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ANALYTICAL STUDY ON CONVENTIONAL AND MODIFIED SOLAR AIR HEATERS

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Abstract
The purpose of this research is to improve the efficiency of a basic solar air heater for drying crops and heating rooms. Sand from the desert has been added to the solar heater as a heat-absorbing substrate. It has been tested in Moradabad, India, in four distinct configurations, using both natural and induced convection, to see how it performs. New configurations of the modified system have greater thermal performance than a traditional solar air heater of a comparable design. There is a major problem with the solar distillation unit's lower distillate production from the solar stills. The primary goal of this experiment is to increase the standard solar still system's distillation rate. Adding a solar air heater (SAH) to a traditional single-slope solar still was the focus of the current study. It was done in Ranchi (India) on a south-facing single slope solar still with an inclination angle of 230.

Key Words: *Solar Air Heater, Solar Energy, thermal energy storage, solar air heater.*

Introduction

In the past, flat-plate solar air heaters have been used for space heating, drying, and other industrial applications that need heated air at low to moderate temperatures. Several design and operation factors influence the thermal efficiency of a solar air heater (collection device). It is essential to know the convective heat transfer coefficient between the absorber plate and the air passing through the collection duct. Solar air warmers are widely utilised in low and moderate temperature settings. To name only a few, there's crop dehydration, wood seasoning, home heating, cooking, and so forth. To put it another way, the thermal efficiency of a solar air heater has been shown to be poor due to its limited thermal capacity and its low convective heat transfer coefficient. The usage of solar panels to store the sun's rays might be a solution to this problem in our future study. As a result of these efforts to increase heat transmission, a pressure decrease has been incurred. The most efficient and cost-effective technique to improve the effectiveness of a solar air heater is to add artificial roughness. When the viscous sub layer is roughened, heat transport is enhanced. Various roughness geometries have been investigated so far to increase heat transmission while reducing pumping power consumption.

Literature Review

SUSHIL KUMAR ET.AL (2021) Using solar thermal collectors for agricultural and industrial purposes is a simple, cost-effective, and environmentally beneficial way to harness the power of the sun. In both single-pass and double-pass solar thermal collectors, the researchers are primarily concerned with improving thermal performance by including a variety of fin forms underneath the absorber plate. This study examines the impact of different-shaped fins on thermal collectors, which have been employed by a variety of researchers. Turbulence and thermal performance have been examined in relation to the design of the fin and the geometries used. According to a review of the literature and a comparison research, a solar air thermal collector with fins transfers heat more quickly than a solar air thermal collector without.

DENGJIAWANG ET.AL (2020) The thermal

September/ October 2020
ISSN: 0193-4120 Page No. 49-53

efficiency of solar air heaters is often lower than that of liquid solar collectors. It has been suggested that an improved solar air heater, with s-shaped ribs and gaps, increase the air-to-heat absorber plate heat transfer efficiency enough. An airflow gap was made on the ribs as well. Experimental data on solar air heater efficiency and pressure drop in the presence of a roughness element composed of several, irregularly spaced, parallel S-shaped ribs with gaps is reported in this paper. The rib geometry size, specifically, the rib spacing, rib width, rib clearance width, channel height, solar radiation intensity, and air mass flow rate were analysed. Factors such as intake and output temperature differences, as well as heat efficiency, were examined. An artificially roughened plate on a solar air heater outperformed a smooth plate by 13–48% under various test settings. There is a 15.8–30 Pa pressure decrease in the work part of this new solar air heater. This upgraded solar air heater will benefit greatly from these findings.

P. SUDHAKAR ET.AL (2019) On the one hand, this study reports on an examination into the thermal performance of both a solar air heater that uses PCM and one that does not. The PCM, or paraffin wax, is placed in spheres set on the absorber plate's perforations and filled with paraffin wax to increase the surface area available for heat transmission. The absorber plate is compared to three distinct layouts. The effectiveness of the collector is affected by a number of variables, which are measured and explained. Conventional absorber plates without PCM for the same circumstances are compared. Flat absorber plate with PCM has a mean efficiency of 39 percent, whereas an inclined absorber plate with PCM has a mean efficiency of 43 percent. In the case of a flat plate absorber with PCM, the encapsulation efficiency is 40%, and the estimated cost of heating 1 kg of air is INR 0.95/$0.014 per kilogramme.

FATIMA CHANAA ET.AL (2018) On a low-cost, low-volumetric-air-flow-rate air heater, an experimental investigation is carried out in the presence of sunshine and a coastal area's sea breeze. Designed for drying red algae Gelidium sesquipedale, this single-pass solar air heater has a corrugated sheet metal absorber. The heater is always facing the sun in order to maximize the amount of energy it absorbs. Temperatures at the absorber surface, the heater's intake and exit air temperatures, and the sun irradiance are all measured. Measuring airflow is done with great care. The thermal and effective performance of the collector is determined by its tilt angle. It is possible to collect 3 kWh/m2 with an efficiency of 41.2% and an increase in temperature of 22 degrees Celsius by tilting the panel 60 degrees and using an average radiation intensity of 811 W/m2. 337 W/m2 corresponds to a specific power of 14.7 times the power of the fan that was employed in the original design. Red algae Gelidium sesquipedale dries more faster using this method than it would with the more standard 28°C drying method because of the higher temperature of the exit air.

PRADYUMNA KUMAR CHOUDHURY ET.AL (2017) The quantity of main and secondary energy required by space heating appliances is substantial. Burning fossil fuel or generating conventional electricity is the primary source of energy in most nations. Climate change and fossil fuel depletion are both directly linked to the usage of these common heating methods. When it comes to space heating, solar air heaters are an excellent way to take use of solar thermal energy, especially in light of the worldwide push for energy conservation and a shift to sustainable energy. Using a solar air heater to heat a room is the subject of this paper's investigation. There are a number of significant difficulties that need to be addressed, such as demand–supply mismatch, installation space limitation, yearly utilisation factor, and undesired changes in output temperatures. Solar air heaters are also briefly explored in light of current research trends.

Conventional Solar Air Heater

In traditional flat plate solar air collectors, the steady state energy balance conditions are stated as follows:

$$I_o \tau\alpha = U_t\left(T_{pm} - T_a\right) + h_1\left(T_{pm} - T_f\right) + h_r\left(T_{pm} - T_{bm}\right) \quad ($$

$$h_r\left(T_{pm} - T_{bm}\right) = h_2\left(T_{bm} - T_f\right)$$

$$\frac{m\, C_p}{B}\frac{dT_f}{dx} = h_1\left(T_{pm} - T_f\right) + h_2\left(T_{bm} - T_f\right)$$

Where, $h_r = \dfrac{4\sigma T_{av}^3}{\frac{1}{\square_p} + \frac{1}{\square_b} - 1}$

Solving these equations we get

$$F' = 1 + \left(1 + \frac{U_t}{h_w}\right)^{-1}$$

$$F_R = \frac{m' C_p}{U_t A_p}\left[1 - \exp\left\{-\frac{F' U_t A_p}{m' C_p}\right\}\right]$$

$$Q_u = F_R A_p [I_0 \tau\alpha - U_t (T_i - T_a)]$$

$$\eta = \frac{Q_u}{I_0 A_p}$$

$$T_o = [Q_u/(C_p m')] + T_i$$

$$T'_{pm} = T_a + \left[\frac{I_0}{U_t}(\tau\alpha - \eta)\right]$$

Mean fluid temperature is calculated by using the formula

$$T_{fm} = \frac{1}{L}\int_0^L T_f\,(x)dx$$

This on substituting terms by relevant gives

$$T_{fm} = T_i + \left(\frac{\eta I_0}{U_t F_R}\right)\left[1 - \left(\frac{F_R}{F'}\right)\right]$$

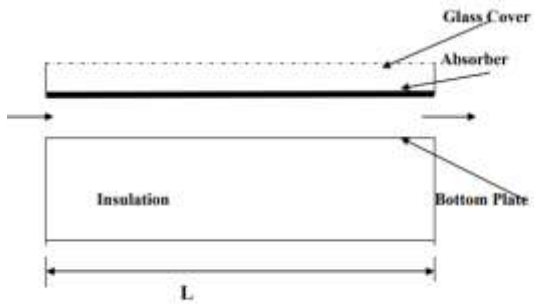

Figure1: Conventional Solar Air Heater

Computational Solution

MATLAB R2009b is used throughout the whole investigation. MATLAB is a set of tools for performing complex numerical computations and visualising the results of such computations. One of the most useful aspects of this software is the interactive environment it offers. It has a high-level programming language that makes it simple to add new features. MATrix LABoratory is the abbreviation for MATrix LABoratory.

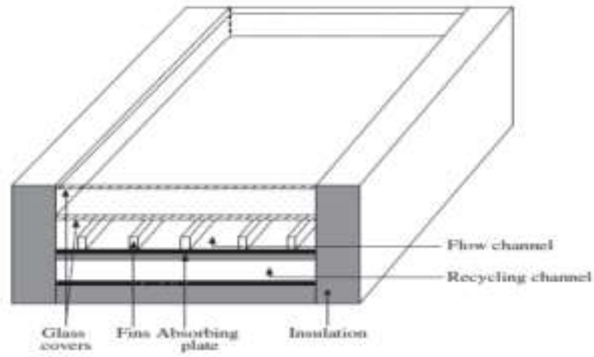

Figure 2: Schematic diagram of double pass internally finned solar air heater

In order to increase the evaporation rate of basin water, A. Senthilrajan experimented with a still-active device that was connected to a biomass water heater. According to the findings, a biomass heater boosts production both during the day and at night. The active still system under forced convection mode of operation was studied by a number of researchers for energy analysis and thermal efficiency. According to Panchal et al., vacuum tubes paired with a solar still may have an extra impact. Vacuum tubes may be utilised to boost distillate production by providing more thermal energy. Tiwari et al. investigated the heat transmission coefficients for single-slope solar stills in active and passive modes (SSSS). Researchers worked on an active system in which a flat plate collector was linked to a solar panel.

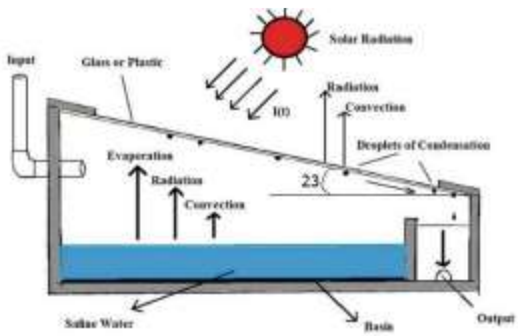

Fig.3. Working on the conventional single slope solar still

Solar air heating system performance was improved and evaluated without the use of a temporary thermal storage material.

Experimental set-up and procedures

It took place in Ranchi, Jharkhand, from 9 a.m. to 6: pm on a day in June 2018 when the city's latitude angle was 23 degrees. A solar air warmer using paraffin wax was tested using two experimental setups that were planned and built. Specific heat (kJ/kg °K)-2.95; latent heat of fusion (173.6 kJ/kg); and thermal conductivity k of (W/m°K)-0.167(liquid) are all related to the density of 790 and the melting point (°C)-50. One of the most common designs for a solar still is seen in Figure 1. With a thickness of 4 mm, the inside walls of the still solar basin are composed of fiber-reinforced polymers (FRP). To further improve absorption, the still basin's bottom is painted a dark black colour (absorptivity: 0.88) In order to accurately measure the volume of the distillate, a measuring jar is mounted to the subordinate vertical height of the basin and connected to a connecting pipe. Silicone rubber and putty have been utilised to prevent leaks from entering the still system. A plastic beaker is being used to collect the distillate output for volume measurement.

Data is being collected hourly on a parameter related to the performance of a passive solar still system. Thermophysical parameters of solar stills may be determined by determining the vapour temperature. After obtaining readings and putting the still in idle mode for a day, it is observed that this is done in order to achieve a steady-state condition for the experiment. There is a schematic design of the improved solar distillation unit shown in Figure 2. It was possible to perform experiments in Jharkhand's latitude angle 230 climate from 9:00 a.m. to 6:00 p.m. Solar radiation, vapour, water, glass, and basin temperature were all recorded. The volume of water in the beaker has also been measured. The water basin is 3 centimetres deep. Because the shallower the water basin, the more productive it is. The solar still with solar air heater has an average daily production of 1.30 liters/m2 /day while the traditional solar still has a daily output of 0.8815 liters/m2 /day, according to research.

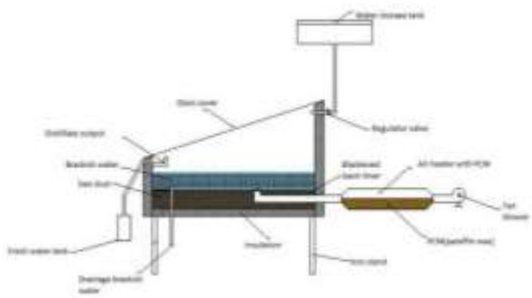

Fig.4. Labeled diagram of the modified single slope solar still with solar air heater with PCM

Conclusion

A solar air heater is a basic gadget that uses the sun's rays to heat the air. Solar air heaters, a renewable energy heating device, are used to generate hot air for room heating. Such technologies generate heat with no additional expense. The only thing that needs to be done is to wipe down the collectors. Energy storage is critical for energy conservation, but it also enhances system efficiency and dependability across a broad variety of energy systems. It is especially critical for intermittent energy sources like solar. The rate of mismatch between energy supply and demand may be reduced by the use of energy storage.. Thermal energy storage may be employed in areas where the temperature difference between day and night is greater. This thorough analysis compiles extensive research on air heating systems, both with and without thermal energy storage.

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September/ October 2020
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