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(RESEARCH ARTICLE)

Investigating the impact of nanoparticle coating concentration variability on the heat absorption and efficiency of solar air heaters

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Abstract

Non-renewable fossil fuels have long supported global economic growth but have also caused detrimental environmental issues such as greenhouse gas emissions and climate change. To address these challenges and meet future energy demands sustainably, researchers are focusing on advanced materials and technologies to harness renewable energy. Solar energy, one of the most abundant renewable sources, offers a clean and widely available solution throughout the year. Among solar thermal technologies, the flat plate solar collector (FPC) stands out for its simplicity, cost-effectiveness, and practical application in thermal energy systems. This experimental study explores the impact of graphene nanoparticle-enhanced selective coatings on the absorber plate of a flat plate solar collector. Graphene, known for its exceptional thermal conductivity and optical absorption properties, was combined with black paint to form a novel coating applied to an aluminum absorber plate. Three samples were prepared with varying concentrations of graphene nanoparticles (0.5%, 1%, and 1.5%**)** and tested under real-time conditions. Air was used as the working fluid at a constant flow rate of 0.0169 kg/s**.** The results revealed a significant enhancement in thermal efficiency: the absorber surface achieved 67% efficiency at 0.5% concentration**,** 71% at 1%**,** and a maximum of 74% at 1.5% concentration**.** The improved performance is attributed to graphene's superior thermal conductivity compared to standard black paint. This research highlights the transformative potential of graphene-based coatings for enhancing FPC efficiency, presenting a novel and cost-effective solution for advancing solar thermal technologies and promoting sustainable energy systems.

Keywords: Graphene coating; XRD; Thermal performance; Flat plate collector

1. Introduction

Energy is essentially a must for life to exist, and it has become one of the most important factors in the development of the global economics system. However, the most recent oil crisis increased discussion about long term changes in the global financial system towards alternative source of electricity and environmental issues [1-2]. The avaibiltiy of coal is limited and could last only a few hundred years. Despite being constrained and impractical for many developing nations to handle commercially, the current power paradigm is dependent on traditional electricity assets [3-5]. Traditionally electricity sources are limited and have an adverse effect on the environment through increased pollution; as a result, they must be electricity sources that are abundant in nature to meet their power consumptions goals [6-8]. Flat plate collector is a heart of a sun warmth series machine designed for operation inside the low to medium temperature range (5°c to 50°C above the ambient temperature). It absorb each beam and diffusion radiation, converts the absorbed radiation into heat and then transfer the heat to water or air flowing through the collector duct [9-11]. The flat plate collector does not require monitoring of the solar and little renovation is needed. A conventional flat plat solar heater with insulation at the bottom and around the borders, a flat absorber plate, and a clear cover at the top [12-16]. The air to be heated flows through the duct under the absorber plate. The flat plate solar heater uses, however, are rather few

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despite the enormous surface area. In order to create heat, which is then transmitted to a fluid, a solar collectors and no concentrating or stationary collectors are the two primary types of solar collecting system [17-20].

A non-size concentrating the same flat collector is used to collect and absorb solar radiation. A focusing collector, on the other hand, uses concave reflecting surfaces and has a similar reception area to divert and concentrate solar light, thereby according absorbing it. The thermal efficiency of air collectors is typically poor [21-24]. Heat transfer inside the channel must be improve while minimising heat loss in order to increase thermal efficiency. Several experts have studied solar sir heater during the past few years. For the purpose of improving the coating material on the absorber plate, which produce high temperature. Researchers have concentrated on examining performance and heat transfer rate at the end results. [25-28]. Black plate and nanoparticle Ni electroplating were employed in the investigation. It increase the black pain heat resilience. The coating on the absorber plate raise the IR value [29-35]. Through the use of coating material on the absorber plat, an experimental was conducted to improve thermal performance. NI-Sn was shown to gave the best performance in the paper when uses as a coating material. The thermal daily thermal efficiency was increased by 29.33% for the use of coating material [36-37]

This study used a multilayer composite coating of Cr-Al-O nanomaterial to increase thermal stability. Due to nano multilayer structure, recent study has demonstrated better thermal stability at temperature near 700°C [38-40]. Here, the nanomaterial made of graphene is used to cover absorber plate with an anti-corrosion additive. Additionally, the absorber plate new selective paint exhibit strong solar selectivity [41-43]. By using forced convection and pressure drop characteristic, fully developed constant turbulent flow in air cooled horizontal equilateral triangle ducts was measuring using hydraulic diameters based on Reynolds numbers in the range of 2800 to 9500. Here, the entire triangular section was continuously heated, and the exterior face was thermally insulated [44-46]. Single wall carbon nanotubes are described in the paper as a type of blackbody absorber plate. It demonstrates how slowly emissive nanomaterial are around 0.98 to 0.99. A TiO_2 nanoparticle coated absorber plate is combined with black paint in the studied innovative solar system to boost performance. The outcomes demonstrates the use of TIO2 nanomaterial, which raises the temperature by 1.5 C in black paint [47-51]. The fully developed flow heat transfer coefficient for the parabolic and triangular section at constant wall temperature were numerically examined. Here it was determine the Poiseuille and Nusselt numbers dependent on the grid number 160 x 160 grid were and that this dependence was appropriate. The analysis findings were then compared to the review of the literature [52-53].

An experimental research was carried out for the solar air heater for the purpose of space heating, and the analysis displays the design, modelling, and performance of the triangle heating system. The mass flow rate determines the system efficiency, and as the mass flow rate rises. The efficiency of the solar air heater declines [54]. Various nanomaterial including copper oxide, alumina, silica and, carbon nanomaterial are employed to increase the thermal stability. The outcomes demonstrate that the use of carbon based nano fluid in solar collector results in an increase in the thermal of the collectors and a decreased in their size. Many heat transfer improvement techniques aim to start or intensity the flow's turbulence by employing. The heat transmission surface have turulators. Examples of such techniques includes ribs, grooves and intentionally roughened surface [55]. Turbulence and the braking up of the boundary layer are the key cause of the improved heat transfer in the ribbed surface. Short ribs have a minimal impact on laminar flows while singe phase and turbulent flows are where ribs perform at their best.

In order to increase the heat, more ribs are employed. Instead of using heat transfer augmentation techniques, the flow velocity can be increased to improve the heat transfer. A higher mass flow rate or velocity results in a unfavourable reduction in the temperature difference between the air flowing in and out. Improvements in heat transfer must be balanced with increased power usage to combat the increased pressure decreased [56-57]. Furthermore, it is crucial that the solar air heaters offer the air-conditioned environment thermal comfort. Solar energy currently play a significant and straightforward role in thermal conversion.

Various types of solar air heaters are employed to harness solar energy efficiently. A traditional solar air heater typically consists of a collector and an absorber plate enclosed by a transparent glass covering. In the present work, the flat plate solar collector system comprises key components: a transparent glass cover, an air passage as the working fluid medium, and an absorber plate designed for maximum solar radiation absorption, as illustrated in Fig. 1. The collector is made of an ordinary metallic material, where the absorber plate faces the sun, capturing solar insolation, converting it into heat energy, and transferring it to the working fluid (air) passing through the system. The transparent glass cover plays a dual role: it allows incoming solar radiation to pass through while minimizing heat loss by blocking infrared radiation and reducing re-radiation losses. The performance of a solar air heater is significantly influenced by the coating material applied to the absorber plate, which requires high solar absorptance and low thermal emittance to enhance efficiency. To achieve improved thermal performance, a nanomaterial coating combined with black paint has been applied to the surface of the absorber plate. Nanomaterials, due to their superior thermal conductivity and absorption properties, enhance heat transfer to the working fluid. The detailed properties of the working fluid (air) and specific parameters of the flat plate solar collector system are summarized in **Table 1 and Table 2**, providing a comprehensive understanding of the system's design and operational parameters.

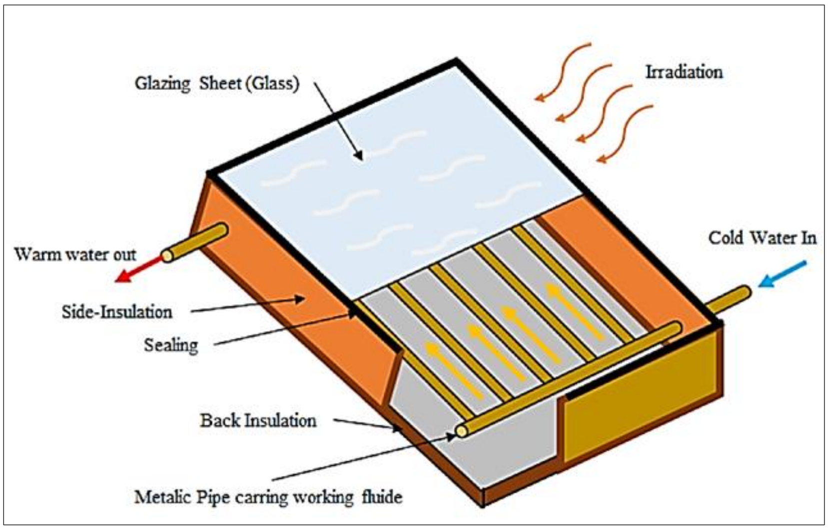

Figure 1 Diagram of flat plat solar heater

Table 1 Properties of operational fluid i.e. air

S.No.	Properties	Values
1	Black paint thermal conductivity (W/m K)	0.025
2	Graphene thermal conductivity (W/m K)	2,000
3	Dynamic Viscosity (N/m^2)	$1.738x10^{-5}$
4	Specific Heat (J/kg-k)	1.006
5	Density (kg/m^3)	1.225
6	Velocity of Air (m/s)	1

Table 2 Detail of flat plate solar air heater

S.No.	Parameters	Values
1	Collector length	110 cm
2	Collector width	60 cm
3	Metallic base thickness	5 cm
4	Thermal conductivity (Al) (W/m K)	230
5	Density (kg/m^3)	1.225
6	Thermal Conductivity air (W/m K)	0.0267

2. Material and methods

2.1. Raw materials

The reinforcements, graphene powder were purchased from Platonic Nanotech Private Limited, Dist –Godda-Jharkand, Pincode:- 814154-India. The average thickness and lateral dimension of GPNs where 5-10nm and 5-10um with >99% purity with density 2.5 g/cm^3 and the surface are is 200-240 m^2/g respectively.

2.2. Characterization of graphene powder

To understand the properties of graphene powder standards characterization is examined. Fig.2 (a) X-ray diffraction analyses of the graphene powder are carried out in a Philips XPert instrument using Cu Kα radiation for phase identification of the powder. In this analysis, the diffraction pattern of the powder was obtained in the 2θ range of 5° to 90° at a scanning speed of 0.60° per second and using a step size of 0.02°. TGA analysis of the prepared sample (~ 5mg) was performed using a Mettler Toledo TGA/DSC rating 2 with a heating rate at 10 °C/mi in air condition at a flow rate of 60 mL/min as discussed in Fig.2 (b), shows thermogravimetric analysis (TGA) was employed to investigate the thermal stability of the graphene powder. In Fig. 2(c) Insulation resistance tests were performed on using Nicolet 8700 IR spectrometer (Band range400-4000cm^{-1}) to analyze the IR transmission spectra of graphene powder. Similarly in Fig.2. (d-e) for Scanning electron microscopy, Novanano SEM 450 equipped with an EXD analysis facility is used. This instrument is capable of analyzing morphological details of the samples at higher magnifications along with the advantages of an elements mapping in clusters.

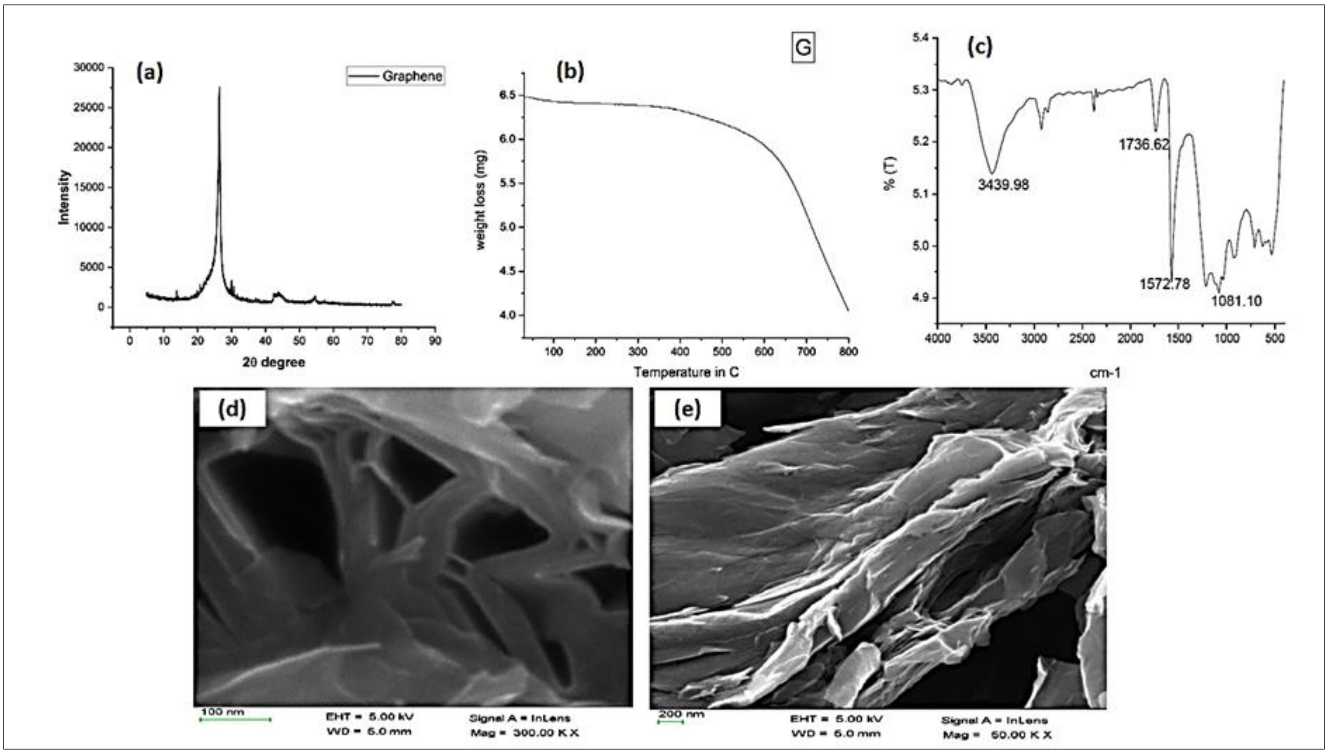

Figure 2 (a) The X-ray diffraction analyses of the graphene powder, (B) Thermogravimetric analysis (TGA), (c) Insulation resistance test (IR), and (d-e) Scanning electron microscopy of graphene powder

2.3. Experimental Procedure

The experimental configuration comprises of an aluminium sheet constructed rectangular portion. The rectangular segment has dimensions of length 110 cm, width 60 cm and thickness 5 cm. The inlet and outlet sections are the same length form end to end. Therefore, thermal characteristics are constant along the whole length of the test section, and the flow is considered to be entirely turbulent within the rectangular portion with no slip the wall. With the aid of blower, air is drawn into the section's intake side at room temperature. In the experiment described here, three distinct types of absorber surfaces were used. And graphene nanoparticle were doped into black paint in three different percentages (0.5%, 1%, and 1.5%). The aluminium absorber plates having a selective coating on them. An essential part is the absorber plate the sun radiation is absorbed by the rectangular shaped heating part. Although the other two side of the rectangular absorbed plates, one side of the rectangular has a glass cover that serves as glazing. The K-type (Ni-Cr/Ni-Al) thermocouple was used to measure the temperature at the inlet and out flow. The glazing plate is explore to solar radiation is measured using solar intensity meter. Solarimeter set up in the same inclined plane on the glass sheet. The micro manometer has recorded the pressure at the inlet and out flow. Using a digital anemometer, air speed was measured. A control mechanism at output regulates the hot air's output. In the studies, a unique type of coating is created on the absorber plate using graphene nanoparticle. The graphene powder is mixed with the black paint using a magnetic stirrer to 1 hours for homogenous mixing. The absorber plate is covered in a black paint that has been doped with various concentration of graphene nanoparticle. In order to boost the absorptivity and reduce emissivity of absorber plate, black paint is first doped with a fraction of graphene nanoparticle.

2.4. Thermal performance of solar air heater

The thermal performance of solar collectors can be described by the following equation [14] in accordance with ASHRAE standards.

$$\eta_{th} = F_R \left[(\tau\alpha) - U_L \left(\frac{t_i - t_a}{I}\right)\right] \quad \text{……………. (1)}$$

Eq. (1) becomes $\eta = F_R(\tau\alpha)$. If the input parameter is equal to the ambient temperature. Results from this performance expression are ineffective and cannot display the actual operative temperature. The following equation of the efficiency of solar air heaters.

$$\eta_{th} = F_0 \left[(\tau\alpha) - U_L \left(\frac{t_i - t_a}{I}\right)\right] \quad \text{……………………. (2)}$$

WhereF_0, which refers to the output temperature, is the heat removal factor, is expressed as;

$$F_0 = \frac{GC_p}{U_L}\left[Exp\left(\frac{U_L F'}{GC_p}\right) - 1\right] \quad \text{………. (3)}$$

According to Eq. (2), efficiency will be plotted against $[\frac{t_0 - t_i}{I}]$and produce a straight line with a slope of $F_0 U_L$. Additionally, the temperature gain produced by the controller can be used to express thermal performance and is expressed as follows:-

$$\eta_{th} = \frac{GC_p\,(t_0 - t_i)}{I} \quad \text{………….. (4)}$$

3. Results and discussion

In this section, we looked into how varied percentage of graphene nanoparticle coated absorber plates affected the thermal efficiency analyses. In order to investigate experimentally we must adhere to ASHRAE standards at solar air heater. For each set of experimental observations, twenty-minute time intervals were obtained in order to preserve the steady state condition. The thermal efficiency of the solar air heater varies with respect to mass flow rate for various concentrations of selecting a coating, as shown in Fig.3. At constant solar intensity $I = 800\ W/m^2$ and ambient temperature$T_a = 289\ K$, for each set of absorber plate coating material. The maximum thermal efficiency is observed at 0.0169 kg/s and increases with the air mass flow rate. At a mass flow rate of 0.0169 kg/s, the highest thermal efficiency is 69% (0.5% graphene), 71% (1% graphene), and 74% (1.5% graphene) depending on the absorber coating percentage. When the maximum mass flow rate in the account, it is found that the thermal efficiency for the 0.5% graphene -black paint is 54% very low at the mass flow rate of 0.0035 kg/s, It is observed that at a mass flow rate of 0.0169 kg/s for 0.5% graphene have highest thermal efficiency is 67% with black paint coating. Similarly for 1% graphene coating with black paint have minimum thermal efficiency is 59% at the mass flow rate of 0.0035 kg/s, but it increases with 71% maximum at 0.0169 kg/s rate of mass flow. Where the effect of 1.5% graphene it is observed that minimum thermal efficiency is 62% achieved at the mass flow rate of 0.0035 kg/s as compared to the remaining percentage of coating.

However, the maximum thermal efficiency with 1.5% graphene coated with black paint is 74% observed at the mass flow rate of 0.0169 kg/s. Fig.4. demonstrated how daytime hours affect the effectiveness of solar air heater. Experimental results show that the time at 15 hours the thermal efficiency value is maximum for 0.5% coated graphene with black plate at 52%, On the other hand, 64% efficiency is notified as compared to 0.5% graphene In case of 1% coated black paint graphene and its taken time for 19 hours to show the impact of 1% graphene coating. Similarly, it is observed that 69% thermal efficiency was calculated for the same 19 hours of 1.5% graphene as similar to 1 % of graphene, So it is observed that 19 hours' time rate is significant for reaching maximum efficiency of solar air heater, but after it decreased with increasing time up to 20 hours which is considered as a negative impact on thermal efficiency of solar air heater.

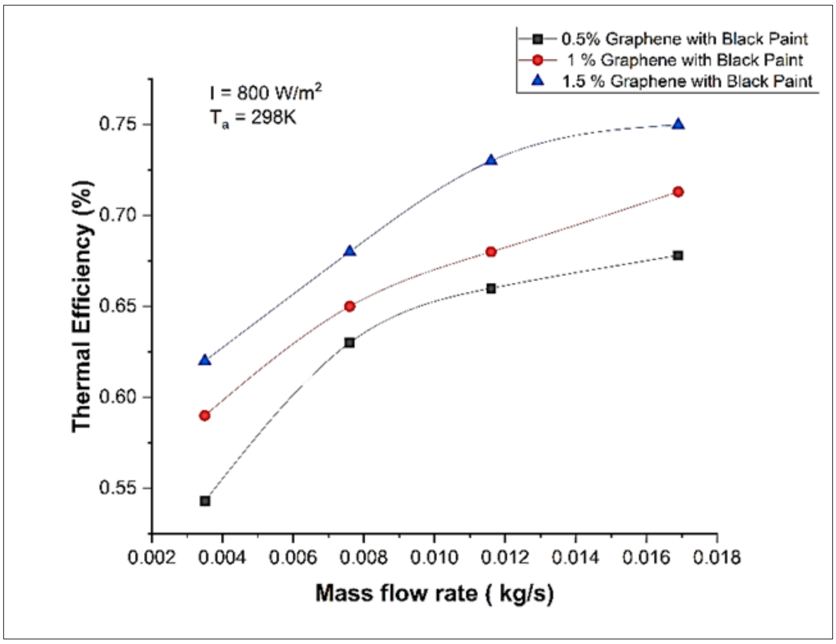

Figure 3 Thermal Efficiency vs mass flow rate for different absorber plate coating

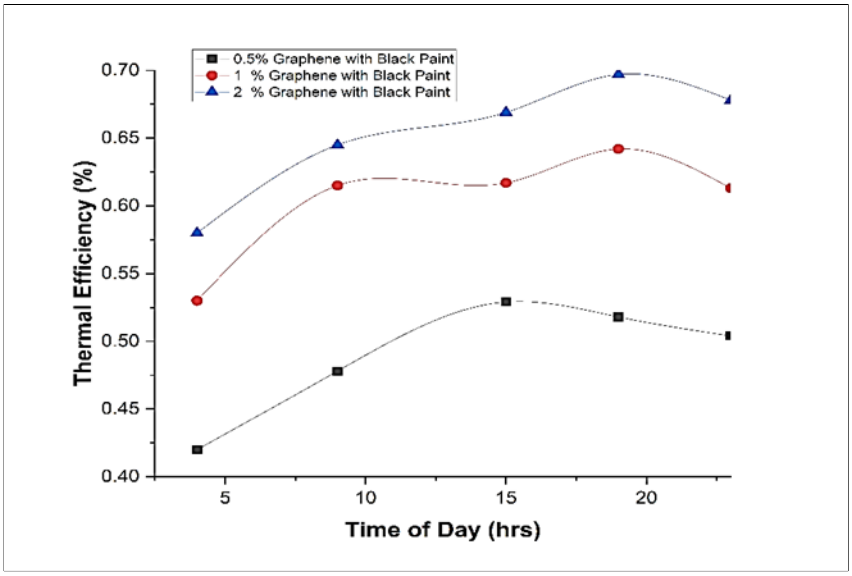

Figure 4 Comparison between Thermal Efficiency (%) of Solar air heater with different percentages of graphene embedded in black paint vs time of day (hrs)

4. Conclusion

The goal of the current study was to enhance the thermal efficiency of a solar air heater by utilizing a black paint coating infused with varying concentrations of graphene nanoparticles (0.5%, 1%, and 1.5%) applied to the absorber plate. The investigation was conducted while maintaining a constant air mass flow rate and analyzing performance at different day hours. The experimental results demonstrated a clear correlation between the graphene concentration and thermal efficiency. Specifically, it was observed that the absorber plates coated with 1% and 1.5% graphene nanoparticles achieved maximum thermal efficiencies of 64% and 69%, respectively, over a cumulative operating duration of 19 hours. The inclusion of graphene nanoparticles significantly enhanced heat absorption and thermal conductivity due to graphene's excellent thermal properties, resulting in improved heat transfer from the absorber plate to the air stream. Notably, the average thermal efficiency for the absorber plate with graphene coatings was found to increase to 62.26% over a 14-hour operational window, showcasing the superior heat capture and retention capabilities of the nanomaterial coating. The study introduces a novel approach to improving the thermal efficiency of solar air heaters by optimizing graphene nanoparticle concentration in black paint coatings. Unlike conventional coatings, graphene provides an advanced thermal management solution due to its exceptional conductivity, high surface area, and absorption properties. By systematically investigating multiple nanoparticle concentrations, the study provides valuable insights into the performance thresholds and optimal concentrations (1%–1.5%) required for maximizing efficiency. Additionally, the observed efficiency gain of up to 69% highlights the potential of graphene nanomaterials as a cutting-edge coating solution for solar thermal applications.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Alami, A. H., and K. Aokal. 2018. Enhancement of spectral absorption of solar thermal collectors by bulk graphene addition via high-pressure graphite blasting. Energy Conversion and Management 156:757–64. doi:10.1016/j. enconman.2017.11.040. n.d.

[2] Vengadesan, E., and R. Senthil. 2020. A review on recent development of thermal performance enhancement methods of flat plate solar water heater. Solar Energy 206:935–61. doi:10.1016/j.solener.2020.06.059. n.d.

[3] Ahmadi, A., Ganji, D.D., Jafarkazemi, F., 2016. Analysis of utilizing Graphene nanoplatelets to enhance thermal performance of flat plate solar collectors. Energy Conve n.d.

[4] Choi, S.U.S., Eastman, J.A., 1995. Enhancing thermal conductivity of fluids with nanoparticles. ASME Int. Mech. Eng. Congr. Expo 66, 99–105. http://dx.doi. org/10.1115/1.1532008. n.d.

[5] A.A. El-Sebaii, H. Al-Snani, Effect of selective coating on thermal performance of flat plate solar air heaters, Energy 35 (4) (2010) 1820–1828, https://doi.org/ 10.1016/j.energy.2009.12.037. n.d.

[6] T.K. Abdelkader, Y. Zhang, E.S. Gaballah, S. Wang, Q. Wan, Q. Fan, Energy and exergy analysis of a flat-plate solar air heater coated with carbon nanotubes and cupric oxide nanoparticles embedded in black paint, J. Clean. Prod (Nov. 2019), https://doi.org/10.1016/j.jclepro.2019.119501 119501. n.d.

[7] Tiwari, A., Kumar, N., & Banerjee, M. K. (2024). Applications of genetic algorithm in prediction of the best achievable combination of hardness and tensile strength for graphene reinforced magnesium alloy (AZ61) matrix composite. *Results in Control and Optimization*, *14*, 100334.

[8] Prasad, C. D., Soni, P. K., Eswaran, A., Deshmukh, K., Shrivastava, R., & Tiwari, A. (2024). Studies on Wear and Microstructure assessment of WC-Co Reinforced Iron Based HVOF Coating. *Results in Surfaces and Interfaces*, 100237.

[9] Tiwari, A. (2015). Design and Fabrication of Double Acting Winch Type Elevator. *International Journal of Mechanical Engineering and Robotics Research*, *4*(1), 41.

[10] Tiwari, A. (2015). To study and fabrication of air cushion vehicle. *INTERNATIONAL JOURNAL of RESEARCH–GRANTHAALAYAH*, *3*, 70-84.

[11] Sakhaei, S. A., and M. S. Valipour. 2019. Performance enhancement analysis of the flat plate collectors: A comprehensive review. Renewable and Sustainable Energy Reviews 102:186–204. doi:10.1016/j.rser.2018.11.014 n.d.

[12] Tiwari, E. A. (2015). Design and fabrication of desiccant wheel dehumidifier. *International Journal of Advanced Research in Mechanical Engineering & Technology (IJARMET)*, *1*(1), 7-16.

[13] Tiwari, A. (2015). Design and Fabrication of Automatic Blackboard Duster. *International Journal of Emerging Technology and Innovative Engineering, ISSN*, 2394-6598.

[14] Kumar, E. S., & Tiwari, E. A. (2015). A work study on minimize the defect in aluminium casting. *Int. J. Emerg. Technol. Eng. Res*, *3*(1), 32-38.

[15] Prajapati, S., Yadaf, P., Tiwari, A., & Kumar, A. (2017). Design and Fabrication Of Go-Kart For Achieve High Speed Without Differential Mechanism. *Int. J. Eng. Sci. Res. Technol.*, *6*(7), 340-365.

[16] Swarnkar, H., Jain, R., Tiwari, A., & Vasnani, H. (2024). Phase change material application in solar cooking for performance enhancement through storage of thermal energy: A future demand.

[17] Sharma, A., Tiwari, A., & Vasnani, H. (2020). Optimization of various process parameters for Co2 laser machining of carbon fiber reinforced polymer (CFRP). *Int J Sci Technol Res*, *9*, 466-472.

[18] Sarsam, W.S., Kazi, S.N., Badarudin, A., 2020. Thermal performance of a flat-plate solar collector using aqueous colloidal dispersions of graphene nanoplatelets with different specific surface areas. Appl. Therm. Eng. http://dx.doi.org/10. 1016/j.applthermaleng.2020.115142 n.d.

[19] T.N. Anderson, M. Duke, J.K. Carson, The effect of colour on the thermal performance of building integrated solar collectors, Sol. Energy Mater. Sol. Cells 94 (2) (2010) 350–354. n.d.

[20] Kumar Sharma, L., Tiwari, A., & Vasnani, H. (2020). Optimization Of Tig Welding Parameters And Their Effect On Aluminium 5052 Plate. *International journal of scientific & technology research*, *9*(3).

[21] Kumar, Y., Tiwari, A., Vasnani, H., & Kumar, N. (2018). Investigation of mechanical behavior of Al 6063 & SiC composite materials. *International Journal of Advanced Technology and Engineering Exploration*, *5*(47), 376-384.

[22] Tiwari, A., Vasnani, H., Kumar, N., & Labana, M. (2017). A Review on Waste Heat Recovery and Reused of Exhaust Gases from Diesel Engines. *International Journal of Advance Reaserch in Science and Engineeing, Volume*, (08).

[23] Israr, M., Tiwari, A., Labana, M., & Gangele, A. (2015). Performance analysis and fabrication on a turbocharger in two stroke single cylinder petrol engine. *Int. J. Eng. Technol. Innov*, *2*(2), 14-21.

[24] Njomo D, Daguenet M. Sensitivity analysis of thermal performances of flat plate solar air heaters. Heat Mass Transfer 2006;42:1065–81. n.d.

[25] Israr, M., Tiwari, A., & Gangele, A. (2014). Implementation and application of nanotechnology in industrial sector. *Int. J. of Multidisciplinary and Scientific Emerging Research*, *3*(2).

[26] Tiwari, A., Kumar, N., & Banerjee, M. K. (2024). Ageing Characteristics of Stir Cast AZ 61 Alloy with Minor Additions. *Recent Patents on Engineering*, *18*(6), 67-82.

[27] Swarnkar, H., Jain, R., & Tiwari, A. (2024). Comparative Energy and Exergy Performance of Box-Type Solar Cookers Using Various Pot Materials. *International Journal of Machine Systems and Manufacturing Technology*, *2*(01), 9-15.

[28] Tiwari, A., Vasnani, H., Jain, R., Swarnkar, H., Tanwar, H., & Srivastava, S. (2024). Fabrication of low-cost metal polishing machine for preparation of microstructure samples of lightweight alloy and composite material. *Global Journal of Engineering and Technology Advances*, *19*(3), 112-123.

[29] Tiwari, A., Vasnani, H., & Labana, M. (2017). The process for manufacturing of ball bearing and effect of material in bearing life. *Int. J. Adv. Res. Sci. Eng*, *6*, 235-252.

[30] Gabra, M. H., Jain, R. K., & Tiwari, A. (2017). Energy efficient cupola furnace via hybridization with a biomass gasifier. *Int. J. Emerg. Technol. Eng. Res*, *5*, 54-62.

[31] Sachin, B., Rao, C. M., Prasad, C. D., Tiwari, A., Ravikiran, Raghavendra, T., ... & Madhusudhana, R. (2024). Interactive design and development of an intelligent vision-driven 3D printed precision sorting mechanism for silk cocoons. *International Journal on Interactive Design and Manufacturing (IJIDeM)*, 1-10.

[32] Sharma, P., Patel, V., Singh, A. K., & Tiwari, A. (2024). Phase Transformation of Manganese Steel: A Role of Alloying Elements. *Trends in Mechanical Engineering & Technology*, *14*(2), 15-20p.

[33] Hegazy, A.A. Thermohydraulic performance of air heating solar collectors with variable width, flat absorber plates. Energy Convers. Manag. 2000, 41, 1361–1378. [CrossRef] n.d.

[34] Chopra, A., Jain, T. K., Saxena, N., & Tiwari, A. (2023). Predictive Analytics of a Community Survey Data by Artificial Neural Network-A Subset of Machine Learning. *Indian Journal of Science and Technology*, *16*(34), 2778-2788.

[35] Tiwari, A., Kumar, N., & Banerjee, M. K. (2023). Effect of Hot Rolling on Microstructure and Mechanical Properties of Stir Cast AZ 61 Alloy with Minor Additions. *Indian Journal of Science and Technology*, *16*(24), 1810-1822.

[36] Tiwari[1], A., Israr, M., & Gangele, A. (2014). Utilization of Waste Material in Pyrolysis Plant.

[37] Tiwari, A. (2024). Prediction model for hardness and tensile strength of graphene reinforced AZ 61 alloy based composite using Metaheuristic Algorithm. *Global Journal of Engineering and Technology Advances*, *20*(03), 042-052.

[38] TIWARI[1], A. M. I. T., & KUMAR, D. N. Characterization Study for Reducing Corrosion & Fracture Problem of Rail Track by Fabrication of Composite Material. *International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) ISSN (P)*, 2249-6890.

[39] Soni, P. K., Prasad, C. D., Manjunath, H. R., Tiwari, A., Raju, V. P., Athithan, S., ... & Kumar, A. (2025). Comparison of Tribological Behavior of Hard Faced Fe-Based Metallic Composite Coatings Sprayed Using HVOF. *Journal of Bio- and Tribo-Corrosion*, *11*(1), 5.

[40] Soni, P. K., Tiwari, A., Nayak, S., Vasnani, H., & Jha, S. K. (2025). Ultrafine Grain Refinement and Improved Mechanical Strength of Compositionally Modified AZ 61 Alloy Composite. In *Innovative Materials for Environmental and Aerospace Applications* (pp. 327-362). IGI Global Scientific Publishing.

[41] Prasad, C. D., Tiwari, A., Suryawanshi, S. R., Dileep, B. P., Gowda, A. C., Masum, H., ... & Bavan, S. (2024). Overview of thermal spray coating on additive manufacturing. *Progress in Additive Manufacturing*, 1-21.

[42] Skullong, S.; Promthaisong, P.; Promvonge, P.; Thianpong, C.; Pimsarn, M. Thermal performance in solar air heater with perforated-winglet-type vortex generator. Sol. Energy 2018, 170, 1101–1117. [CrossRef] n.d.

[43] Swarnkar, H., Jain, R., & Tiwari, A. (2024). Graphene Coating and its Effect on Performance of Box Type Solar Cooker: An Experimental Investigation. *Recent Patents on Mechanical Engineering*.

[44] Patel, V., Sharma, P., Tiwari, A., & Vasnani, H. (2024). Magnesium alloys in the automotive industry: Alloying elements and their impact on material performance. *Global Journal of Engineering and Technology Advances*, *21*(01), 130-145.

[45] Kumar, Y., Tiwari, A., Vasnani, H., & Kumar, N. EFFECT OF SILICON CARBIDE PARTICLES ON ALUMINIUM 6063 METAL MATRIX COMPOSITE.

[46] Soni, V., Tiwari, A., & Kumar, N. ANALYSIS OF ETHANOL-GASOLINE-BUTANOL BLENDS IN SI ENGINES: A REVIEW.

[47] Tiwari, A., Labana, M., & Vasnani, H. THE IMPROVE QUALITY OF WATER PURIFICATION BY CONTROL IMPURITY THROUGH HEAT EXCHANGER.

[48] SHARMA, L. K., & TIWARI, A. A Review on-Investigation & Optimization of Tig Welding Parameters And Their Effect on Aluminum Plate (AL 5052).

[49] Tiwari, A., Labana, M., Kumar, N., & Vasnani, H. UNIQUE COMBINATION OF PALLET TRUCK & CRANE MACHINE FOR REDUCING HUMAN EFFORT IN INDUSTRIES.

[50] Jain, R., Jain, P., & Tiwari, A. Reducing Surface Temperature of Photovoltaic Panel using Phase Change Material: A Comprehensive Review.

[51] Tiwari, A. K. V. S. A., & Yadav, S. P. P. Design of Can Crushing Machine for Increasing Load Capacity of Machine.

[52] Tiwari, E. A., & Purbia, E. H. Reduced of Exhaust Gases of Two Wheeler Vehicle and Increasing Average with Decreasing of Fuel Supply by Arrangement of Dual Spark Plug or Magnet Inside the Piston Design.

[53] Tiwari, A., Kumar, N., Vasnani, H., & Jha, S. K. (2024). A Review on The Role of Nanoparticles in Modifying Mg Alloys and Composites. *International Journal of Fracture Mechanics and Damage Science*, *2*(01), 24-32.

[54] Dubey, Y., Sharma, P., Vasnani, H., & Singh, M. P. (2014). Escalating Efficiency of Soft Water Pumping Station by Altering Centrifugal Pump of Superior Capacity: A Case Study. *International Journal of Engineering Research*, *3*(6).

[55] Vasnani, H., & Kumar, N. (2023). An intelligent data driven approach for fault diagnosis in industrial machinery. *Journal of Integrated Science and Technology*, *11*(3), 521-521.

[56] Vasnani, H., & Kumar, N. (2021). Design and Analysis of fault diagnosis system using vibration analysis and fuzzy logic. *Int. J. Mech. Eng*, *6*(3), 3347-3352.

[57] S.K. Verma, A.K. Tiwari, D.S. Chauhan, Experimental evaluation of flat plate solar collector using nanofluids, Energy Convers. Manag. 134 (2017) 103–115, https://doi.org/10.1016/j.enconman.2016.12.037. n.d