Solar Air Heater Studies in Dryer Applications

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Abstract

Energy crisis and global warming lead to find an alternative way to overcome the above worsening situation. Renewable energy plays a major solution and there by meets our energy demand and reduces the CO_2 emission which reduces the greenhouse effect. In the renewable energy side, Sun is the mother for all sources and harnessing the solar energy in proper ways can eliminate the energy crisis of the world. This paper presents the overview of solar air heater studies in drier application and main objective of this work is to enhance the heat transfer of a solar air heater by using multi pass flow channel with phase change materials. In this work, effort has been made to fabricate the multipass flow solar air heater for dryer applications.

Keywords: *Multipass flow channel, solar air heater, solar radiation, Absorber plate, Glass*

1. Introduction

Solar air heaters have vast applications both in industrial and agricultural sectors. So, huge research is going on to enhance the performance of solar air heaters by putting number of effort in various enhancement techniques like increasing the heat transfer rate, proper tracking geometry and better heat absorbing medium of high absorptive and various thermal energy storage mediums(1). Solar air heater is a system which collects solar energy and transforms it into heat. It has an important place with solar thermal systems and widely used in buildings, agricultural and industrial drying for low and moderate temperature applications. It has low efficiency due to low convective heat transfer coefficient in the smooth absorber surface air limitation to energy extraction and flow rate limitations. Due to this reason, it has necessary to develop new techniques to enhance the heat and mass transfer in solar air heater (2). One of the effective ways to enhance the convective heat-transfer rate in solar air heater is to extend the heat-transfer surface area by using roughened surfaces in order to increase the turbulence inside the channel and many studies have been carried out on this aspect. On the other hand, the jet impingement concept is an effective method of increasing convective heat transfer in a solar air heater. Jet plate solar air heater is extensively used in the fields of space heating, drying of agriculture crops and supply of hot air in buildings due to its higher convective heat transfer coefficient and efficiency of solar collector(3).

2. Literature Review

Research activities carried out on solar air heater by earlier researchers, scientists and technologists as well, are summarized in the following paragraphs.

Vinsonadidhrma et.al.(4) have experimented the thermal analysis in solar flat plate collector by using jet impingement methods. They have fabricated the solar jet impingement air heater for improving the performance of the solar air heater system. They have investigated three different designs of perforated plates to evaluate the thermal performance of solar air heater

system. According to them they have found that geometric design does not show strong influence in overall performance of the system.

A R Celma et.al.[5] have examined the energy and energy analysis in solar drying units in the olive mill waste water plants. They have carried out the experiments under the natural convection phenomena. They have evaluated the energy analysis, to estimate the amount of energy gained from solar air heater and ratio of energy utilization in the drying chamber. They have found that decrease in energy efficiency in the drying chamber, for the increase in inlet temperature of air.

Sharad Kumar et.al.[6] have carried out simulation studies in a solar flat plate air heater using CFD. They have experimented in solar air heater duct by using artificial roughness in the form of thin circular wire using numerical simulation procedures. They have computed heat transfer co-efficient, friction factor and performance enhancement for the effect of arc shaped geometry. They have also simulated the same procedure for the various Reynolds number ranging from 6000-18000 and solar radiation 10000 W/m². They have shown that overall enhancement ratio was found to be 1.7 for the range of parameters.

Hikmet Esen[7] has experimented the energy and exergy analysis in a double flow solar air heater for different obstacles on absorber plates. They have also carried out the experiments to study the energy characteristics for several obstacles and without obstacles. They have measured the inlet and outlet temperature, absorbing plate temperature, solar radiations for various obstacles in absorbing plate. They have simulated the same procedure for various mass flow rate of air. They have concluded that the largest irreversibility is occurring at a flat plate collector (without obstacles) in which collector efficiency is very low.

Ting Ting Zhu et.al.[8] have carried out the experiments in solar air heater based on flat micro heat pipe arrays. They have described the structure, working principle and test facility in detail. They have determined the efficiency, pressure drop and time constant for the FMHPA solar air heater (flat micro heat pipe arrays). They have found to be 70% thermal efficiency in solar flat plate collector. It has more efficiency than traditional solar flat plate collector according to them.

Abhishek saxena et.al.[9] have investigated the solar air heater by the mode of natural and forced convection principles. They have fabricated the thermal heat storage medium inside the solar air heater. They have evaluated the performance analysis in the solar air heater with or without thermal heat storage medium. They have compared the solar air heater with two similar design of solar air heater. They have found to be 18.04 - 20.78 % of thermal efficiency in natural convection mode and 52.25 - 80.05 % of thermal efficiency in forced convection mode.

Abhishek saxena et.al.[10] have reviewed the solar air heating system for the applications of space heating, timber seasoning and agricultural drying. They have investigated the thermal performance of solar air heater by varying parameters of the absorber tray, duct area, glazing, insulation thickness, extended surface and tilt angles parameter. They have also optimized the air heater system for the different construction elements using thermal heat storage medium.

Raheleh Nowzari et.al. [11] have analyzed the single and double pass solar air heater by using normal and perforated covers. They have simulated the solar air heater by using statistical software. They have found the strong agreement between the theoretical and experimental values according to them.

Ranchan chauhan et.al.[12] have examined the analysis of different impingement jet studies in solar air heater. They have also carried out the experiments in solar air heater to improve the thermo hydraulic performance by the variation of Reynolds number, diameter of the jet, steam wise and span wise pitch. Based on their studies, they have found to be 70% of efficiency in impingement jet solar air heater compared to conventional type of the solar air heater.

A A Mohamad et.al.[13] have examined the novel type solar air heater by using porous absorber. Their main idea has to minimize the heat loss from the front cover and maximize the heat extraction from the absorber in solar air heater system. They have found their thermal efficiency more than 75% under normal operating condition.

Suppramaniam satcunanatham et.al.[14] have investigated the solar air heater with two-pass mode operation. Their studies have included avoiding the losses from the bottom and side surface of the solar air heater by adding adequate insulation material. They have measured about 10-15% of higher efficiency compared to conventional single pass flow air heater.

Based on the literature review, the designing of multipass solar air heater by using phase change materials appears to be a promising approach.

3. Solar Air Heater

Blower is used for forcing air into the air heater. A solar air heater absorbs the incident solar radiation and converts it to useful heat. It consists of flat plate collector, absorber plate, multi pass flow channel and Insulation material. Flat plate Collector is a rectangular duct in which air is supplied by a blower. It is a transparent cover system at the top and insulation at the bottom and on the sides. The whole assembly is enclosed by sheet metal frame. Flow diagram of solar air heater has been modeled by using CREO software as shown in figure 1.

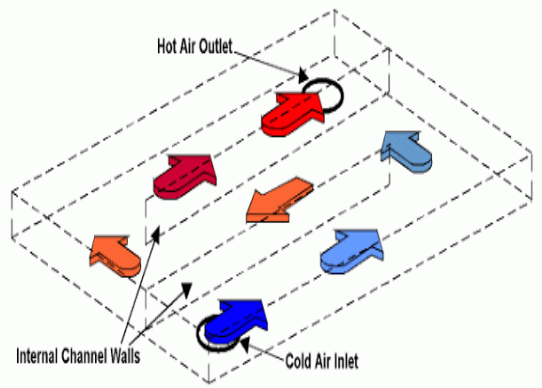

Figure 1. Flow Diagram of Solar Air Heater

In the multi pass solar air heater, cold air enters in to the duct by the blower and then be heated by multi pass absorber plate from the conductive properties of the material and the convective properties of the moving air. Multi pass absorber plate have the most surface area which enables relatively high conductive heat transfer rates, but significant pressure drop in the solar air heater. Due to this reason, fan power will be more in the solar air heater. Finally, hot air drove away from the outlet tube of air heater. Schematic diagram of solar air heater has been modeled by using solid edge modeling software as shown in figure 2.

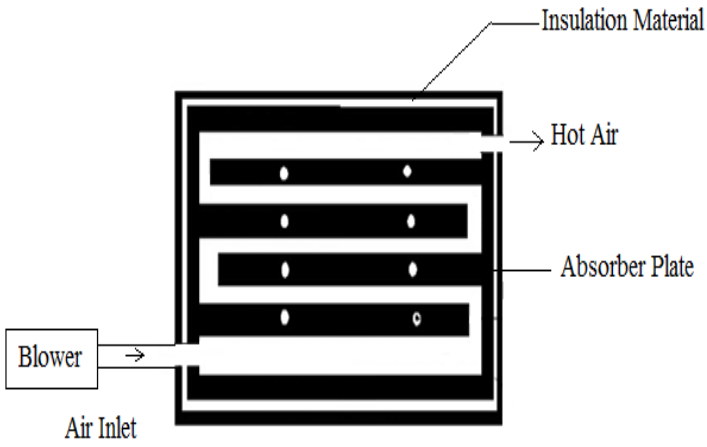

Figure 2. Schematic Diagram of Solar Air Heater

3.1 Design and Fabrication of Solar Air Heater

The air blower was switched on condition; the atmospheric air got sucked and sent into the heater through the multi pass flow channel. The heat absorbed by the collector plate from Sun radiation is transferred to the air in the multi pass flow channel of the chamber, and then the heated air moved to the next pass in the flow channel of solar air heater. If the cloud distracts the Sun radiation it did not affect the heat transfer rate as the heat absorbed by the paraffin wax in the thermal storage pipe release sufficient heat to the air. The heated air exits through the pipe in the flow channel.

The collector plate is used a flat plate collector with no reflector. The chamber is made up of wood. The chamber is in rectangular shape because it can hold more air and it is easy to construct. Wood is used for making stand due its light weight, low cost, easily machinable and easily available. The air flow chamber is insulated on the bottom and lateral sides to prevent heat loss to the surroundings. Multi pass collector plate is placed along inside the box. Glass plate is enclosed with air heater. It is made up of silica and boron trioxide.

Thermal storage is the process of storing the heat energy. Thermal storage is used to maintain same temperature of the exit air when the sunshine in not at peak. Phase change material (PCM) is one that is capable of changing its state on observing heat and liberates the heat by returning to its original state. Paraffin wax is used as a PCM in this work. When temperature reaches around 50°C the heat becomes latent and hence phase change occurs. Thus the solid paraffin changes to liquid paraffin. After this the wax remains in the molten state. When there is a fall in sunshine the temperature of the wax reduces. Thus it starts to solidify by liberating the heat to the surroundings.

Paraffin wax is stored in a multi pass flow channel tube and it has attached with the collector plate. The multipass flow channels are placed in contact with the collector plate at equal distance from each other. There are about three pass flow channel is connected with collector plate. It has blackened on the outer surface. By performing various machining processes, every parts of the air heater are fabricated based on the design and dimensions. The solar air heater assembly details have been represented is shown in table 1.

Table 1. Solar Air Heater Assembly Details

Item	Material	Geometry
Chamber	Wood	Length: 760 mm Thickness: 35 mm
Collector Plate	Aluminum	Length: 450 mm Breadth: 45 mm
Glass Plate	Silica and boron trioxide	Length: 630 mm Breadth: 400 mm
Insulation Material	Thermocol	

The outer rectangular box is welded to each other and folded at its sides. The collector plate is placed and sealed along the corners. Then the thermal storage material along with multi pass flow channel absorber plate is attached with collector plate by using proper adhesive. Finally glass is placed above the entire apparatus and sealed.

The multipass flow solar air heater was fabricated with collector plate length of 450 mm, breadth 45 mm which were based on the designated dimension of solar air heater used in this investigation. The assembled view of solar air heater with and without glass plate is shown in figures 3 and 4 whereas the fabrication of solar air heater assembly is shown in figure 5.

Figure 3. Assembled view of solar air heater with glass plate

Figure 4. Assembled view of solar air heater without glass plate

Figure 5. Fabrication of Solar Air Heater Assembly

4. Conclusion

An attempt has been made here to investigate the overview of solar air heater studies in dryer applications. Further, this work can be extended by working on the performance evaluation of multi pass flow solar air heater using experimental approach. The results so far discussed, indicate that the fabrication of multi pass flow air heater and solar air heater studies in dryer applications is very promising.

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