Influences Of Nanofluid and Investigation of Thermal Behaviour/Power Conversion Efficiency of Flat Plate Collector

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**Abstract:** Flat plate solar collectors familiar in heat exchanger, air dryer, and space cooling utilization because of its unique characteristics like uniform temperature distribution, better heat transfer performance and enhanced fluid outlet temperature. However, climatical changes lead to minimizing the thermal properties and solar conversion efficiency behaviour. The motto of the investigation is to overcome the above difficulties and enhance the solar power conversion behaviour of solar collectors featured with alumina (Al2O3) nanofluid. The investigation into the effects of alumina nanofluid on thermal storage systems revealed remarkable enhancements in key performance metrics, including thermal conductivity, photocurrent density, thermal solar power, and solar power conversion efficiency. When compared to traditional solar systems, alumina nanofluid emerged as a game-changer in electrical solar power applications. It achieved high (0.58 W/mK) thermal conductivity, a photocurrent density of 2.9 mA/cm², and a substantial solar output of 4.8 kW. Most notably, it delivered an exceptional solar power conversion efficiency (SPCE) of 52%, a significant improvement over standard solar panels that do not incorporate nanofluid technology.

# Introduction

Solar renewable energy has found significance in various applications like multipurpose heating systems, Agriculture, thermal storage applications, water heaters, and heating/cooling applications. Recently, the utilization of renewable green energy has increased to overcome the difficulties of artificial fossil fuels [1]. The low-temperature solar heater gained importance in residential applications. The phase change material adopted by solar energy systems was investigated for building energy applications and found higher temperature electrothermal film with improved heat storage efficiency of 65% [2]. Similarly, the coated solar cell improved thermal storage during high/low solar light. The solar thermal energy of this system was raised by introducing nanofluids in conventional systems having solar PV cells with heat exchanger pipes. In the two model phases, oil and copper monoxide, utilized as nanofluid to increase the solar conversion efficiency, the finite elemental model was generated and found the variations in thermal distribution during the solar system [3]. The thermal stress of the system was analyzed by computational fluid dynamics [4].

The nanofluids have the potential for high thermal conversion with increased heat flux. That system was implemented for solar renewable energy for building heat storage applications [5-6]. ZnO nanofluid adopted a spectral splitting solar cell was experimentally evaluated, and the high spectrum was realized. This results in enhanced solar power efficiency compared to conventional solar PV cell systems [7-8]. Moreover, the nanofluid has superior thermal behaviour, and the magnesium oxide is combined with distilled water and ethylene glycol in solar collector applications. 0.4% concentration with 2.5 litres/min offered a better thermal efficiency of 69.1% [9]. Parabolic solar collectors configured with alumina nanofluid was investigated by computational fluid dynamics analysis and detailed the impact of alumina fluid-operated solar collectors has better thermal conductivity with improved thermal performance related to solar panels without nanofluid. It has 15% on 500 to 600K temperatures [10]. A cobalt oxide/water nanofluid influences the thermo-electrical generator's electrical, thermal conductivity, energy, and solar efficiency for heat sink applications. Cobalt oxide found significance in solar PV cells to found higher thermal conductivity and electrical power compared to normal solar PV systems and showed a 12.28% improved overall efficiency of electrical [11-15]. Ag/MgO/biochar has good thermal adsorption behaviour compared to ZnO-based nanofluid [16-18]. However, the composite-based structure was a better insulation material for building heating and cooling applications [19-21]. The hybrid nanofluid in solar energy systems found wonderful building, transport and heat exchanger applications. It found superior thermal management with increased thermal conductivity, which raises electrical power with improved photocurrent density [22-26]. However, nanofluid technology adopted the trend of solar renewable energy, facilitating high thermal performance with efficient power conversion.

Here, the fluid played the main role in transfer, and improved heat energy gained from solar was proved by finite elemental analysis and experimentally. Based on this, the current research presents the enhancement of solar energy thermal performance via alumina nanofluid mixed with water at 10 and 20%. The results of thermal conductivity, photocurrent density, thermal solar power, and SPCE of thermal storage systems evaluated the influences of alumina nanofluid in the present systems.

# Materials and Methods

## Materials

Fig.1 illustrates the experimental setup of solar collectors with the thermal storage system. Fig. 1(a) represents a solar collector with a 10mm tube for alumina nanofluid circulation, and the thermal storage system heating and cooling pipe setup is shown in Fig. 1(b). Initially, the water fixed a fluid medium to transmit the thermal energy from solar, after alumina is mixed with water fluid at 10 and 20%.

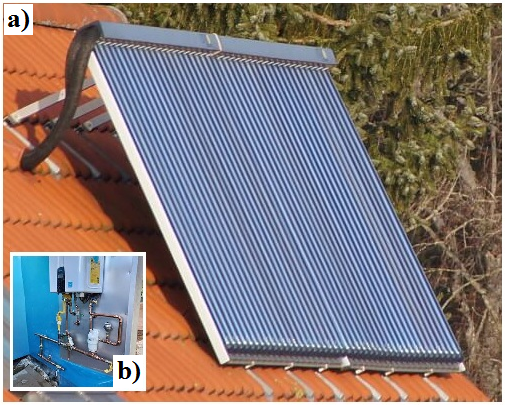


Fig. 1 Solar collector setup for thermal storage system a) solar collector with thin tube surfaces and b) thermal storage system setup

The operational layout for the thermal heating/cooling setup is illustrated in Fig. 2. It contains the solar collector, pump, storage tank, and boiler arrangements. During the starting, the water is considered a fluid medium for solar absorption. The second and third stages are 10 and 20% alumina nanofluid blended with water fluid. The fluid medium was circulating with the help of a pump assembly and fed into a solar rise pipe inlet. The thermal energy is gathered from the solar collector via a fluid medium with an applied fluid flow of 10 litres/h [27-30]. The temperature sensors and pressure gauges monitored the collector's temperature and pressure.

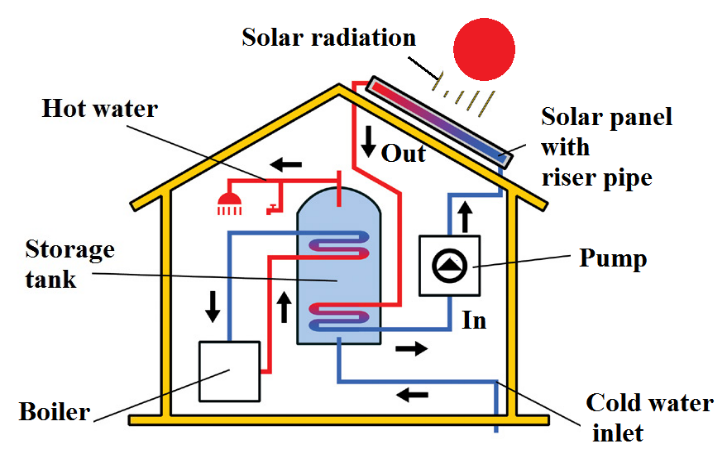


Fig. 2 Model layout representation for thermal storage heating and cooling system

Influences of Al2O3 nanofluid on thermal conductivity, photocurrent density, thermal solar power, and SPCE was calculated, and its results were compared with water fluid.

# Results and Discussion

## Effect of alumina nanofluid on thermal conductivity of thermal storage system

Thermal conductivity (k) behaviour of present study is shown in Fig. 3, which heat storage system operated by water, 10% alumina, and 20% alumina nanofluid. It was noted from Fig. 3 that alumina nanofluid's thermal conductivity was higher than water fluid's thermal conductivity. Based on the temperature rise, it was measured. The thermal conductivity of water flow showed gradual improvement from 0.23W/mK at 20ºC to 0.42W/mK at 60ºC. While the 10% alumina blends with water fluid showed a hike in k of a thermal storage system. It showed a 39% improvement in k during 20ºC [31-34]. It was the reason for the content of alumina absorbing the heat from solar radiation. Compared to water fluid, the nanofluid has enhanced thermal behaviour. The major k quality of 0.58W/mK was observed by 60ºC with 10lit/h fluid flow (20% alumina/water). The k value in the thermal system operated with alumina (20%) blends with water fluid was found to be 0.58W/mK and improved by 38% compared to water flow at 60ºC. The thermal conductivity varied based on the flow rate [35-38].

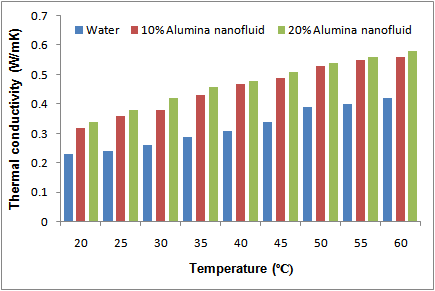


Fig. 3 Thermal conductivity of thermal storage system

## Effect of alumina nanofluid on photocurrent density of system for thermal storage

Figure 4 represents the J-V curve of this system. From Fig. 4, the alumina nanofluid's photocurrent density was larger than the water fluid. It was due to the effect of thermal management [17 and 39-42]. Higher thermal conductivity results in increased solar power. The photocurrent density of water, 10, and 20% of alumina nanofluid initiated at 0.15, 0.21, and 0.22 volts.

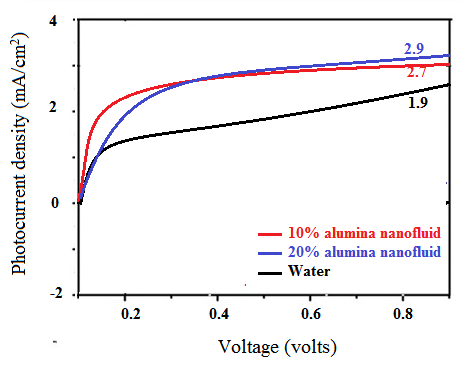
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Fig. 4 Photocurrent density (J) Vs voltage (V) curve of thermal storage system

Based on the solar radiation, it was gradually uptrend and a higher value of 1.9mA/cm2 was noted on water fluid at 100ºC. It was due to the solar absorption behaviour of base (water) fluid. Similarly, the Al2O3 nanofluid-operated system for thermal storage shows a higher voltage and found a 52.63% improvement (20% Al2O3 nanofluid) related to conventional fluid. The reason for improved photocurrent density was higher thermal performance with increased thermal conductivity [43-45]. This is evidenced in Figure 3. According to the two layers of the solar collectorand nanofluid circulating tube, the behaviour of photocurrent density was increased and attained the maximum power level compared to water fluid.

## Effect of alumina nanofluid on solar power of system for thermal storage

Fig. 5 represents the solar power of the system for thermal storage measured by water, 10, and 20% alumina nanofluid. From Fig. 5, the solar power for the current system was linearly increased with the increased collector temperature to fluid flow. The solar power during a water fluid-operated system for thermal storage was 0.8 kW at low temperatures and gradually improved from 1.1 to 2.35 kW with improved temperatures from 20 to 60ºC. While introducing nanofluid facilitated high thermal performance, these results improved solar power. A similar trend was proved in the most recent literature. Moreover, the nanofluid performed higher thermal than normal solar collector systems [46-49].

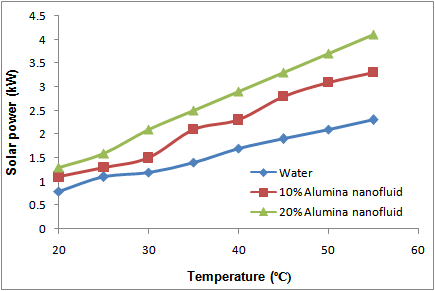
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Fig. 5 Solar power of system for thermal storage

The 20% alumina blended with water fluid enhanced solar power and increased by 1.04 times compared to water fluid flow. The alumina nanofluid was the prime reason for this enhancement.

## Effect of alumina nanofluid on solar power conversion efficiency of system for thermal storage

Fig. 6 indicates the solar conversion efficiency related with temperature of thermal storage solar setup.

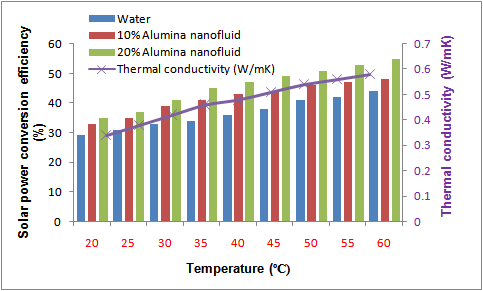
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Fig. 6 Solar conversion efficiency of the system for thermal storage

The above Fig. 6 noted that the efficiency percentages of the thermal system varied due to the temperature and thermal conductivity of the present setup under water, 10, and 20% alumina nanofluid. The solar conversion efficiency of the operated solar thermal setup was lower than that of the alumina nanofluid-operated thermal storage system. It was offered 29% to 44% under low to higher temperatures of 20 to 60ºC. Meanwhile, the Al2O3 nanofluid featured thermal storage setup showed higher solar conversion efficiency and significant improvement because of the high self-heat effect on alumina fluid flow. It offered high thermal behaviour compared to others. This leads to maximum photocurrent density, as shown in Fig. 4. The 20% alumina nanofluid blended water has a maximum solar conversion efficiency of 55% at 60ºC under 4.8kW solar power. It was compared to water and 10% alumina blend water as improved by 25% and 14.5%, respectively. The improvement in solar conversion efficiency was a higher heating effect given by nanofluid. Moreover, the 20% alumina nanofluid proved their behaviour better in the thermal storage system [50-53].

# Conclusion

This attempt to enhance solar power conversion efficiency attained by introducing alumina nanofluid blended with water fluid was discussed effectively with thermal storage application. Compared to all others, the thermal storage system with 20% alumina nanofluid blended with water-enhanced solar thermo-electrical power. The thermal conductivity of 20% alumina nanofluid was found to be a 38% improvement compared to water fluid-operated solar collectors on thermal storage systems. The photocurrent density attained a maximum value of 2.9mA/cm2 and hiked by 52.63%. The solar power of thermal storage was raised 1.04 times larger than water fluid. The solar conversion efficiency of the thermal storage system operated with 20% alumina nanofluid blended with water has 55% solar conversion efficiency. This system was implemented for household applications with thermal storage systems.

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