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"Performance Enhancement Of Double Pass Solar Air Dryer-A Review Paper"

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Abstract

The utilization of solar energy has gained significant attention as a sustainable alternative to conventional fuels. Solar air heaters are one of the most economical devices for converting solar radiation into useful thermal energy, mainly for space heating and drying applications. However, conventional single-pass designs often suffer from low thermal efficiency due to limited heat transfer between the absorber plate and the working fluid. To overcome this limitation, the double pass solar air heater has been developed. In this configuration, air flows over the absorber surface twice, which enhances the contact period and improves heat exchange. The dual-pass arrangement not only reduces heat losses but also increases the overall system performance. Owing to its simple structure, cost-effectiveness, and higher efficiency, the double pass solar air heater is emerging as a reliable solution for renewable energy utilization in domestic as well as industrial applications. The solid copper rod, matrix integrated with the absorber plate serves to intensify thermal conduction and airflow interaction. This is new arrangement is intended to the boost heat collection capability of the solar air heater.

Key Word– Double Pass Solar Air Heater, Solid Copper Rod Matrix, Solar Radiation,

1.0 Introduction

In the era of evolving energy needs and environmental urgency, solar thermal solutions have gained prominence for their efficiency and sustainability. Solar air heaters (SAHs), renowned for simplicity and low maintenance, are widely used in building heating, greenhouse applications, and agricultural drying. Yet, the single-pass SAH is restricted by limited air absorber interaction and not able heat losses.

To overcome these constraints, the double-pass solar air heater (DPSAH) has emerged as a superior configuration. By directing air over and under the absorber, DPSAHs increase heat transfer surface, enhance turbulence, and extend residence time—resulting in significant thermal gains.

Energy conservation and thermal management have always been crucial aspects of engineering and research. In various thermal systems, when one fluid is at a higher temperature and the other is relatively cooler, a heat exchanger is employed to facilitate controlled heat transfer. A heat exchanger is essentially a device that allows heat exchange between two fluids through a solid surface, without direct mixing of the fluids.

Types of Heat Exchangers.

1.1 Parallel Flow

In a parallel flow arrangement, both hot and cold fluids enter the heat exchanger from the same side and flow in the same direction. At the inlet, the temperature difference (ΔT) is maximum. Along the length, this temperature difference.

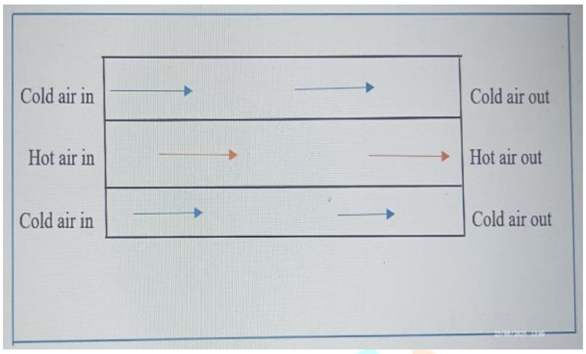

Fig 1.1 Solar air heater parallel flow.

1.2 Counter Flow

In a counter-flow arrangement, the hot and cold streams travel in reverse directions to each other. Such a design enables better thermal exchange and helps attain higher outlet temperatures with greater efficiency**.**

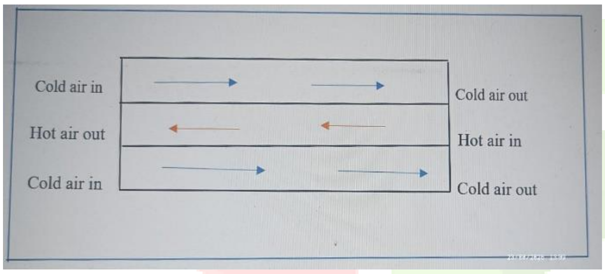

Fig 1.2 Solar air heater counter flow.

1.3 Cross Flow

A cross flow heat exchanger is a thermal device in which two working fluids exchange energy while moving at right angles to one another. In this arrangement, one stream generally passes inside tubes or flat ducts, while the second stream flows over the outside surface in a direction perpendicular to it. This orthogonal configuration allows higher surface utilization and makes the device suitable when one fluid is a gas with low heat capacity, such as air.

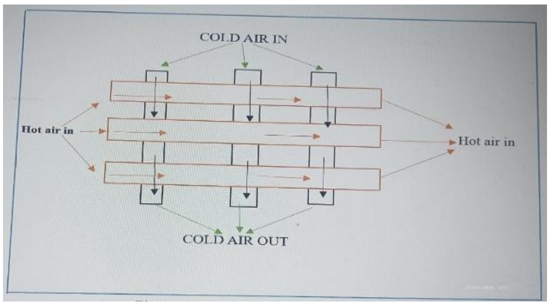

Fig 1.3 Solar air heater cross flow.

2.0 Literature Review

Manish Sharma et. al- The analysis of the thermal performance of a Solar Air Heater (SAH) with V rib with gaps, V rib without gaps and plain observer plate has been carried out in this research for varying mass flow rates on the SAH. The work on "V rib with gap," "V continuous," and "without rib. "Has been done to compare the performance of the three rib geometries for solar air heaters. [01]

Anand Patel et. al- The evolution of heat exchangers from the simplest to the most complex is examined, with a focus on how important they are for reaching better energy conversion rates. It focuses on design, material advancements, and the many heat exchanger types appropriate for different purposes while exploring developments from basic to advanced heat exchangers. [02]

Sachin Bhaskar, Santosh Kumar Rai et. al- Primary function is to capture solar thermal energy transfer hot air & Based on an extensive review of the existing literature, a substantial amount of research has been dedicated to the enhancement of Total Heat Power (THPP) and reduction of friction value in artificially roughened Solar Air Heaters (SAHs) with different shapes and design parameters, focusing on both single and double pass configurations. [03]

Poonam S. Pardeshi & Andries (Hennie) van Heerden et. al-Solar air heaters are devices that can convert solar energy into thermal energy for moderate and low-temperature applications such as space heating, preheating, crop drying, and the food industry. Different concentrations of nanoparticles mixed in black paint and hybrid nanofluid technology should be investigated. [04]

Antonio Delgado et. at- SAH he as knowledge is discussed and all the physics involved in terms of heat transfer is considered. The basic functionality of the solar air heater is also discussed and different designs are showcase. He simulations validated using references from experiments as well as theoretical calculations. [05]

Suneet Mehta et. al- The present water colling technique system is producing cooling effect by using refrigerants like Freon, Ammonia etc. Using these refrigerants one can achieve maximum output but one of the major ack is its poisonous gas emission and global warming we can cope up this problem with use of thermoelectric module and thereby protecting the environment. [06]

Wajahat Baig, Hafiz Muhammad ali et. al- While using TSMs during the winter season in which outside air temperature ranges between 6 and 20°C and solar flux ranges between 350 and1050 W/m2, PCM' smelting strongly depends on outside air temperature. [07]

Ratan Sanjay, Rishabh Balun & Rohit Kumar et. al- Encompassing industrial environments, agricultural product dehydration, material conditioning, and residential heating. Inadequate convective transfer can hinder Variations of Pitch space between roughness can be improved and Heat transfer rate and focus on analysis the full life cycle of solar air heater. [08]

Ankush Headu et. al- Different heat transfer roughness elements were employed to Study on the thermal performance of double pass solar air heater with PCM-based thermal energy storage system Science enhance the heat transfer coefficient, while different PCM arrangements were used to increase efficiency and operational hours and Using semicircular PCM tubes and perforated blocks as roughness elements, a three-dimensional transient numerical investigation is conducted to analysis the thermal and pumping power characteristics of double pass solar air heater (DPSAH). [09]

Prashant Tirkey, Sunil Kumar et. al- This paper study includes an overview of solar air heater technology, and information on solar air heaters that use alternative absorber plate surface geometries to speed up heat transmission and PCM (phase change material) is used to deliver heat energy when it is cloudy. An overview of solar air heater technology and information on solar air heaters that use alternative absorber plate surface geometries to boost heat transfer comes under this study. [10]

Vijay Chaudhary et. al- The study's findings suggest a number of intriguing new directions for solar air heater research and development. The first step towards greater efficiency is the exploration of cutting-edge materials for absorbers and selective coatings. Nanomaterials, which have improved heat absorption capabilities, are an example of a novel material that deserves investigation. In addition, research into solar air heater integration with energy storage devices should be pursued. [11]

Anand Patel et. al- Solar energy is a clean, renewable energy that is used for drying, desalination and hot air heating. The aim of the current work is to design and develop an experimental setup and major conclusion of present work is that wire mesh better and cheapest option to improve thermal performance of solar air heater. [12]

A.F. Abd Hamid et. al- This paper investigates double-pass solar air thermal collectors with lava rock as the porous media. The addition of lava rock serves as short-term sensible thermal storage for a solar drying system. The use of lava rock in a DPSAH system was evaluated using energy balance in this study. Several findings have been achieved, including optimal efficiency, pressure drop, porosity, and differences between conventional and system that have been analysis against the time. [13]

Varun Pratap Singh et. al- Current efforts toward the necessary energy transition are predominantly focused on climate change mitigation in relation to decarbonization measures. The analysis has been performed to cope with the necessity to produce insights that traditional energy system optimization models are not able to deal with, attempting to answer to a crucial question in the actual energy field how much can we exploit carbon emissions as an indicator of sustainability. [14]

V.S. Hans et. al- Various designs of solar collectors viz, evacuated tube, flat plate, multiple passages, a cross-section of the flow passage, etc. are reported and discussed. Techniques which are used for performance enhancement of SAHs such as artificial roughness, fins, baffles, vortex generators, etc. The heat energy available in the solar radiation can be easily collected with the help of a solar collector and the collected heat is further utilized for heating and cooling applications. [15]

Yousif Muhammad et. al- The design and testing of a high-temperature thermal energy storage based on rocks is presented. Tec in a rock bed represents a low-cost energy storage solution with a high heat-to-heat storage efficiency. This paper presents the construction and performance of a downscaled HTTES for power to-heat or power-to-power applications with a thermal capacity. [16]

Murugesan Palaniappan et. al- The impingement jet Solar Air Heater (SAH) achieves roughening through the incorporation of conical ring shapes, strategically placed between the straight fins of the absorber plate. An innovative solar air heater design for hot air production used for industrial air heating Applications is reported in this research. The system integrates the jet impingement heat transfer technique with artificial roughness to improve performance. [17]

Eduardo Venegas-Reyes et. al- This work details the design, construction, and experimental evaluation of a novel double-pass V-trough solar air heater with semicircular receivers. According to the results, the double-pass V-channel solar air heater increased the air temperature by more than 30 ◦C for inlet temperatures close to ambient temperature. An air outlet temperature of up to 70 ◦C was achieved, which can dry most food products such as fish, beef, banana, grapes, mango, pineapple, chili, and others. [18]

Mahyar Abedi, Xu Tan, Share Cite Parnab Saha, James F. Klausner et. al- The performance of solar desalination systems based on a humidification–dehumidification (HDH) approach is significantly enhanced by preheating the air entering the evaporator. In this study, we examined the potential of an integrated SAH with a direct-contact packed-bed HDH desalination system that can be applied globally. [19]

Dogan Burak Saydam et. al- In today's world, many researchers are focusing on designs that occupy the same dimensions but can generate more useful energy. During the experimental study, the energy, exergy and enviro-economic analyses of both SAHs were made by using the measurements taken from different points on the system, and Experimental investigation and artificial neural networks (ANNs) based prediction of thermal performance of solar air heaters. [20]

3.0 Objective

- To increase the surface area of soler air dryer for increase heat transfer.
- To improve the mass flow rate of air.
- To improve soler air dryer outlet temperature and thermal efficiency.

4.0 Proposed Methodology

The methodology adopted for this study involves the systematic design, fabrication, and experimental analysis of a double pass flat plate solar air heater (DPSAH) integrated with Phase Change Material (PCM) and embedded copper rods. The steps followed are detailed below:

4.1 Design and Conceptualization

Fixing solid copper rod in square shape on the absorber plate.

A novel double pass solar air heater (DPSAH) will be designed, consisting of a steel absorber plate integrated with square-shape solid copper rods.

The steel plate will act as the primary absorber surface, while the copper rods, due to their high thermal conductivity, will enhance heat transfer and increase turbulence of the airflow.

The system will be structured to allow air to flow in two successive passes: the first below the absorber plate and the second above it, ensuring maximum utilization of absorbed solar energy.

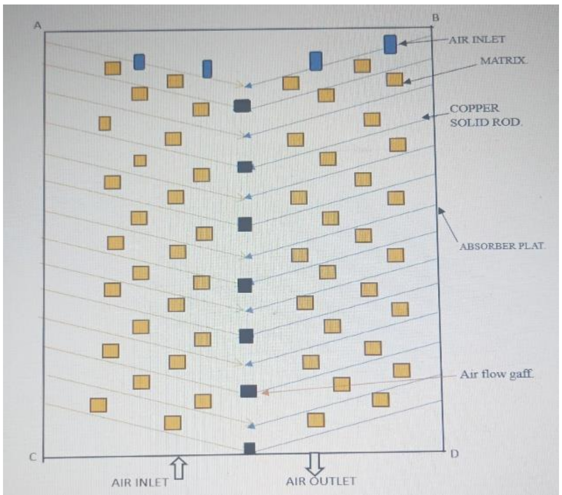

Fig. 4.1 Absorber flat plate.

4.2 Material Selection

Absorber Plate: Mild steel sheet of standard thickness, coated with selective black paint to maximize solar absorption.

Heat Transfer Elements: Solid copper rods of square cross-section, fixed onto the absorber plate to improve conduction and disrupt boundary layer formation.

Insulation: Glass wool or equivalent insulating material will be placed beneath the absorber plate to minimize heat loss.

Glazing: Transparent glass sheet of suitable thickness will be installed above the absorber plate to reduce convective and radiative losses while allowing maximum solar transmission.

4.3 Fabrication and Assembly

The absorber plate will be cut to the desired dimensions and fitted into a rectangular duct.

Copper rods will be attached in a parallel arrangement across the steel plate using brazing or mechanical fastening.

The glazing sheet will be fixed at the top with aluminium framing for stability.

Transparent glass- Transparent glass (2mm) was used as the top cover to allow solar radiation while minimizing convective losses.

4.4 Expected Outcome.

4.4.1 In absorber plate use matrix and increase heat transfer rate & improve thermal efficiency.

4.4.2 The proposed model is expected to deliver higher outlet air temperatures compared to single-pass and conventional models.

4.4.3 Increased air residence time will allow more absorbed solar energy to be converted into useful heating.

5.0 Conclusion of Literature Review

Square solid copper rods on steel plate increase heat transfer area and turbulence. High thermal conductivity of copper improves conduction and raises outlet air temperature. System efficiency found better than conventional DPSAH. Design is structurally stable and suitable for practical use.

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