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EXPERIMENTAL INVESTIGATION OF SOLAR AIR HEATER INTEGRATED WITH PCM FOR ENHANCEMENT HEAT TRANSFER ENHANCEMENT

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Abstract

Enhancement of heat transfer in solar air heater (SAH) by employingthe artificial roughness inabsorber plate and increasing heat discharge duration by assimilating phase change material (PCM)–paraffin wax were experimentally investigated. A study focused to raise the heat transfer rate at peak radiation and extending heat discharge duration from PCM in OFF sun radiation.The researchis done in two different types of absorber plates positioned in SAH (Type-I - Flat plate) and (Type-II Circular rib in plate) with and without PCM in SAH. Instantaneous thermal efficiency and hourly heat distribution parameters are taken to analyze the augmentation of heat transfer in charging and discharging. The result reveals that Type-II circular rib plate produces higher heat transfer than Type-I due to turbulence in fluid flow and heat discharge duration extend up to 8 pm Indian Standard Time (IST)at nominal temperature

Keywords:

Solar air heater;
PCM;
Circular rib absorber plate;
Thermal efficiency.

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1. INTRODUCTION

Now a day's solar energy-based thermal application is consumed more in domestic and industrial purpose. Among them, solar air heater is significant to produce heat energy for agriculture purposes.SAH has produced low thermal energy due to a lack of relative roughness between absorber plate surface and fluid results in poor thermal efficiency. The outcome of that roughness surface absorber plates is widely used to increase the heat transfer rate. Varun et al [1]

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did a review of the various shape of rib in SAH and found improvement in thermal performance. AymenEi et al [2] carried out an experimental investigation in SAH united with and without phase change material for augmentation of heat transfer. The researcher reported that using PCM33% of energy efficiency reached in the night time and higher heat transfer occurred. A.E. Kabeel et al [3]done an experimental investigation in SAH with stored PCM by varying mass flow rate for enhanced of thermal performances and result reveals higher heat transfer occurred.V. V. Tyagi [4] done a comparative study of SAH with different materials of PCM and without PCM. Findings reported that a gradual increment of outlet temperaturesoccurred in all PCM.An experimental analysis carried out by Edward K. Summers et al. [5] in SAH integrated with 8 cm of PCM beneath of absorber plate for increasing outlet temperature. Result reveals that 35% of thermal efficiency has received. Double pass solar air heaters (DPSAH) with PCM as a thermal energy storage system (TES) were experimentally investigated byS.S. Krishnananthet al [6]. Different methods implement for investigated and reported that PCM delivered greater temperature than without plate.SalwaBouadila et al.[7] carried out an experimental investigation using a spherical shape of PCM in capsules placed in the SAH bed for higher thermal performance. Result reveals that 32% to 45% thermal efficiency has achieved. An inorganic -PCM salt in ball type were fixed in the PCM channel by S. Esakkimuthet al [8] for increasing heat transfer in SAH. A researcher reported that the sizes of the ball and inlet temperature increase the outlet temperature and increasing discharge duration in off sunset. A numerical investigation has done by E. [9} for heating and cooling the building with PCM stored in SAH. The simulation report reveals that significant improvement found in reducing heat inside the building.

An experimental and numerical review work done by CirilArkarIn et al.[10] in solar collector integrated with PCM for producing heat energy to the building. The research reveals that the augmentation effect increase based on design and selecting thermal modeling in simulation.Abduljalil A et al. [11].studied a numerical and experimental analysis for the internal and external fin in HVAC ventilator using solidification PCM. Result reveals that implementing PCM in HVAC charging duration achieved within the minimum period. MojtabaEdalatpour et al.[12] carried out an experimental study in double pass glazed SAH for enhanced heat energy. Result reveals that 58.4% to 68.8% energy has achieved using PCM in SAH. E M.Sparrow [13] and MaryamGharebaghiet.al [14] illustrate the charging and discharging performance of PCM and numerical procedure used in SAH. Inthe literature survey, it is observed that integrated PCM in SAH has a significant performance of yielding higher thermal energy than without PCM.Among that roughness,the surface plays an important role in rapid charging in peak radiation. But still, the discharging duration of heat energy from PCM yields minimum duration. Present work focused to implement a circular shape of rib – produce maximum turbulent at a nominal mass flow rate in SAH were investigated with PCM as TES for increasing thermal performance in both charging and discharging. The parameter is thermal efficiency and hourly heat distribution is considered for evaluating the enhancement of thermal performance in SAH. It observed that implementing the circular shape of the rib in the absorber plate assimilated with PCM has attained maximum thermal efficiency and also increasing discharge duration.

2. EXPERIMENTAL PROCEDURE:

The schematic diagram of the experimental setup of a solar air heater was shown in fig.1.A sectional view of SAH pictorial as shown in fig 2. A mainpart of the experimental setup is a) centrifugal blower used to produce mass flow rate between test sections b) 1× 1m^2wooden square cross-section duct used as test section c) glass cover positioned to transmit radiation from sun to absorber plate.d) an absorber plate placed on the top surface of the duct were heated energy transfer from the outer surface to fluid flow inside test sectione) PVC pipe chose to connect between the blower and square duct.f) Calibrated thermocouple positioned in the absorber plate, inlet, and outlet section to measure the temperature of various points.g) A solar

meter used to record radiation from the sun.h) An anemometer measures the velocity of the test section at the exit point, I) PCM channel attached in the lower portion of SAH.

2.1 *Working procedure:*

The preliminary connection between the entire experimental setup is properly checked to avoid heat or pressure leakage from the SAH. A centrifugal blower stream the mass flow rate to the test section at the rate of 0.048Kg/s. Entry section, test section, and exit section temperature are recorded by a thermocouple connected to digital indicator. Test section analysis in two types of absorber plate a) flat plate absorber plate (Type-I) b) circular rib positioned in absorber plate (Type-II). Initially, Type-I absorber plate positioned in SAH to record augmentation of heat transfer without PCM, later it replaced by circular absorber plate follows the same parameters. A constant mass flow rate 0.048kg/s blow inside SAH in Type –I and Type-II individually. Further PCM – paraffin wax (liquid form) poured inside the PCM channel and initiate the investigation in both types of absorber plate and temperature at the various locations are recorded. Results are plotted in a graph to identify the augmentation of heat transfer and charging & discharging of heat energy during off sun radiation. The performances of SAH using PCM were briefly presented in the result.

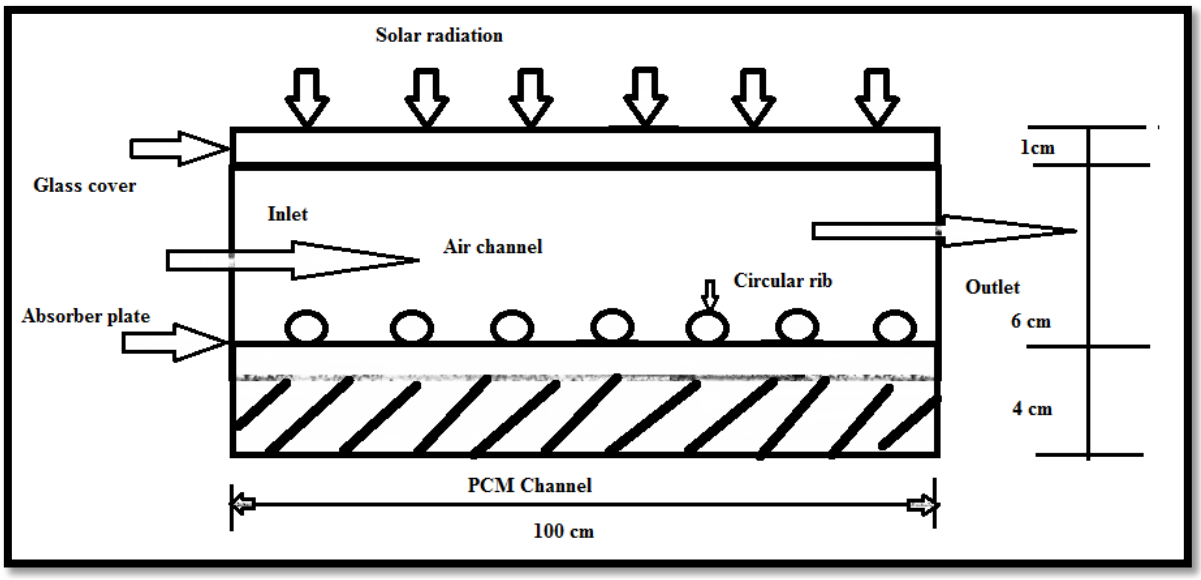

Fig.1 Schematic diagram of solar air heater - circular rib absorber plate

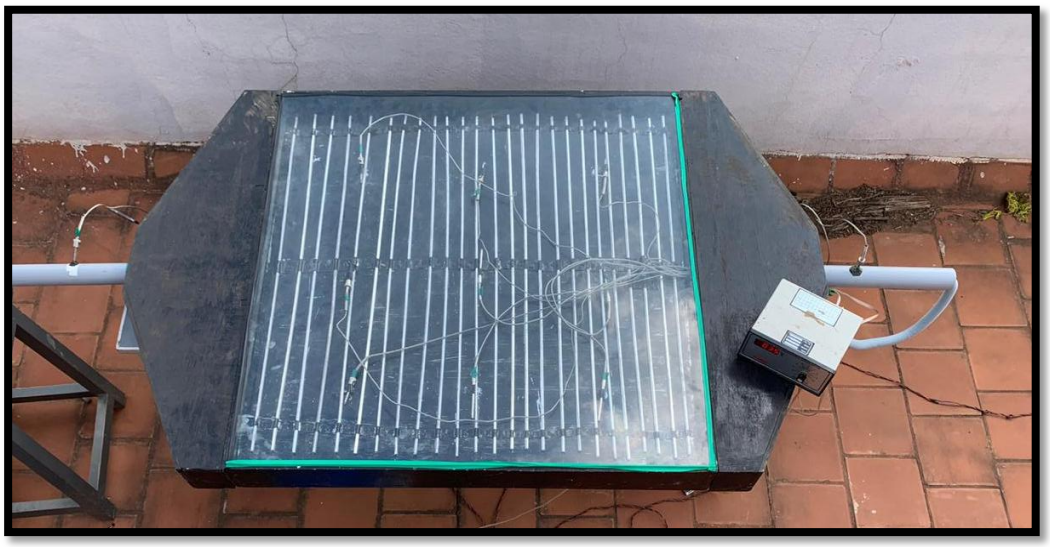

Fig .2asectional view of SAH pictorial

3 DATA AND EQUATION:

Thermal performances of solar air heater are calculated by the following equation

a. Heat energy (Q) consumed from the experimental setup of a solar air heater evaluated by the equation

$$Q = m \times c_p \times (T_{out} - T_{in}) \qquad 1$$

Where 'm' as the mass flow rate of air inside the test section Kg/s, 'Cp' as Specific heat of air = 1.005 J/Kg ^{0}C, and temperature difference of test section (Outlet temperature – Inlet temperature)

b. The instantaneous thermal efficiency of SAH can be calculated by the following equation

$$\eta = {}^{Q}/_{I \times Ac} \qquad 2$$

where'Q' as heat gained from the test section, 'I' as solar irradiation and 'Ac' as an area of cross-section of SAH.

4 RESULT AND DISCUSSION:

The experimental investigation of solar air heater integrated with paraffin wax - PCM and without PCM performances were briefly presented. A smooth surface of the absorber plate was placed in the test section later roughness surface were positioned for investigation. The examination carried out in with and without PCM in the solar air heater. Analysis carried out between 9am to 5pm - without PCM to identify the augmentation of thermal performance and 9am to 8 pm - with PCM in solar air heater for discharging heat energy from paraffin wax and duration of heat exchanger were studied. In fig [3] illustrate the comparison of heat destruction in smooth surface and roughness surface without PCM material in solar air heater. It illustrates clearly that implementing roughness surface in the absorber plate execute more heat energy that smooth surface due to turbulence occurred in the flow direction of the fluid. It explained that a circular rib can produce turbulent in fluid flow causes more heat energy stored in flow direction results in higher heat transfer occurred than a smooth surface.

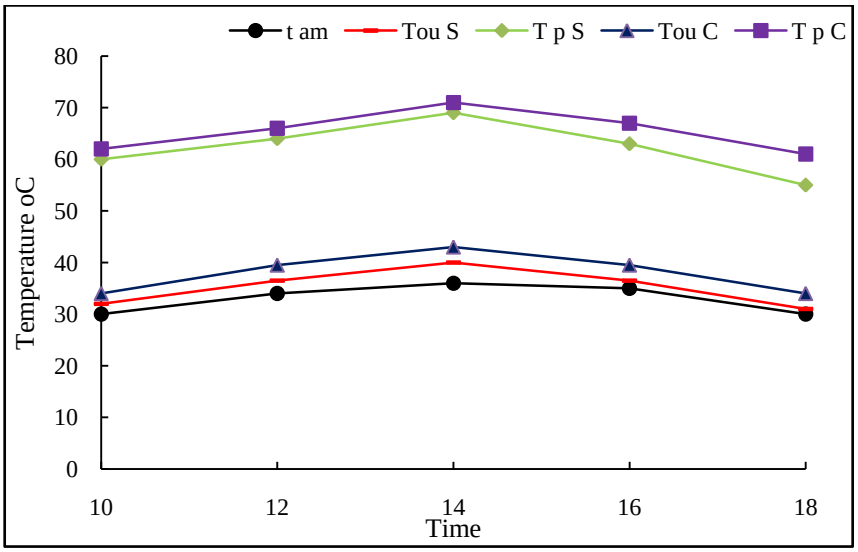

Fig.3 Hourly heat distribution in SAH without PCM

In fig [4] illustrate that integrating PCM material with roughness surface has produced more thermal performancethana smooth surface and also charging duration of PCM quicker than a smooth surface. it observed from fig [4] that happens nearly 11.30am to peak radiation 2.30pm, later decreasing radiation heat energy stored in the PCM layer up to the temperature maintained 54^{o}C . it observed from fig [4] that closer to 4.30pm the temperature of surface decreasing lower than PCM temperature of paraffin wax were discharging of heat energy from PMC to surface were occurred. The distribution of heat energy were recorded maximum up to 8pm the next day. It illustrates that the physical property of paraffin wax has a maximum discharging duration than

other organics components. Due to the chemical property of paraffin wax it capable to maintain a higher temperature than the ambient temperature in the solar heater. In fig [4] illustrate that it maintained a maximum discharging duration also due to the implementation of the roughness surface of the absorber plate.

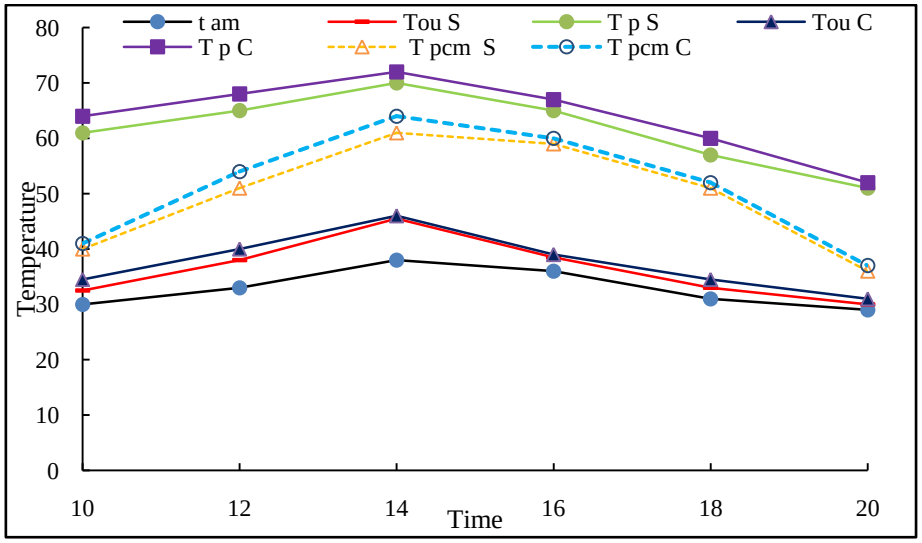

Fig.4 Hourly heat distribution in SAH with PCM

Thermal performances of both plates with and without PCM are plotted in fig. 5. It observed that higher temperatures occurred when engaging PCM in both plates than without PCM. It shows that a nominal increment produced up to 2 pm in all cases later its start decreasing. A minimum increment in with PCM absorber plates after 6 pm – discharging heat energy from PCM then it decreasing normal to ambient temperature.

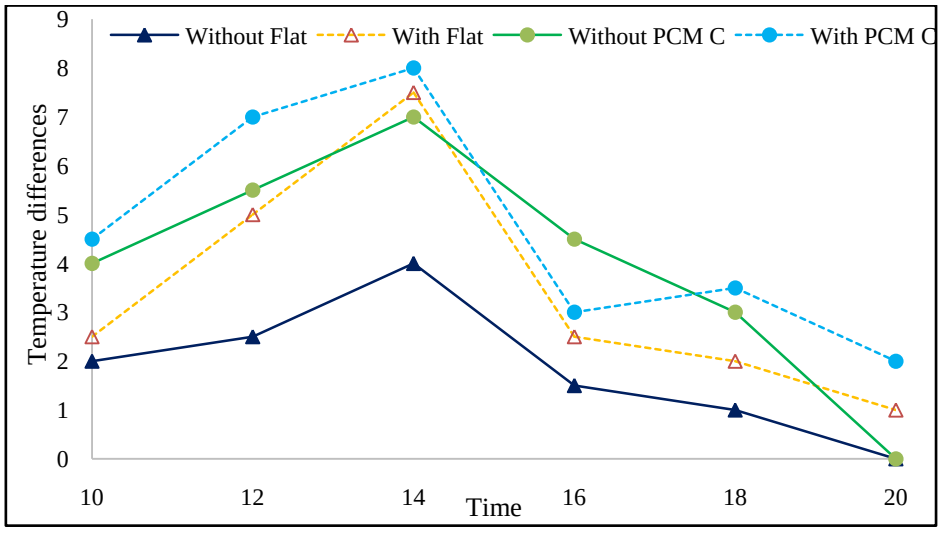

Fig.5 Comparison of temperature differences between with and without PCM in SAH

In fig [6] illustrate the thermal efficiency of with and without PCM in the smooth surface and roughness surface of the absorber plate. it detailed that implementing roughness surface in solar air heater interpreted with PCM has distributed maximum thermal efficiency than others

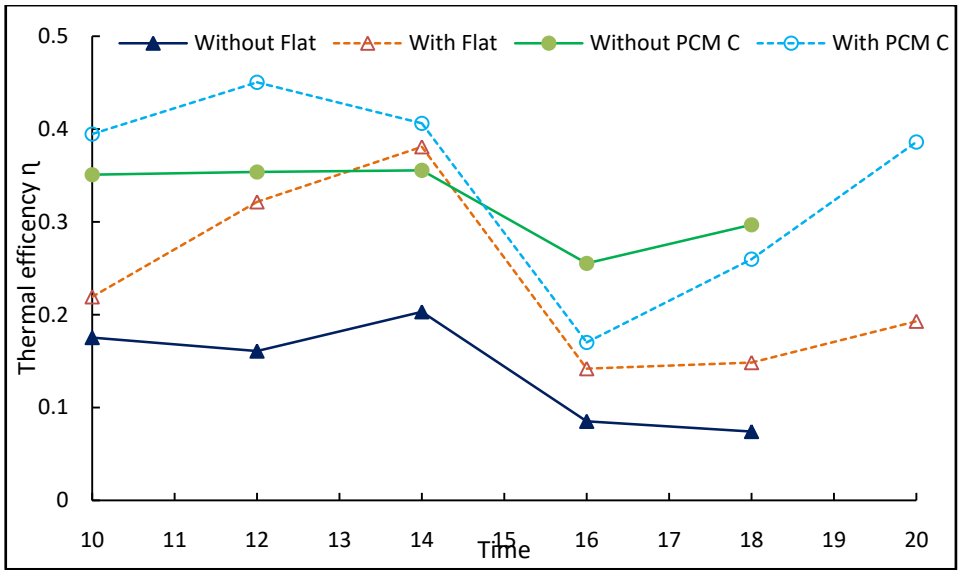

Fig.6 thermal efficiency of SAH with and without PCM

5 CONCLUSION:

The experimental study carried out in solar heater implementing circular rib in absorber plate integrated with PCM material for thermal augmentation and increasing heat discharge duration in off sunshine hours. It observed that maximum heat transfer occurred I circular roughness surface than smooth surface due to turbulence occurred in floe direction causes the higher temperature in the outlet and using PCM it has increasing discharge duration after sunset up to 8pm. It observed that thermal distribution among with and without PCM implementing roughness surface has maximum than others and it has produced higher thermal performances.

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Nomencalture

αAbsorptance of the absorber plate
mMass flow rate of air (kg/s)
η Thermal efficiency of Solar Air Heater (%)
τTransmittance of the glass cover
Ac Collector aperture area (m2)
CpSpecific heat of the air (J/kgK)
F Collector efficiency factor
FrHeat removal factor of solar collector
I Radiation over the surface (W/m^2)
Q Useful energy gain of collector (W/m^2)
TpAbsorber plate temperature of SAH
Ta Ambient temperature (^oC)
Ti Collector inlet air temperature (^oC)
To outlet temperature (^oC)