International Journal of Scientific Research and Engineering Development-– Volume 9 Issue 2, Mar-Apr 2026
Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

Thermo-Hydraulic Performance Enhancement of Evacuated Tube Solar Air Collector Using Loose-Fit Perforated Twisted Tape Inserts

S Ram Kumar, Vishnudas K K, Rizwin Ahammed, Rameez Raja, Tomin Saby Vadakkan
Assistant Professor, Mechanical Engineering, Hindusthan College of Engineering and Technology, Coimbatore.
ramkumar2121991@gmail.com
Student,Department Of Mechanical Engineering, Hindusthan College Of Engineering And Technology, Coimbatore.

Abstract
This study presents the design, fabrication, and experimental investigation of an evacuated tube solar air collector integrated with loose-fit perforated twisted tape inserts to enhance thermo-hydraulic performance. Experiments were conducted under steady-state conditions by varying mass flow rates and tape geometries. Results showed a significant enhancement in heat transfer due to induced swirl flow and turbulence. The Nusselt number increased by 70–94% compared to a plain tube, with optimal performance at a twist ratio (y/D) of 2 and hole ratio (d/D) of 0.0714. However, an increase in friction factor was observed due to higher flow resistance. The maximum thermal performance factor reached 1.27, indicating overall system improvement. The system demonstrates strong potential for solar thermal applications such as air heating and agricultural drying.

1. Introduction
The depletion of fossil fuels and environmental concerns have intensified the need for renewable energy solutions. Solar energy is abundant, clean, and sustainable, making it a viable alternative. Among solar technologies, solar air collectors are widely used for heating and drying applications.
Evacuated tube collectors (ETCs) offer higher efficiency compared to flat-plate collectors due to vacuum insulation, which minimizes heat loss. However, their performance is limited by laminar airflow and thermal boundary layer formation.
To overcome this limitation, twisted tape inserts are introduced to enhance turbulence and improve convective heat transfer. This study focuses on evaluating the impact of loose-fit perforated twisted tapes on the performance of an evacuated tube solar air collector.

2. Literature Review
Previous studies have highlighted the importance of enhancing heat transfer in solar collectors. Twisted tape inserts have been widely used in heat exchangers to improve thermal performance.
Research shows:
- Heat transfer enhancement up to 25–30% using baffles and inserts
- CFD studies confirm improved turbulence and mixing
- Evacuated tube collectors provide superior efficiency under varying conditions

However, limited studies exist on the application of **perforated twisted tapes in evacuated tube solar air collectors**, which forms the basis of this research.

3. Methodology
3.1 Experimental Setup
An evacuated tube solar air collector system was designed with:
- Borosilicate glass tubes (length: 1800 mm)
- Aluminum inner tube (air passage)
- Variable-speed blower for airflow control
- Pyranometer for solar radiation measurement
- Thermocouples for temperature measurement

3.2 Twisted Tape Design
Twisted tapes were fabricated with:
- Twist ratios: 2, 2.5, 3
- Hole ratios: 0.0714, 0.107, 0.143
- Material: Aluminum

Perforations allow partial bypass flow, reducing pressure drop while maintaining swirl intensity.

3.3 Experimental Conditions
- Mass flow rate: 100–400 kg/h
- Solar irradiance: 850–1000 W/m²
- Reynolds number: 4860–24130

3.4 Procedure

1. System stabilized under steady-state conditions
2. Airflow adjusted using blower
3. Data recorded for temperature, pressure, and radiation
4. Experiments repeated for all configurations

4. Results and Discussion

4.1 Heat Transfer Enhancement

- Nusselt number increased with Reynolds number
- Maximum enhancement: **70–94%**
- Best configuration: **y/D = 2, d/D = 0.0714**

4.2 Friction Factor

- Increased due to turbulence and swirl
- Highest for lowest twist ratio
- Reduced with larger hole diameters

4.3 Thermal Performance Factor

- All configurations showed $\eta > 1$
- Maximum η = **1.27**
- Indicates net performance improvement

4.4 Key Observations

- Lower twist ratio → higher turbulence → better heat transfer
- Smaller holes → stronger swirl → improved efficiency
- Trade-off exists between heat transfer and pressure drop

5. Conclusion

This study demonstrates that loose-fit perforated twisted tape inserts significantly enhance the thermo-hydraulic performance of evacuated tube solar air collectors.

Key findings:

- Heat transfer improved up to **94%**
- Optimal configuration: **y/D = 2, d/D = 0.0714**
- Thermal performance factor reached **1.27**
- Enhancement is more effective at moderate Reynolds numbers

The results confirm that twisted tape inserts are an effective passive technique for improving solar air heater performance, making them suitable for practical applications such as drying and space heating.

Keywords
Evacuated tube collector, twisted tape inserts, heat transfer enhancement, solar air heater, thermo-hydraulic performance

