EFFECT OF A PACKED ABSORBER ON THE THERMAL EFFICIENCY OF A TUNNEL-TYPE SOLAR DRYING UNIT

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Abstract

In this study, the effect of a packed absorber on the thermal-technical efficiency of a tunnel-type solar drying unit was investigated. Experiments were carried out under solar radiation of 400-900 W/m^2, ambient temperature of 28-41°C, and airflow velocities of 20-35 m/s. The results showed that the packed absorber enhances heat transfer intensity, increasing the convective heat transfer coefficient from 22-24 to 27-31 W/m^2·K, the useful heat power from 4.2-4.8 to 5.0-5.8 kW, and the efficiency from 0.52-0.55 to 0.58-0.62.

Keywords: Solar dryer, tunnel dryer, absorber, packing, heat transfer, raw brick, efficiency, solar collector.

Introduction

In the production of construction materials, the drying process of raw bricks is characterized by high energy consumption, long duration, and strong dependence on weather conditions. In open-air drying, moisture removal is uneven, leading to reduced product quality. Therefore, the development of active and hybrid drying systems based on solar energy is considered highly relevant. Recent studies confirm the effectiveness of direct solar dryers, parabolic concentrators, and hybrid systems [1].

Literature analysis shows that dryer efficiency largely depends on the absorber material, geometry, and flow regime. Enhancing the absorber surface increases heat transfer intensity. Based on this, the use of a packed absorber is proposed to increase turbulence and reduce the boundary layer thickness. In this study, a comparison between packed and smooth absorbers in a tunnel-type solar dryer is carried out, and their impact on thermal efficiency is evaluated [2].

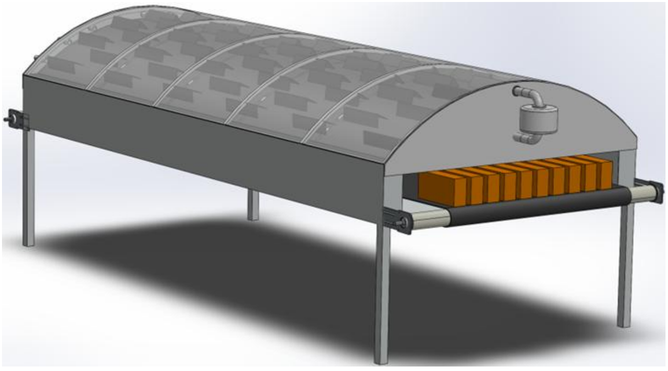


Figure 1. General structural scheme of the tunnel-type solar drying unit.

Research Object and Methodology

The research object is a tunnel-type solar drying unit designed for the primary dehydration of raw bricks. The system consists of a semi-cylindrical solar collector (3.0×1.2 m, 3.6 m^2; curved surface 4.5 m^2), a 3 mm transparent acrylic cover, and a 1.0 mm black-painted galvanized steel absorber. The корпус is insulated with fiberglass. Airflow is provided by a 550 W fan, while the conveyor is driven by a 330 W motor. The drying material consists of raw bricks with dimensions of 250×120×65 mm.

Two configurations were studied: a smooth absorber and a packed absorber. The packing elements disturb the airflow and enhance heat transfer. Experiments were conducted under solar radiation of 400-900 W/m^2, ambient temperature of 28-41°C, and airflow velocities of 20-35 m/s, with actual air velocity in the brick zone of 5.2-6.1 m/s.

During the experiments, inlet and outlet air temperatures, ambient conditions, solar radiation, and air velocities were measured. The analysis was based on the evaluation of useful heat power and collector efficiency using the following expressions:

$$Q = \dot{m} c_p (T_{chiq} - T_{kir}) \qquad (1)$$

$$\eta = \frac{Q}{G \cdot A_{pr}} \qquad (2)$$

Here, Q is the useful heat power (W); $\dot{m}$ is the air mass flow rate (kg/s); c_p is the average specific heat capacity of air (J/(kg·K)); T_{out} and T_{in} are the outlet and inlet air temperatures (°C), respectively; G is the solar radiation (W/m^2); and A_{pr} is the projected area of the collector (m^2) [3].

This approach was deliberately selected: the energy input is evaluated based on $G \cdot A_{pr}$, while heat transfer and losses are analyzed using the curved surface area A_s. If this distinction is not explicitly stated, it may lead to objections regarding the accuracy of efficiency calculations [4].

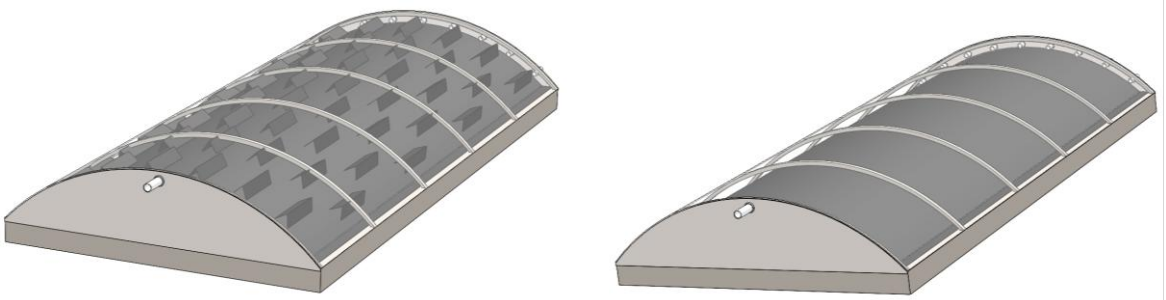
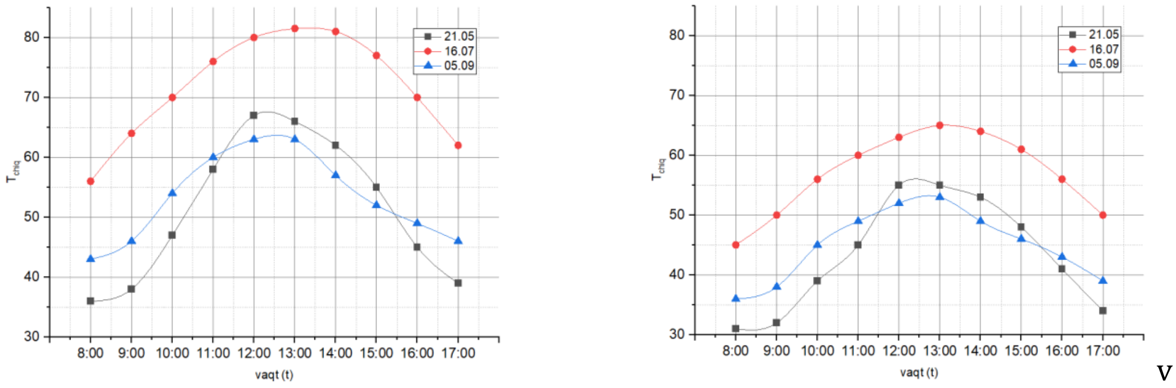


Figure 2. Comparative structural scheme of smooth and packed absorber surfaces.

The experimental results showed that the use of a packed absorber significantly improves the thermal-technical performance of the collector. Local disturbances formed on the absorber surface increase the heat absorption capacity of the airflow, resulting in higher outlet temperature and useful heat power. In the smooth absorber case, the convective heat transfer coefficient was 22-24 W/m^2·K, while in the packed case it increased to 27-31 W/m^2·K. Accordingly, the outlet air temperature rose from 60-65°C to 65-68°C, and the temperature difference increased from 18-20°C to 20-24°C. The useful heat power increased from 4.2-4.8 kW to 5.0-5.8 kW.

When evaluated based on the projected area, the collector efficiency ranged from 0.52-0.55 for the smooth absorber and 0.58-0.62 for the packed absorber. The value of 0.62 corresponds to the maximum operating condition and should not be interpreted as an average value. These results are consistent with studies showing that enhanced heat transfer surfaces improve heat transfer performance [5].

From a physical standpoint, the packing elements do not merely obstruct the flow but modify its structure, increasing turbulent mixing and heat transfer intensity. However, excessive size or density of the packing increases aerodynamic resistance, leading to higher fan energy consumption and potential efficiency loss. Therefore, the effectiveness of a packed absorber must be evaluated in conjunction with optimal geometry and flow conditions.



v = 20 m/s

v = 35 m/s

Figure 3. Variation of solar radiation (G) and outlet temperature (T_{out}) over time.

The effect of air velocity was also analyzed. Increasing the velocity from 20 m/s to 35 m/s enhances heat transfer intensity; however, the absolute temperature rise does not increase proportionally. This is due to the higher mass flow rate at increased velocity, while the residence time of air inside the collector decreases. Therefore, the optimal operating regime should be determined not only by maximum velocity but by a combined assessment of Q, ΔT, efficiency (η), and pressure losses. For a thesis format, it is sufficient to demonstrate this balance: the packed absorber is effective, but only when the airflow regime is properly selected.

Conclusion

The use of a packed absorber in a tunnel-type solar drying unit significantly intensifies heat transfer due to increased turbulence. As a result, the convective heat transfer coefficient increases from 22-24 to 27-31 $W/m^2 \cdot K$, the useful heat power from 4.2-4.8 to 5.0-5.8 kW, and the collector efficiency from 0.52-0.55 to 0.58-0.62. These results confirm the energy efficiency of the proposed design and its potential to accelerate drying while reducing energy consumption. Further optimization of packing geometry, pressure losses, and final moisture content is required.

References

1. Sandali, M., et al. “New Design of a Direct Solar Dryer Used for Solar Drying of Clay Bricks.” Journal of Renewable Energies, 2025, pp. 31-41.
2. Nthieri, P., et al. “Harnessing Solar Energy Using Parabolic Dish Concentrator for Clay Brick Drying.” Advances in Materials Science and Engineering, 2025, Article ID 8566655.
3. Regino-Ubarnes, F., et al. “Implementation of an Automated Dryer with Solar Collector to Improve the Drying Process of Handmade Bricks.” Journal of Physics: Conference Series, vol. 2163, 2022, 012002.
4. Partheeban, P., et al. “Cleaner Production of Geopolymer Bricks Using Solar-LPG Hybrid Dryer.” Journal of Cleaner Production, vol. 442, 2024, 141048.
5. Bououd, A., and Mechaqrane, A. “Concentration Solar Dryer with Water-to-Air Heat Exchanger: Modeling and Parametric Studies.” International Journal of Hydrogen Energy, vol. 42, 2017, pp. 161-175.