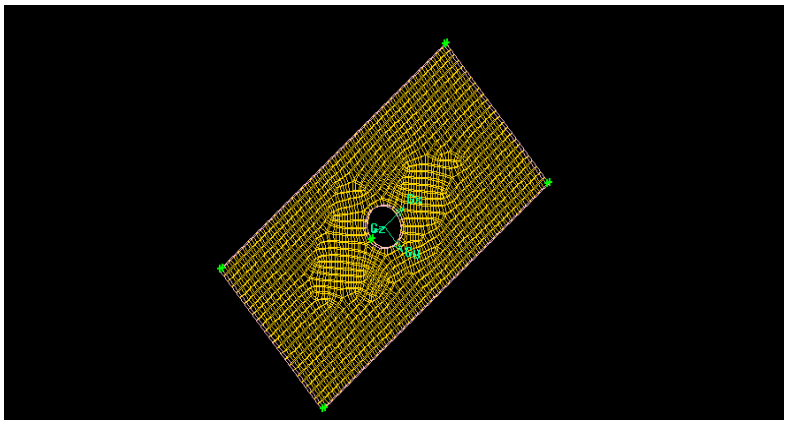
Specification of Heat Pipe
Based on the theoretical calculations, the available commercial heat pipe was purchased from 'Global Star Technical Services', Pune.
The specifications of heat pipe are as follows:

Diameter of the heat pipe - 1.2cm
Length of the heat pipe - 25cm
Material - Copper
Type of Mesh - Sintered screen mesh
Working Fluid - Water

Design of Fins
The Dimensions of the fins that has to be attached to the heat pipe is decided by conducting a series of CFD analyses in FLUENT 6.3. The geometry of the fins was drawn in GAMBIT 2.4 and is shown below.



3D profile of fins .The above geometry was meshed in GAMBIT 2.4. The Meshed model is shown below.



Meshed model of fins

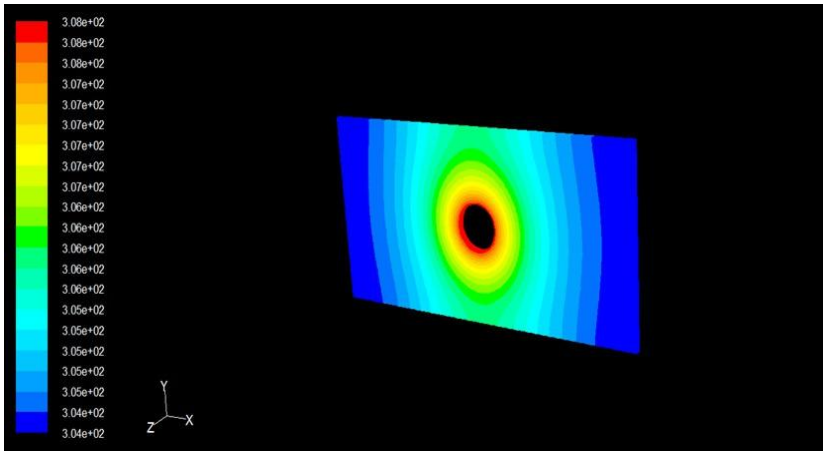
The mesh details are shown below.

Element Type	Spacing(cm)	Number of Nodes	Number of Elements
Hex	0.2	2738	1284

Boundary conditions
The above meshed file was exported to FLUENT 6.3 for doing a 3d, steady state, pressure based analysis. The boundary conditions that were given are.

Base - Constant Temperature - 308K (because, the wall temperature of heat pipe is constant)
Tip - Convection - 10W/m^{2}K
Surface - Convection - 10W/m^{2}K

After doing a series of CFD analysis for different dimensions, the best dimension suiting our requirement was 10cm x 5cm of aluminium material.
The temperature contour of the fin is shown below.

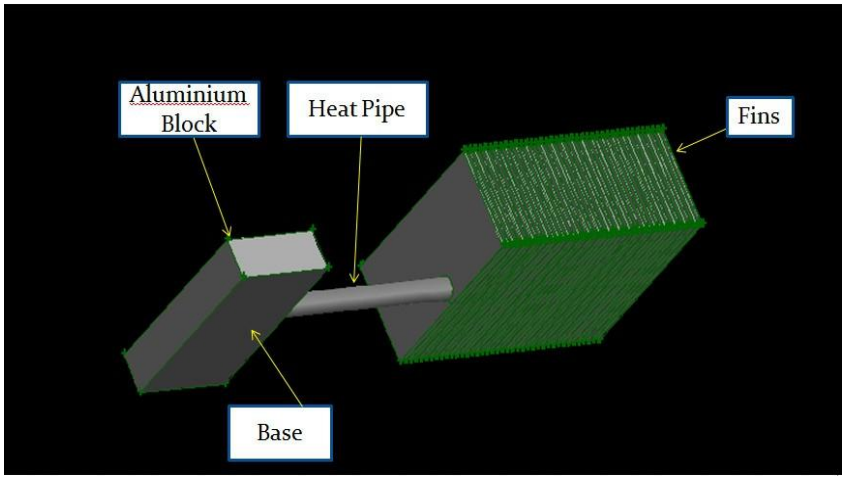


Temperature contour of fins .From the analysis, it has been obtained that the heat removed by 1 fin is 1.13W(Q_{fin}). The total amount of heat that has to be remove is 44.5W(Q_{total}).
Therefore, number of fins(n) required is

$n = Q_{total} / Q_{fin}$ $n = 44.5 / 1.13$
$n = 39.3$

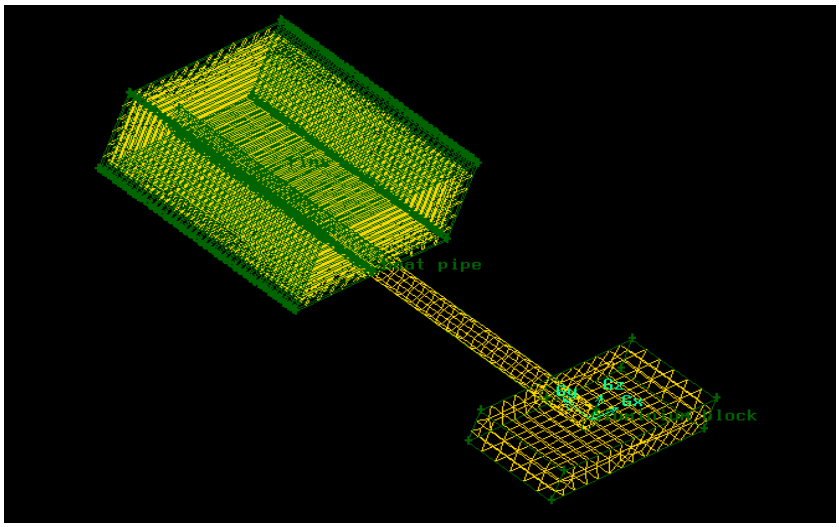
This shows that the number of fins required is 40.

Computational study of solar panel with Finned Heat Pipe
The CAD geometry of the solar panel with finned heat pipe was created in GAMBIT 2.4 and is shown below.



Profile of finned heat pipe

The above model was meshed in GAMBIT 2.4 and is shown below.



Meshed model of finned heat pipe.The details of the mesh are given below.

Domain	Element type	Spacing (cm)	No of nodes	Number of elements
Aluminium block	Hex	0.8	357	196
Heat Pipe	Hex	0.8	612	202
Fins	Hex	0.8	7700	3067

Boundary Conditions

The meshed file was exported and imported in FLUENT 6.3 for doing a 3d,steady state , pressure based analysis. The boundary conditions that were given are.
Base - Heat Flux - 550W/m^2
Heat Pipe - Constant Temperature - 308K
Fins - Convection - 15W/m^2K
Aluminium block except base - Convection - 15W/m^2K

RESULTS AND DISCUSSION

The temperature contour of the solar panel with finned heat pipe is shown below.

Temperature contour of finned heat pipe

It has been seen in the literature review that the maximum temperature that the solar panel achieves without cooling is 343K. In simulation, we can clearly see that the steady temperature reached with finned heat pipe is 323K. Therefore, the proposed finned heat pipe is able to reduce the temperature of the solar panel by 20K.

VI CONCLUSION

The benefits of a finned heat pipe for practical application, particularly in the high-temperature area, are confirmed by this investigation. For power generating systems installed on a roof, the PV panel's temperature may rise over 700C. By accepting a high heat flow via natural convection, the suggested finned heat pipe may be utilized to passively remove heat. A series of CFD calculations were performed on a copper heat pipe with fins connected and water as the working fluid. The ideal temperature to cool under environmental circumstances was found using CFD calculations, and it falls within the 300 C operational temperature range of solar cells. It promotes further research in this area with the ultimate objective of developing a cooling mechanism to keep the cell temperature within the parameters of the surroundings.

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