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Performance Analysis of Solar Air Heater using Different Material

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Abstract: *Outlet air temperature can be seen as one of the main determinants of the functioning of the solar air heaters and this is one of the main features of the PCM. Variations in solar radiation can be considered a key determinant of the functioning of solar air heaters used in residential applications. Weather conditions can influence the presentation of the air heaters operated by solar energy to a great extent. Structuring of collector plates needs to be done in an effective manner by designers of air heaters used in residential applications. The contact surface of the collector plates is the other determinant of the presentation of the air heaters. A blower is one of the most vital components used in air heaters and the efficiency of the blower can improve the execution of this device. Transport fluid has been identified as a vital factor that can have a huge impact on the functioning of air heaters operated by solar energy. Air thermal capacity can be considered as the other determinant of the functioning of this device. The high cost of fluid circulation has been found as one of the negative factors in the structure and functioning of the air heaters used in residential applications.*

Keywords: Solar air heaters, Phase change materials, Environmental factors, Thermal capacity, Solar energy

I. INTRODUCTION

In this paper, the thermal efficiency of a solar air collector called unglazed transpired collector (UTC) has been studied using CFD. Experimental results were validated. The study was done to calculate efficiency of solar air heater under hot climatic conditions with two different mass flow rates of air. A commercial finite volume software (CFX) was used to model the heat transfer through the UTC. It was found that temperature rise decreases with increasing air mass flow rate and the efficiency increases with increasing air mass flow rate. Increasing the irradiation level seems to have a very limited effect on the collector efficiency for both mass flow rates. Still, the results show a small increase in efficiency as the irradiation intensity decreases for both mass flow rates. Energy consumption is on increase and the fossil fuels cannot last forever. Extensive fossil fuel consumption by human beings has led to some undesirable phenomena such as atmospheric and environmental pollutions. Consequently, global warming, greenhouse effect, climate change, ozone layer depletion and acid rain terminologies started to appear in the literature frequently. So, it has become the need of an hour to use the energy resource which is clean and ecofriendly. Solar energy is one of the better options for clean energy. Solar air heating is a heating technology used to heat or condition air for buildings or process heat applications. It is typically the most cost-effective out of all the solar technologies, especially in commercial and industrial applications, and it addresses the largest usage of building energy in heating climates, which is space heating and industrial process heating. Solar air collectors can be commonly divided into two categories:

• Unglazed Air Collectors or Transpired Solar Collector
• Glazed Solar Collectors

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In this study we are going to focus on Unglazed Transpired Collectors. Unglazed transpired collectors (UTC's) are now a well-recognized solar air heater for heating outside air directly. They are key components in many engineering applications, such as in institutional and residential heating, industrial processes like sewage wastewater treatment, and food processing, crop drying. They differ from conventional solar air collectors in that their external wall is replaced by a black perforated sheet, that is unglazed, that allows the collection of solar irradiation. After studying number of papers related with solar air heater it was observed that very less work has been carried out to study the performance of the device under hot climatic conditions like India. In this work the performance will be studied with CFD software in hot climatic conditions. Also the effect of different parameters such as air flow rate, ambient temperature, solar radiation intensity on the performance of the solar air heater system will be studied.

Problem Statement:

Low air density is one of the main issues which need to be given high importance by the designers engaged in developing thermal air heaters. Along with these, low level of air thermal capacity has been found as the other factor which has led to issues in the air thermal heaters. Moreover, lack of thermal storage is another factor that has affected the functioning of air heaters operated by solar power. Several obstacles face the design and performance analysis of a solar air heater with phase change material (PCM) heat storage for residential use [37] [38] [33]. Optimising PCM selection, constructing efficient heat exchangers, integrating and distributing PCMs throughout the system, conducting accurate performance analysis and optimisation, and resolving practical implementation and scalability challenges are all part of the process. To maximise the thermal performance, energy efficiency, and practicality of solar air heaters with PCM heat storage in residential contexts, several problems must be overcome.

Objective:

- To critically analyse the presentation and designs of SA heaters.
- To analyse the role of PCM in enhancing the performances of solar air heaters.
- To identify the advantages of using PCM in air heaters operated by solar energy in residential applications.
- To identify the drawbacks of using PCM in air heaters operated by solar energy used for residential purposes.

II. WORKING PRINCIPLE

The basic principle of working of an Unglazed Transpired Solar Collector is as shown in figure 1.The unglazed transpired collector (UTC) has a dark perforated surface through which air is drawn. Unlike typical solar air heaters, the UTC does not have a layer of glazing covering its front, and, unlike matrix collectors, it uses a single thin perforated sheet instead of a thick matrix for the solar absorber. The collector is typically mounted on the south side of the exterior of a building. Figure1 shows irradiation heating the absorber surface through which air is heated as it is swept across the surface to the holes. The warmed air then moves up the plenum and is delivered to the building interior by a fan. A fan is necessary to overcome the pressure drop across the collector to drive the air through the absorber. The absorber surface is most commonly a thin perforated aluminum sheet, although other materials have been used such as fabric. The porosity of the collector surface is typically 0.5 to 2%. The space behind the absorber is called plenum. Figure1 shows a cross-section of an unglazed transpired collector and building. The depth of the plenum varies from one collector design to another. Typical depths are between 5 and 30 cm. The back wall of the plenum is commonly the building's exterior surface. After sunrise, as the radiant intensity increases, the temperature of the absorber increases, then the air in the plenum is heated by the absorber, when the air temperature reaches the set point, the temperature controller starts the blowing fan and forms negative pressure in the plenum, so outside air is sucked into the plenum and heated during the passage of air through the plenum, then hot air is delivered by air pipes to the place where heat is needed.

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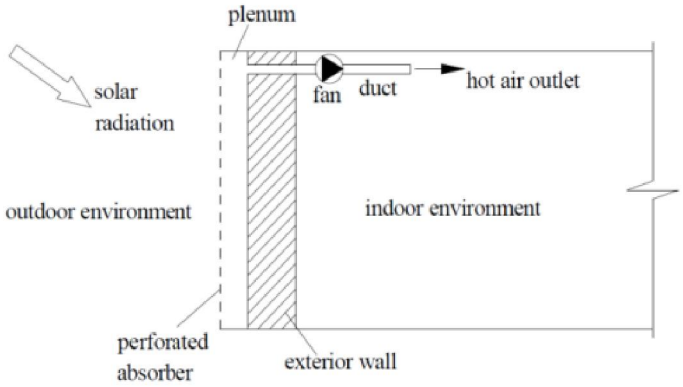

Fig. 1: Basic Principle of working of solar Air Heater

A. Solar Air Heater Model Specification

The solar air heater mainly consists of UTC (Unglazed Transpired Collector) plate, plenum space and a suction duct at the back of the collector plate. We selected the different parameters of device as specified in paper Experimental study of solar air heating system based on unglazed transpired collector ,Proceedings of the ASME 2011 5th International Conference on Energy Sustainability ES2011 August 7-10, 2011, Washington, DC, USA by Lixin Gao ,Hua Bai, Xiumu Fang. The unglazed transpired collector is constructed from metal plate, which is perforated and covered with selective coating. The collector is mounted out 150 mm from the south exterior wall of a building to form an air cavity (also termed plenum). The structure of UTC-based solar air heating system is shown in figure 2 and the system consists of two sub-systems, that is, solar energy collecting subsystem and heated air delivering sub-system. The solar energy collecting sub-system with an area of 2.5 m² was used for experiments. We also used the device with same dimensions for validation of the experimental results and CFD results.

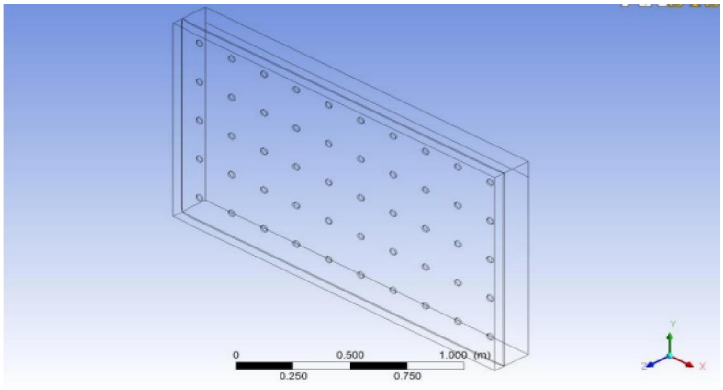

Fig. 2: Actual model of solar air heater

B. Plate Geometry

The collector plate construction is as shown in figure 3. The area of the plate is 2.5m².The length of plate is 2m and breadth is 1.25m.The thickness of the plate is taken as 5mm.The perforations on the plate are 2% that is the 2% area out of total area is perforated. Basically the hole diameter is between the range of 1.5-2.5mm.But we have selected diameter as 18mm because if we had selected the diameter as 2-2.5mm the total numbers of holes required becomes almost equal to 2500.It becomes quite difficult to create a model with so much number of holes. And for such models

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mesh size should be very much small which leads to such a high number of elements which requires high capacity computers. To overcome this problem we have selected the large whole diameter keeping the total percentage of perforated area constant that is equal to 2% of the total area.

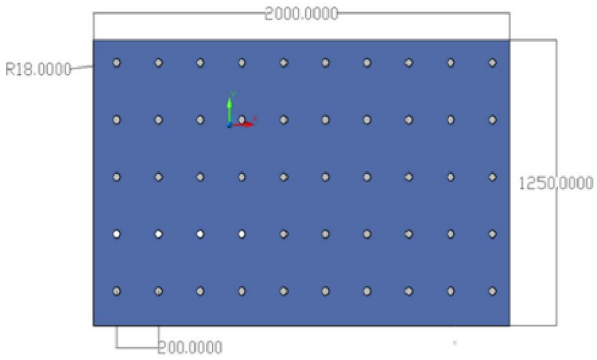

Fig. 3: Collector plate geometry

III. STRUCTURE & EXECUTION OF SA HEATER

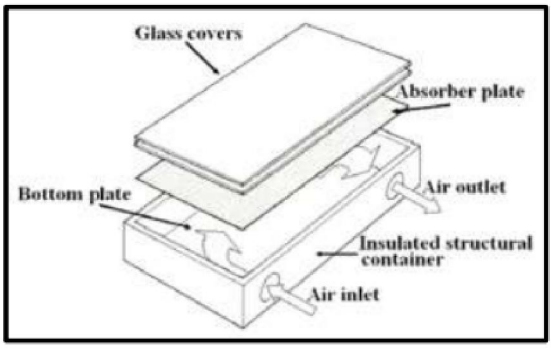

Fig. 4: Structure of SA heater

The heating of the air stream is done by the collector plate and the back side of the plate is used in this method. In order to boost the contact surface, fins are attached to the collector plate [1]. The usage of mineral wool can be seen in the collector plate for the purpose of insulation. Usage of a blower can be found in some cases for drawing air within the collector and the hot air is transmitted into the dryer. Elimination of freezing is done in the device by using transport fluid. Along with these, the usage of transport fluid prevents issues due to corrosion. It has been found that larger air volume than liquids can lead to issues in the functioning of air heaters operated by solar energy [2]. At the same time, the low thermal capacity of air can have an adverse impact on the functioning of air heaters. The cost of fluid circulation has been found high in the functioning of air heaters operated by solar energy. Moreover, the study has identified a high level of noise in the functioning of the device

A. Role of Phase Alter Material (PCM) in Improving the execution of SA Heater

In SA heaters, salt hydrates are used as phase change materials to heat air as they undergo phase changes over time [4]. There have been some delays in heat penetration in PCM as a result of low thermal conductivity levels. Aside from these, it has been found that discharge lag in the storage units can also depressingly impact the execution of the storage units as a consequence of the discharge lag in this system. There is increasing evidence that the use of tubular containers can significantly improve the execution of solar-powered air heaters that operate on solar energy [5].

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Moreover, using naked encapsulates for the air heaters powered by solar energy is another factor that can lead to a noteworthy increase in the competence of the air heaters powered by solar energy. As a way of improving the execution of SAheaters, the use of Rabitz wire meshes has been identified as an Effective method.

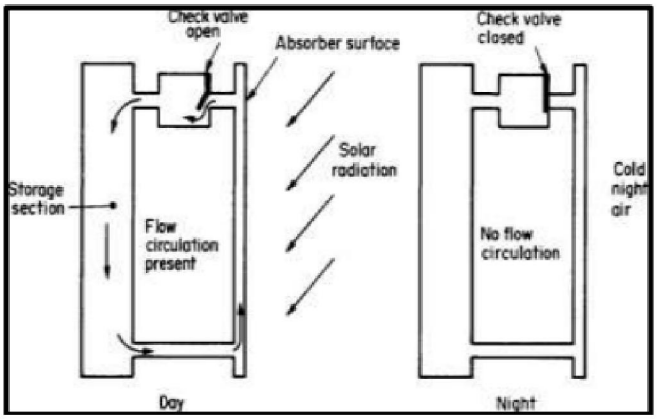

Fig. 5: Design of solar air heater

In SA heaters, salt hydrates are used as phase change materials to heat air as they undergo phase changes over time [4]. There have been some delays in heat penetration in PCM as a result of low thermal conductivity levels. Aside from these, it has been found that discharge lag in the storage units can also depressingly impact the execution of the storage units as a consequence of the discharge lag in this system. There is increasing evidence that the use of tubular containers can significantly improve the execution of solar-powered air heaters that operate on solar energy [5]. Moreover, using naked encapsulates for the air heaters powered by solar energy is another factor that can lead to a noteworthy increase in the competence of the air heaters powered by solar energy. As a way of improving the execution of SAheaters, the use of Rabitz wire meshes has been identified as an Effective method.

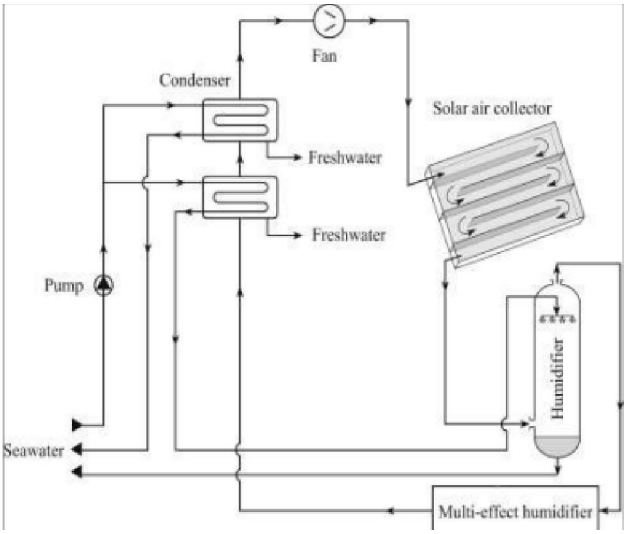

Fig. 6:Procedure of solar air heating

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IV. CONCLUSION

The performance of solar air heating system based on unglazed transpired collector has been discussed. The efficiency of an UTC has been investigated numerically. After studying the results obtained the conclusions can be stated as:

• Results show that temperature rise decreases with increasing air flow rate, while collector efficiency increases with increasing air flow rate.

• The efficiency increases with increasing air mass flow rate. This is because the heat transfer capacity depends directly on the mass flow rate, which induces higher velocities through the perforations and more heat transfer from the plate to the air.

• Increasing the irradiation level seems to have a very limited effect on the collector efficiency for both mass flow rates. Still, the results show a small increase in efficiency as the irradiation intensity decreases for both mass flow rates. Nevertheless, this small effect may be due to the reduction of the absorber plate temperature, resulting in lower losses from the collector at low irradiation. books in [11-25].

ACKNOWLEDGMENT

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