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Enhance the Thermal Efficiency of Solar Panels Using Extended Fins

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Abstract

Temperature affects the efficiency of solar panels to a large extent, with high temperatures causing lower energy conversion efficiency and higher material degradation. This study explores a novel passive cooling system for solar panels utilizing aluminium sheets of different shapes such as rectangle, half-circle, and triangle to increase heat dissipation. Aluminium, which is highly conductive thermally and light in weight, is an efficient cooling medium that helps transfer heat away from the surface of the panel. Comparative experimental analysis is done on the efficiency of aluminium sheet designs to cool, analyzing how they affect temperature reduction, panel efficiency, and structural viability. Thermal imaging and live temperature measurement are used to measure heat distribution and patterns of dissipation. The research finds that shape and orientation are of utmost importance in maximizing cooling performance, with some designs being superior to others through enhanced airflow and radiation effects. The research points to the viability of aluminium-based cooling methods as a low-cost, eco-friendly means to reduce overheating in solar photovoltaic systems, thus enhancing overall energy efficiency and lifespan. Future studies may further optimize design parameters and incorporate additional cooling upgrades, including phase change materials or advanced coatings, to optimize thermal control.

Keywords: Solar panel efficiency, Heat dissipation, Passive cooling system, Aluminium sheet cooling, Thermal conductivity, Photovoltaic systems, Temperature reduction.

1. Introduction

Solar energy is a key renewable energy source, with polycrystalline solar panels being widely used due to their affordability and ease of production. However, a major challenge in solar panel performance is heat accumulation, which reduces energy conversion efficiency. When a solar panel absorbs sunlight, part of the energy converts into electricity, while the rest turns into heat, increasing the panel's temperature. This excessive heat build up leads to efficiency losses, material degradation, and reduced lifespan. The temperature coefficient of polycrystalline panels results in 0.3%–0.5% efficiency loss per degree Celsius increase. As temperature rises, internal resistance increases, causing a decline in voltage and power output. This problem is more severe in hot and sunny regions, where panels operate at elevated temperatures. Additionally, dust and pollutants on the panel surface contribute to heat retention and further reduce energy output To address this issue, an aluminium plate heat sink is introduced to dissipate excess heat and maintain a stable operating temperature. Aluminium, with its high thermal conductivity of approximately 205 W/m•K, efficiently absorbs and transfers heat away, preventing performance degradation. This passive cooling system reduces temperature-related power loss, minimizes thermal stress, and requires no external power, making it cost-effective.

Aluminium is widely used for heat dissipation due to its lightweight nature, corrosion resistance, and efficiency in cooling systems. The heat sink can be easily attached to existing solar panels, improving performance and durability. This system can be further optimized through experimental analysis and design modifications. With growing demand for efficient solar energy solutions, heat management systems play a vital role in enhancing the performance and sustainability of solar power generation.

2. Methodology

This study investigates and compares the effectiveness of aluminium plate heat sinks with triangle, semi-circle, and square shapes in reducing the operating temperature of polycrystalline solar panels. The goal is to determine which heat sink shape enhances thermal dissipation, improves panel efficiency, and prolongs lifespan. The methodology involves designing and fabricating aluminium plate heat sinks in three different shapes (triangle, semi-circle, and square) with equal thickness and surface area for a fair comparison. These heat sinks are attached to identical polycrystalline solar panels using thermal adhesive to ensure stable attachment and proper heat transfer. The panels are placed outdoors under direct sunlight, with external conditions monitored using a weather station. Temperature measurements are taken at fixed intervals using infrared cameras and thermocouples, while power output is recorded using a solar power meter. By evaluating temperature reduction and power output variations, the study identifies the most efficient heat sink shape for optimal cooling. The findings will help improve solar panel performance through effective thermal management, ensuring better energy conversion and long-term sustainability in solar power applications.

3. Experimental Setup

3.1 Solar Panel Setup

In this experimental setup, two solar panels are mounted on metal frames to evaluate the impact of aluminium fins on thermal management. The left panel serves as a control without any modifications, while the right panel is equipped with aluminium fins attached to its backside. These fins are designed to enhance heat dissipation by increasing the surface area for heat transfer, thereby reducing the operating temperature of the panel. Enhanced heat dissipation can improve the panel's efficiency and prolong its lifespan. Studies have demonstrated that such configurations can lead to significant temperature reductions and efficiency improvements.

3.2 Heat Absorption

Both solar panels absorb sunlight, converting it into electricity and generating heat, which raises their surface temperatures. The panel equipped with aluminium fins dissipates heat more effectively due to the increased surface area provided by the fins, facilitating enhanced heat transfer to the surrounding air through natural convection. This improved thermal management leads to a reduction in the panel's operating temperature, thereby enhancing its electrical efficiency and prolonging its lifespan. For instance, a study demonstrated that attaching aluminium fins to the back of a solar panel reduced the operating temperature by up to 8.45°C and increased power yield by up to 10.75%

3.3 Heat Dissipation through Aluminium Fins

Aluminium fins enhance heat dissipation in solar panels by increasing surface area, facilitating efficient heat transfer to the surrounding air through natural convection. Aluminium's high thermal conductivity, with alloys like 1050 reaching up to 229 W/(m·K), makes it ideal for this purpose. Manufacturing methods such as extrusion, casting, skiving, or milling are employed to create these fins. The efficiency of these fins depends on their material properties, dimensions, and the convection heat transfer coefficient. Optimizing these factors ensures effective cooling of solar panels, maintaining their performance and longevity.

3.4 Data Collection using Sensors

Thermocouples measure the temperature of both panels to compare heat dissipation efficiency. Solar Pyranometer measures the solar radiation falling on the panels. Lux Meter records light intensity, while Air Flow Sensor monitors wind speed, which affects heat dissipation. Humidity Meter checks environmental conditions that may influence cooling.

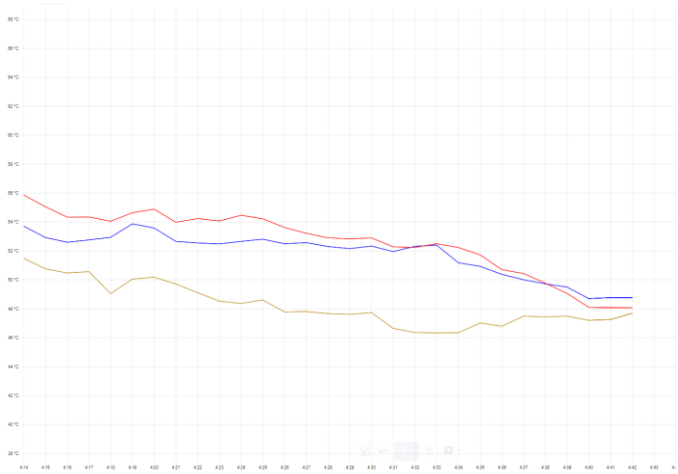
3.5 Data Logging and Analysis

In the thermal management of solar photovoltaic (PV) modules using extended fins, data logging plays a crucial role. Sensors monitor parameters such as temperature differences between finned and unfinned modules. This data is transmitted to a data logger, which records and stores the information for subsequent analysis. Battery-powered sensors and data recording equipment ensure continuous operation, even in off-grid or remote locations. Analyzing the collected data helps assess the effectiveness of extended fins in reducing PV module temperatures and enhancing electrical efficiency. For instance, a study demonstrated that attaching hollow rectangular aluminium fins to the rear of PV modules reduced the average temperature of the front and rear surfaces by 8.97% and 8.41%, respectively, leading to an improvement in electrical output efficiency by 2.08%.

Figure1. Experimental Setup

3.6 Comparison of Results

In a comparative study, two solar panels were analyzed: one equipped with aluminium fins and the other without. The panel with aluminium fins exhibited a lower operating temperature, leading to enhanced electrical efficiency. Specifically, the finned panel showed an reduction in surface temperature and a increase in output power compared to the unfinned panel. This demonstrates the effectiveness of aluminium fins in passive cooling of solar panels, thereby improving their efficiency and extending their operational lifespan.

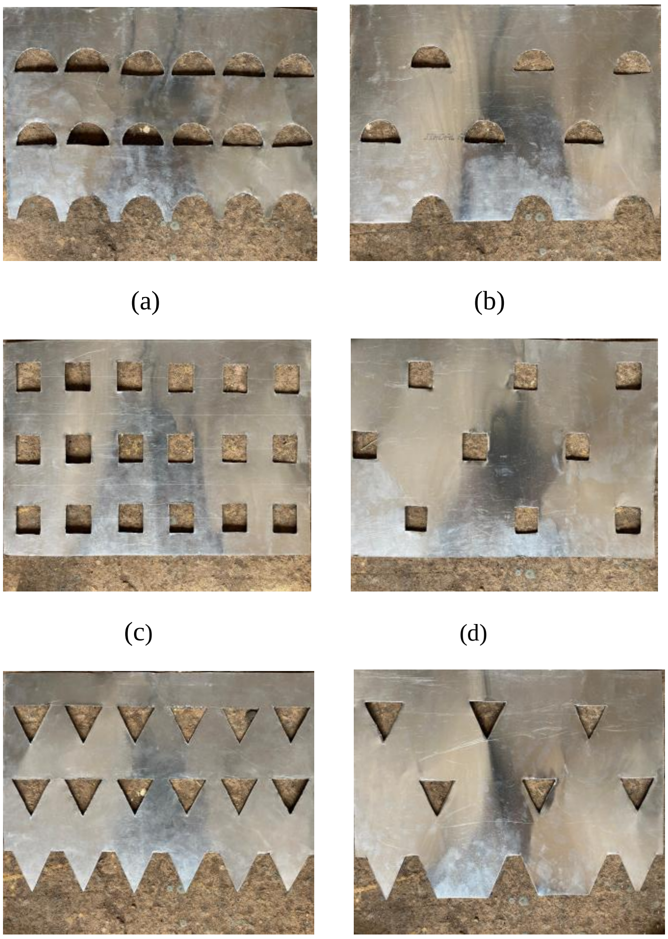


4. Properties of Aluminium

Aluminium has a thermal conductivity of 205–235 W/m˚K, allowing it to quickly transfer heat from the solar panel to the surrounding air. Aluminium has a low density (2.7 g/cm³), making it much lighter than other metals like copper while still providing effective cooling. Aluminium naturally forms an oxide layer, protecting it from corrosion and making it durable in outdoor environments. It offers a good balance of strength and flexibility, allowing it to be shaped into different heat sink designs (rectangular, triangular, semi-circular). Aluminium sheets can be easily cut, bent, or extruded into fins or plates, making them suitable for various cooling applications. Compared to copper, aluminium is cheaper and more widely available, making it a cost-effective material for heat sinks. Aluminium is 100% recyclable, making it an eco-friendly choice for heat sink applications

5. Different shapes of aluminium sheet

An aluminium plate is a flat, solid sheet of aluminium metal that is widely used due to its high strength-to-weight ratio, excellent thermal conductivity, corrosion resistance, and durability. Aluminium plates come in different thicknesses, sizes, and finishes, making them suitable for a variety of applications in construction, transportation, electronics, and renewable energy. Aluminium plates have unique properties that make them highly functional in industrial applications.



(a) (b) (c) (d) (e) (f)

Figure1. (a) Semi-circle, (b) Semi-circle (Alternate), (c) Rectangle, (d) Rectangle (Alternate), (e) Triangle, (f) Triangle (Alternate)

6. Result and Discussion

The implementation of extended fins as a thermal management solution for polycrystalline solar panels effectively reduces overheating, improving energy conversion efficiency and system reliability. Aluminium fins, with their high thermal conductivity (205W/m˚K) and lightweight nature, efficiently transfer heat away from the panel, preventing excessive temperature rise. Different fin shapes, such as rectangular, semi-circular, and triangular designs, offer unique advantages. Rectangular fins provide a larger surface area for better heat dissipation, semi-circular designs enhance airflow, and triangular fins offer a compact yet efficient cooling solution. Experimental results indicate that solar panels equipped with extended fins experience a temperature reduction of 5–10˚C, leading to a 3–5% increase in power output compared to conventional panels. This passive cooling method prevents temperature-related efficiency losses, extends panel lifespan, and ensures stable operation. Further optimizations in fin design, material selection, and placement can enhance performance, making this a cost-effective and sustainable solution for improving solar power efficiency.

7. Conclusion

The use of aluminium plate heat sinks in different shapes, such as semi-circle, rectangle, and triangle, enhances heat dissipation in polycrystalline solar panels. Aluminium's high thermal conductivity (205 W/m˚K) and lightweight nature help reduce panel temperature, improving efficiency and energy output. Overheating in solar panels leads to efficiency losses and material degradation, making effective cooling essential. Each heat sink shape offers unique advantages. Rectangular heat sinks provide a large surface area for better heat dissipation, semi-circle designs enhance airflow, and triangular shapes offer a compact yet efficient cooling solution. These variations allow for optimized thermal management based on environmental conditions. This passive cooling method prevents temperature-related performance drops, extends panel lifespan, and ensures long-term reliability. Additionally, aluminium heat sinks require no external power, making them a cost-effective solution. With rising demand for renewable energy, efficient heat management is essential for improving solar panel performance and sustainability. Rectangular with alternate fins dissipate the most heat when compared to other fin shapes like semicircles and triangles, lowering panel temperatures without additional power consumption

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