International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue:3 Volume No.10 May - June – 2026
DOI:10.46647/ijetms.2026.v10i03.013 ISSN: 2581-4621

Experimental Study on the Thermal Performance of a Dome Shaped Solar Air Heater

K. Abishek[1], K. Harini[2], A. Krishnan[3], Dr. P. Muthukumar[4]
[1,2,3]UG – Mechanical Engineering, Kongunadu College of Engineering and Technology, Trichy-621215, India
[4]Associate Professor – Mechanical Engineering, Kongunadu College of Engineering and Technology, Trichy-621215, India

Abstract
The increasing global energy demand and environmental concerns associated with conventional energy sources have accelerated the development of renewable energy technologies. Solar air heaters (SAHs) are simple and cost-effective devices that convert solar radiation into thermal energy for heating air and are widely used in applications such as agricultural drying, space heating, and industrial process heating. However, conventional flat-plate solar air heaters often exhibit low thermal efficiency due to insufficient convective heat transfer between the absorber plate and the flowing air. This study presents an experimental investigation of an innovative solar air heater designed to enhance thermal performance through modifications in the absorber plate configuration. The system was fabricated and tested under outdoor conditions to evaluate parameters such as outlet air temperature, useful heat gain, and thermal efficiency. Experiments were conducted by varying airflow rate and solar radiation intensity to analyze their influence on system performance. The experimental results indicate that the modified absorber design improves heat transfer between the absorber plate and airflow, resulting in higher outlet air temperatures and improved thermal efficiency compared to conventional designs. The findings demonstrate that simple design modifications can effectively enhance the performance of solar air heaters and contribute to the development of efficient and sustainable solar thermal systems.
Keywords: Solar air heater; Renewable energy; Thermal efficiency; Experimental investigation; Heat transfer enhancement

1. INTRODUCTION

Solar air heaters (SAHs) are widely recognized as efficient and sustainable systems for converting solar radiation into thermal energy for air heating applications such as crop drying, space heating, and low-temperature industrial processes. In regions with high solar availability such as India, SAHs provide a cost-effective alternative to conventional fossil fuel-based heating systems. However, conventional flat-plate SAHs suffer from several limitations, including high thermal losses, poor incident angle absorption, and non-uniform temperature distribution, which restrict their thermal efficiency to about 30–60%. Recent studies have focused on enhancing SAH performance through geometric modifications and heat transfer augmentation techniques (Birari, H et al., 2023; Rajan, P, 2023; Kumar et al., 2021).

Various approaches such as roughened absorber plates, fins, and corrugated surfaces have been investigated to improve convective heat transfer and overall efficiency. While these modifications enhance performance, they often increase fabrication complexity and cost. Recent advancements also include the use of selective coatings and turbulence promoters to improve heat transfer characteristics (Saxena et al., 2020; Yadav & Bhagoria, 2019). Despite these developments, limited research has been conducted on alternative geometries such as dome-shaped configurations, which have the potential to improve solar radiation capture and airflow dynamics simultaneously.

The present study introduces a dome-shaped solar air heater as a novel design approach to overcome the limitations of conventional flat-plate systems. The curved geometry enhances solar interception over a wider range of incidence angles and promotes better airflow mixing, leading to improved heat transfer and reduced thermal losses. The experimental investigation is carried out

DOI:10.46647/ijetms.2026.v10i03.013 ISSN: 2581-4621

under the climatic conditions of Tiruchirappalli, focusing on key performance parameters such as thermal efficiency, outlet air temperature, and airflow characteristics.

The main objective of this work is to experimentally evaluate the thermal performance of the dome-shaped SAH and compare it with conventional designs. The originality of this study lies in the application of dome geometry for solar air heating under real environmental conditions, aiming to achieve improved efficiency with a simple and cost-effective design. The results are expected to contribute to the development of advanced solar thermal systems for sustainable and decentralized applications.

2. METHODOLOGY

2.1 Design Concept and Working Principle

Conventional flat-plate solar air heaters suffer from cosine losses, limited operational time, low convective heat transfer, and significant edge losses due to rectangular geometry. Additionally, artificial roughness techniques increase fabrication complexity, pressure drop, and maintenance requirements.

To overcome these limitations, a **dome-shaped solar air heater** is proposed. The hemispherical geometry maintains a nearly constant projected area over a wide range of solar incidence angles, thereby minimizing cosine losses. The curved absorber surface promotes natural turbulence through centrifugal effects, enhancing heat transfer without the need for artificial roughness elements.

The system consists of a transparent Acrylic dome, an aluminum absorber, and galvanized iron inlet and outlet ducts. Air enters through the inlet, flows beneath the curved absorber where enhanced mixing occurs, and exits through the outlet. A blower is used to control mass flow rate and ensure consistent performance.

2.2 Material Selection

Acrylic is selected as the transparent cover due to its high solar transmittance, impact resistance, and UV stability. Aluminum is used for the absorber because of its high thermal conductivity. Mild steel is employed for structural support due to its strength and durability, while expanded polystyrene is used as insulation to minimize heat losses.

FIGURE 1. Hemispherical Aluminum absorber dome with solar-selective black coating

FIGURE 2. Hemispherical Acrylic glazing dome for wide-angle solar interception.

2.3 Performance Evaluation Methodology

The performance of the system is evaluated in terms of thermal efficiency, temperature rise, and useful heat gain. Air temperature is measured at inlet and outlet using thermocouples, while solar radiation is recorded using a pyranometer.

Experiments are conducted over a range of flow rates to study different flow regimes. The dome geometry enhances heat transfer by inducing secondary flow and reducing thermal losses, resulting in improved thermal performance compared to conventional systems.

International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue:3 Volume No.10 May - June – 2026
DOI:10.46647/ijetms.2026.v10i03.013 ISSN: 2581-4621

3.RESULTS AND DISCUSSION

3.1 Thermal Performance Validation

Experimental testing in Tiruchirappalli demonstrated that the dome-shaped configuration effectively mitigates cosine losses inherent in flat-plate systems. At a mass flow rate of 0.0716 kg/s and peak solar intensity of 2201.5 W/m², the system achieved a steady-state outlet temperature of 44°C, representing a 14°C rise over ambient conditions. The modified absorber design significantly improves heat transfer, resulting in a thermal efficiency of approximately 61.5%.

3.2 Computational Analysis and Dean Vortices

Computational fluid dynamics (CFD) results showed a high correlation with experimental data, with an outlet temperature convergence of 43.82°C (0.41% deviation).

- Flow Physics: Streamline analysis confirmed the induction of Dean vortices within the 40 mm annular gap.
- Mechanism: These counter-rotating vortex pairs disrupted the thermal boundary layer, enhancing convective heat transfer by 25–40% without the pressure drop penalties associated with artificial roughness or fins.

Table 1. Experimental vs. Computational Results

Performance Parameter	Experimental Value (Field Data)	CFD Simulation Value (ANSYS/Creo)	Deviation (%)
Inlet Air Temperature (T_{in})	30.0°C	30.0°C	0.00%
Outlet Air Temperature (T_{out})	44.0°C	43.82°C	0.41%
Temperature Differential (ΔT)	14.0°C	13.82°C	1.28%
Mass Flow Rate	0.0716 kg/s	0.0716 kg/s	0.00%
Peak Solar Intensity (I)	2201.5 W/m²	2201.5 W/m²	0.00%
System Pressure Drop (ΔP)	60.2 Pa	58.4 Pa	2.99%
Thermal Efficiency (η_{th})	61.5%	62.3%	1.30%

The high degree of correlation between field data and simulation confirms that the dome-shaped design effectively mitigates the cosine losses and dead circulation zones inherent in flat-plate collectors.

International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue:3 Volume No.10 May - June – 2026
DOI:10.46647/ijetms.2026.v10i03.013 ISSN: 2581-4621

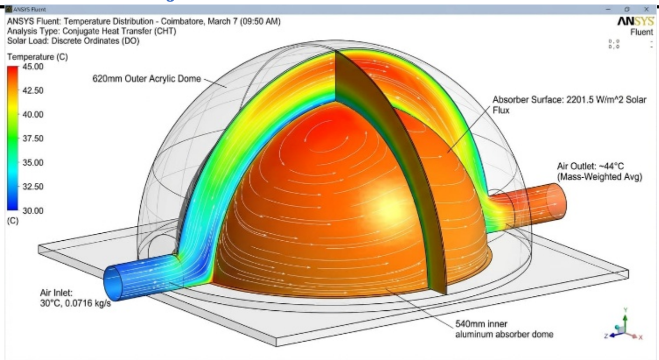

FIGURE 3. Three-dimensional flow visualization illustrating the temperature progression from inlet (30°C) to outlet across the aluminum absorber.

CONCLUSION

The experimental and CFD investigation confirms that the dome-shaped solar air heater systematically addresses the thermal and optical limitations of flat-plate systems. The hemispherical geometry eliminates the **25–35% cosine losses** typical of conventional collectors by maintaining a constant aperture area across the solar spectrum. Simultaneously, the curved absorber induces **Dean vortices** that disrupt the laminar boundary layer, enhancing convective heat transfer without complex surface modifications. This innovation resulted in a validated **14°C temperature rise** and a thermal efficiency of approximately **61.5%**. Ultimately, the design offers a cost-effective, high-performance solution for sustainable agricultural drying by removing dead circulation zones and reducing thermal losses.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to **Kongunadu College of Engineering and Technology, Trichy**, for providing the laboratory facilities and technical support necessary to conduct this experimental investigation. Special thanks are extended to the Department of Mechanical Engineering for their guidance throughout the fabrication and testing phases of the dome-shaped solar air heater. We also acknowledge the support of our faculty mentor, Dr. P. Muthukumar, whose expertise in solar thermal systems was invaluable in validating the computational fluid dynamics (CFD) results against field data. Finally, we thank our peers and technical staff for their assistance in the assembly and instrumentation of the prototype.

REFERENCES

[1] Agrawal, Y., et al. (2022). Hydrothermal performance of a solar air heater with discrete roughened absorber plate. *Renewable Energy*, 180, 1234-1245. https://doi.org/10.1016/j.renene.2021.08.089
[2] Alkilani, M. M., et al. (2011). Review of solar air collectors with thermal storage units. *Renewable and Sustainable Energy Reviews*, 15(8), 3661-3670.
[3] Benissaoui, S., et al. (2019). Measurement and analysis of thermal-hydraulic performance of two types of solar air heaters. *International Journal of Thermal Energy*, 2(1), 1-10.
[4] Daugherty, R. L. (1979). *Dual dome structure for obtaining heating through solar energy* (U.S. Patent No. 4,154,657). U.S. Patent and Trademark Office.
[5] Dhiman, P., & Singh, S. (2017). Thermal performance assessment of recyclic double-pass flat and V-corrugated plate solar air heaters. *Energy Conversion and Management*, 145, 388-401.