Journal of Energy Technologies and Policy
ISSN 2224-3232 (Paper) ISSN 2225-0573 (Online)
Vol.6, No.4, 2016

Performance Enhancement of Solar Air Heater by Increase Air Travel Distance in Solar Air Heater

Ritesh Lahori
PG, Scholar, Mechanical Engineering, RITS, Bhopal,India

Dr. Vishal Gupta
Assistant Professor, Mechanical Engineering

Mr. Arun Kumar Yadav
Assistant Professor, Mechanical Engineering

Abstract
With the increased attention the efficiency of solar heating facilities and the performance of additional equipment are becoming increasingly important. In the present study, thinking is giving on the heat transfer characteristics of solar air heater with some modifications in design to increase air travel length. Performance of solar air dryer would be checked with and without air heater. Effect of climate conditions would also be studied on its performance.
Keywords: Solar Air Heater, Air Heater, Heat transfer, Solar Collector, Solar Energy.

Introduction

The increasing demand for renewable energy in various forms has lead to search for alternative energy resources. The renewable energy resources accepted prominent thought in present-day. Solar energy which is usable for free of cost and inexhaustible source of energy and none polluting sources of energy. The simple and efficient form of utilizing solar energy is to convert it into thermal energy for heating application by using solar air heater. Solar air heater is mostly flat plate collector used for producing hot air for applications such as crop drying, industrial heating, space heating, timber seasoning etc. The disadvantages of conventional solar air heaters are heat loss to the close and poor heat convection. [1] A suitable and effective method of increasing thermal efficiency and performance of conventional solar air heaters is by applying roughness in the form of ribs on the underneath of absorber. The heat transfer enhancement on ribs in rectangular and square duct for applications in turbine blades and compact heat exchanger. Ribs enhance heat transfer by restraining viscous and thermal boundary layer on the heat transferring surface. But channel roughness with ribs cause higher pumping power. Both enhanced heat transfer and pumping power must be studied for selecting a rib roughness for channel. [2] Solar energy has been wide utilized in a several application with the approaching of the energy crisis. Solar Collector is designed to collect heat by absorbing solar energy. They may be mainly divided into three types: evacuated tube collector, flat-plate collector, and concentrating collector. Both the exhausted tube collector and also the flat-plate collector are typically formed to collect heat for low temperature applications. The market for solar evacuated tube water collectors has been increased due to the development of low-cost technology for producing an all-glass evacuated tube absorber.[3] The development of sustainable solar energy for heating application the supply of heating air using solar air collectors causes a great problem at the absence of solar radiation. The thermal energy storage has efficient role in overcoming the repeated and diffused nature of the solar energy. Energy storage method can eliminate the inequality between energy supply and energy demand. Among the most important ideas for the storage of solar energy is the bleeding of latent heat of fusion by using phase change materials (PCM). [4] Solar energy is environment friendly and inexhaustible source of energy available most of the places. It can be strapped for thermal applications. The time dependent nature of solar energy is a major drawback. The application purpose, like drying and heating, will be performed throughout the day time solely. In order to eliminate this, it is required to connect thermal energy storage devices with solar gadgets. The stored energy can be utilized during non-sunny hours. The packed bed solar air heater in order to store thermal energy of hot air.[5] Solar air heaters (SAHs) have been mostly used for energy conservation in an increasing number of installations. They are very enticing for inferior energy applications that need air temperatures less than 100 ºC. Examples include space heating, dehydration of industrial field, and drying of agricultural crops such as grains, vegetables, fruits etc. The conversion of solar radiation to thermal energy is poor in SAHs because of the low heat transfer coefficient between the absorber plate and the air flowing through the channel. [6] Depending on the absorber plate, the collector is classified as transpired or untranspired collector. The unglazed transpired solar collector (UTC). UTCs made of dark colored perforated absorber sheets which are attached to a building's south facing wall to preheat ventilation air. Air is drawn through the solar heated perforated absorber plate into the building by a fan. UTC has no glazing thus, its structure is simple and it costs less compared to glazed collectors There is no reflection or absorption due to glazing as there is no glass or

plastic cover in the UTCs.[7] Solar energy has been used widely in a many of applications. Solar collector is constructed to absorb solar radiation and converts it into heat. In the past years, flat-plate solar air heater used to hold a leading position in the air heater field because of its characteristics differing from conventional solar air heater. In this kind of air heaters, the solar energy is converted into internal energy. Then the energy is utilized to heat the passing air through a duct system located between the bottom and the absorbing plate. The heated air is used for space heating and drying. [8]

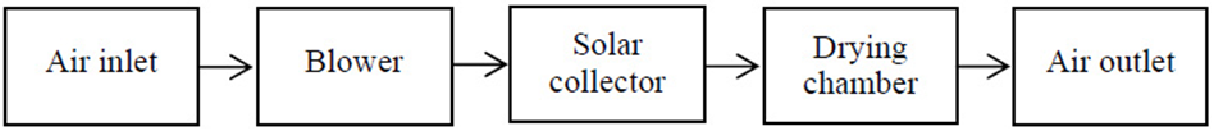
Air Heater

Air heaters are devices used to heat cold air by passing through the heater. They include forced air products as well as all types of radiant and space heaters. Forced air products steady and control air temperature by circulating air through a heat source with a fan or blower. As the cold air flows through the heater it absorbs thermal energy and then out the heater at an inflated temperature. Radiant heaters operate by radiating heat from a point source, heating the objects near that point source. The temperature prong causes a free flowing convection cycle to form, which in turn heats the surrounding air. Space heaters are self-contained devices that can operate by either of the preceding methods. [9]

Solar air heater

Solar air heater is a solar thermal system in which the energy from the solar energy is absorbed by an absorbing medium and used to heat cold air. Solar air heater is a renewable energy heating method used to heat the cold air for buildings and process heat applications.

It is the most cost-effective out of all the solar technologies, mainly in commercial and industrial applications, and it is a largest usage of building energy in heating climates, which is space heating and industrial process heating. [10]



Block diagram of solar air heater and dryer assembly

Type of Solar Air Heater

1. Air heaters with non-porous absorber plate and
2. Air heaters with porous absorber plate

1.2.1. Air heaters with non-porous absorber plate –

Air heaters with non-porous absorber plate the air stream does not flow through the absorber plate. The air may flow above or beneath the absorber plate. The air that blows above the absorber surface increased the convection loss from the cover plate and so it is avoided. Selective coating can be applied to improve collector efficiency. Air heaters with non-porous absorber plate can be classified are as follows-

1. Conventional air heater
2. Air heaters with fins
3. Vee corrugated air heater
4. Double exposure heaters
5. Double flow solar air heater
6. Two pass solar air heater

1.2.2. Air heaters with porous absorber-

The disadvantage of the non porous absorber is the essential of absorbing all incoming solar radiation over the proposed area through a thin layer over the absorber's plate. If some selective coatings are used then radiative losses from the absorber can be minimized and unless the collection efficiency remains poor. The change in pressure along the duct formed between the absorber plate and the rear insulation may also be prohibitive, mainly in the case of added fins to increase the heat transfer area and turbulence rate. The porous absorber solar air heater can be classified are as follows-

1. Packed bed solar air heater
2. Overlapped glass plate air heater
3. Matrix air heater
4. Honeycomb porous bed air heater
5. All plastic solar air heaters. [11]

Advantages & Disadvantages

- *Advantages of Solar Air Heater:-*

1. The use to transfer heat from working fluids to another fluid is excluded as air is being used directly as the working material. The system is small and less complicated.

2. The corrosion is a major problem in solar water heater and this problem is not in solar air heaters.
3. The leakage of air from the solar air heater does not create any problem.
4. The freezing of working fluid does not occur.
5. The pressure inside the solar air heater does not become very high.
6. Thus air heater can be constructed using cheaper as well as lesser amount of material and it is simple to use than the solar water heaters.

- *Disadvantages of Solar Air Heater:-*

1. Air heaters have some disadvantages the poor heat transfer properties of air. Some technique is required to increase the heat transfer.
2. Another drawback is the need for handling large volume of air due to its low density.
3. Air could not be used as a storage fluid because of its low thermal capacity.
4. In the absence of proper construction the cost of solar air heaters can be very high.

Application of Solar Air Heater

Solar air heaters were not used now because it was cheaper to produce that heat with fossil fuels. We succeeded to construct and manufacture the solar air heaters that produce heat minimum times less expensive than fossil fuel heat, and this reason opened the doors of industry and agriculture for solar energy. As solar energy can now be used in such large applications.

Solar air heater produce can be used for:-

I. Use in industrial field:-

a. Air pre-heating for combustion processes, that means number of applications
b. Drying minerals, paper, coal, food industry products, bricks, etc. the drying of brown coal would be very important for power plants.
c. Space heating for warehouses, factories for process application etc.

II. Use in Agricultural field:-

a. Crop drying: fruits, grains, vegetables, etc. Important gained by harvesting the crop drying it with solar heat to protect it from mildew, rodents, etc. and to free the land for a second, brief crop.
b. Space heating for greenhouses, warehouses and animal farms etc.
c. Fruit and other produce dryers.

III. Use in Household purposes:-

1. space heating
2. small driers

IV. Use in commercial purposes:-

1. Space heating for public space, office buildings, shopping malls.

V. Use in camping purposes:-

1. space heating for relief camps or military camps
2. space heating for camping and expeditions in cold climate

Literature Survey

1. A. K. Srivastava, et. al. (2014), In this paper illustrated the feasibility of utilizing lauric acid as a phase change material (PCM) to store excess solar energy and release it when the is not available for solar drying process. With the increased attention on the efficiency of solar heating and drying facilities, the performance of additional equipment is becoming increasingly important. In this paper focused on the heat transfer characteristics of the PCM during the charge and discharge times. The effects of inlet hot air temperature and inlet air velocities on the charge time were calculated, while during the discharge time only the effect of inlet ambient air velocity was taken. [12]

2. Pin-Yang Wang, et.al, (2013), in this paper illustrated experiment and clone are conducted on a new-type all-glass evacuated tubular solar air heater with simplified compound parabolic concentrator (CPC). The system is made up of 10 linked collecting panels and each panel contains a simplified CPC and an all-glass discharge tube with a U-shaped copper tube heat exchanger installed inside. Air is heated when passing through each U-shaped copper tube. The heat transfer model of the solar air heater is recognized and the outlet air temperature, the heat power and heat efficiency are determined. [13]

3. Ravi Kant Ravi, et. al. (2015),It illustrated the performance of a conventional solar air heater can be improved by reducing the losses from the collector surface by providing the providing insulation and increasing the convective coefficient between heat collecting surface and working fluid by increasing the heat transfer area

which can be increased by double pass design. Various experimental and theoretical inspection have been considered to improve the performance of double pass solar air heaters provided with performance enhancement method. Using packed bed materials extended surfaces and corrugated /grooved absorbing surfaces. [14]

4. Kishore Kulkarni, et. al. (2015), a multi-objective optimization of a solar air heater with obstacles on an absorber plate is performed for maximum heat transfer and minimum pressure loss. In this paper, shape optimization is carried out in conjunction with 3-D Reynolds-averaged Navier–Stokes analysis and two basic surrogate models: the response surface approximation and the Kriging models. Three geometric variables were used as design variables for the optimization. The average Nusselt number and friction factor were used to define the two objective functions. The Latin hypercube sampling technique was used to select the design points in the design space. A hybrid multi-objective genetic algorithm coupled with the surrogate model was used to determine the Pareto-optimal solutions. The ideal Pareto-optimal solutions were selected to study the deal with between the two objectives. [15]

5**.** Ping Yang Wang (2015), et. al (2015), This paper illustrated a set of evacuated tube solar high temperature air heaters with simplified CPC (compound parabolic concentrator) and concentric tube heat exchanger is constructed to provide flow air with a temperature of 150 – 230 ºC for industrial production. The solar air heater system made of 30 linked collecting units. Each unit includes a simplified CPC and an all-glass evacuated tube absorber with a concentric copper tube heat exchanger connected inside. A stainless steel mesh layer with high thermal conductivity is filled between the evacuated tube and the concentric copper tube. Air passes through each collecting unit, and its temperature increases progressively. The empirical results established the given high temperature solar air heater have good collecting performance. [16]

6. Panna Lal Singh, et. al. (2015), The thermal performance of the packed bed solar heat storage system was considered under varying solar and ambient conditions. The insulated packed bed heat storage unit was filled with rock pebbles. The solar collection and heat cure efficiency of heat storage system is obtained. Heat improvement efficiency of the developed packed bed was found better as compared to the packed bed filled with phase change material. [17]

7. A.E. Kabeel, et. al. (2016), it researched inspection of flat and v-corrugated plate solar air heaters with built-in PCM as thermal energy storage material. The incorporated solar air heater with paraffin wax as PCM was constructed and checked under existing weather conditions. The parameters affecting the thermal performance of the flat and v-corrugated plate solar air heater were presented with and without PCM. [18]

8. Dongxu jin, et. al. (2015), studied on heat transfer and fluid flow in a solar air heater duct with multi V-shaped ribs on the absorber plate 3-D simulations are conducted using the ANSYS FLUENT code and the Renormalization-group key turbulence model. The computation are performed for dissimilar rib geometries with a varying span wise V-rib number, relative rib pitch, relative rib height, and angle of attack, and for different Reynolds numbers. The effects of the rib geometrical parameters on the Nusselt number, friction factor, and flow structure are obtained and analyzed. [19]

9. Adem Acir, et. al. (2015), In this paper, the heat transfer, friction factor and thermal performance factor uniqueness of a novel solar air heaters (SAHs) with circular type turbulators having different relief angles and distances were performed. Effect of the pitch ratio (PR) and angle ratio (AR) were investigated to improve in heat transfer in SAHs. [20]

10. Roozbeh Vaziri, et. al. (2015), This paper illustrated, the thermal performances of perforated glazed solar air heaters (PGSAHs) having different inner collector colors and a black colored unglazed transpired solar air heater (UTSAH) were inspected experimentally. Two PGSAHs having perforated Plexiglas glazing and different inside bottom colors were designed. The third solar air heater was a UTSAH where the upper cover was black colored perforated sheet metal. No absorber plates were used in PGSAHs, where perforated metal cover is the absorber plate in the UTSAH. [21]

11. Mahdi Hedayatizadeh, et.al. (2015), the main objective of the current study is to perform an in-deep exegetic analysis of a double pass/ glazed v-corrugated plate solar air heater on exergy loss terms., the detailed thermal modeling of the given air heater is carried out. Through an exergy analysis performed with view to internal/external exergy losses, the exegetic efficiency is optimized allowing for four independent variables of distance between the two adjacent glazing, height of v-corrugations, area of the heater and the total mass flow rate. [22]

12. M. Bovand, et.al. (2015), the main objective of this paper was effects of porous material on the heat transfer enhancement and pressure drop. The attention is giving on the effects of many parameters on the combined convection–radiation heat transfer and flow channel. Volume averaged equations are applied to suggest the transport phenomena within the porous substrate. Moreover, the regular continuity, momentum, and energy equations are used in the fluid region. [22]

13. Milad Tajik Jamal-Abad, et.al. (2016), worked on convection radiation heat transfer in solar air-heater filled with a porous medium is evaluated. The effects of porous medium shape parameter and radiation parameter on the collector efficiency are discussed. Estimated analytical solutions for the dimensionless velocity, temperature,

and Nusselt number are obtained using perturbation method. [23]
14. Prashant Verma, et. al. (2015), studied on results of a wire screen matrix packed solar air heater based on a mathematical model developed to investigate the effect of various system and operating elements on the thermo-hydraulic performance. Evaluation of efficiency solving the governing equations numerically using relevant correlations for heat transfer coefficient for packed bed systems. [24]
15. Kasra Mohammadi, et. al. (2014), studied on enhancing thermal performance of an upward type single pass solar air heater by utilize fins and baffles over the absorber plate as well as applying external recycle device under various parametric situation. The energy and useful efficiencies analysis is used to evaluate the performance. The study is carried out for three cases: simple absorber plate, absorber plate with fins and absorber plate with fins and baffles. [25]

Research Scope

1. To modify a solar air heater for convert cold air into hot air.
2. To evaluate the performance of solar air heater using solar collector, blower in pipe, solar dryer.
3. Performance of Solar Air Dryer would be checked with and without air heater. Effect of climate conditions would also be studied on its performance.
4. In the present study, attention is giving on the heat transfer characteristics of solar air heater with some modifications in design to increase air travel length.

Conclusion

The current study exposed that the disadvantages can reduce to a certain extent by using solar air heaters. The research interest in solar air heaters arises due to its high volumetric heat transfer coefficient mostly because of turmoil in the air flow induced in the air flow channel consideration is giving on the heat transfer features of solar air heater with some modifications in design to increase air travel length. And also performance of Solar Air Dryer would be checked with and without air heater. Effect of climate conditions would also be studied on its performance.

References

1. Rajarajeswari, K., and A. Sreekumar. "Matrix solar air heaters–A review." Renewable and Sustainable Energy Reviews 57 (2016): 704-712.
2. Singh, Sukhmeet, Subhash Chander, and J. S. Saini. "Thermo-hydraulic performance due to relative roughness pitch in V-down rib with gap in solar air heater duct—Comparison with similar rib roughness geometries." Renewable and Sustainable Energy Reviews 43 (2015): 1159-1166.
3. Wang, Ping-Yang, Shuang-Fei Li, and Zhen-Hua Liu. "Collecting performance of an evacuated tubular solar high-temperature air heater with concentric tube heat exchanger." Energy Conversion and Management 106 (2015): 1166-1173.
4. Kabeel, A. E., et al. "Experimental investigation of thermal performance of flat and v-corrugated plate solar air heaters with and without PCM as thermal energy storage." Energy Conversion and Management 113 (2016): 264-272.
5. Singh, Panna Lal, S. D. Deshpandey, and P. C. Jena. "Thermal performance of packed bed heat storage system for solar air heaters." Energy for Sustainable Development 29 (2015): 112-117
6. Kulkarni, Kishor, Arshad Afzal, and Kwang-Yong Kim. "Multi-objective optimization of solar air heater with obstacles on absorber plate." Solar Energy 114 (2015): 364-377.
7. Vaziri, Roozbeh, M. Ilkan, and F. Egelioglu. "Experimental performance of perforated glazed solar air heaters and unglazed transpired solar air heater." Solar Energy 119 (2015): 251-260.
8. Wang, Pin-Yang, et al. "High temperature collecting performance of a new all-glass evacuated tubular solar air heater with U-shaped tube heat exchanger." Energy Conversion and Management 77 (2014): 315-323.
9. Air Heater- Wikipedia, 28 January 2016, http://www.globalspec.com/learnmore/manufacturing_process_equipment/industrial_heaters_heating_elements/air_heaters (accessed January 2016)
10. Solar Air Heater - Wikipedia, 8 February 2016, https://en.wikipedia.org/wiki/Solar_air_heat (accessed 8 February 2016).
11. Saxena, Abhishek, and A. A. El-Sebaii. "A thermodynamic review of solar air heaters." Renewable and Sustainable Energy Reviews 43 (2015): 863-890.
12. Srivastava, A. K., S. K. Shukla, and Sandeep Mishra. "Evaluation of Solar Dryer/Air Heater Performance and the Accuracy of the Result." Energy Procedia 57 (2014): 2360-2369.
13. Wang, Pin-Yang, et al. "High temperature collecting performance of a new all-glass evacuated tubular solar air heater with U-shaped tube heat exchanger." Energy Conversion and Management 77 (2014): 315-323.
14. Ravi, Ravi Kant, and Rajeshwer Prasad Saini. "A review on different techniques used for performance

enhancement of double pass solar air heaters." Renewable and Sustainable Energy Reviews 56 (2016): 941-952.
15. Kulkarni, Kishor, Arshad Afzal, and Kwang-Yong Kim. "Multi-objective optimization of solar air heater with obstacles on absorber plate." Solar Energy 114 (2015): 364-377.
16. Wang, Ping-Yang, Shuang-Fei Li, and Zhen-Hua Liu. "Collecting performance of an evacuated tubular solar high-temperature air heater with concentric tube heat exchanger." Energy Conversion and Management 106 (2015): 1166-1173.
17. Singh, Panna Lal, S. D. Deshpandey, and P. C. Jena. "Thermal performance of packed bed heat storage system for solar air heaters." *Energy for Sustainable Development* 29 (2015): 112-117.
18. Kabeel, A. E., et al. "Experimental investigation of thermal performance of flat and v-corrugated plate solar air heaters with and without PCM as thermal energy storage." Energy Conversion and Management 113 (2016): 264-272.
19. Jin, Dongxu, et al. "Numerical investigation of heat transfer and fluid flow in a solar air heater duct with multi V-shaped ribs on the absorber plate." Energy 89 (2015): 178-190.
20. Acır, Adem, and İsmail Ata. "A study of heat transfer enhancement in a new solar air heater having circular type turbulators." Journal of the Energy Institute (2015).
21. Vaziri, Roozbeh, M. Ilkan, and F. Egelioglu. "Experimental performance of perforated glazed solar air heaters and unglazed transpired solar air heater." Solar Energy 119 (2015): 251-260.
22. Hedayatizadeh, Mahdi, et al. "Exergy loss-based efficiency optimization of a double-pass/glazed v-corrugated plate solar air heater." *Energy* 94 (2016): 799-810.
23. Rashidi, Saman, M. Bovand, and J. A. Esfahani. "Heat transfer enhancement and pressure drop penalty in porous solar heat exchangers: A sensitivity analysis." *Energy Conversion and Management* 103 (2015): 726-738.
24. Verma, Prashant, and L. Varshney. "Parametric investigation on thermo-hydraulic performance of wire screen matrix packed solar air heater." *Sustainable Energy Technologies and Assessments* 10 (2015): 40-52.
25. Mohammadi, Kasra, and Majid Sabzpooshani. "Appraising the performance of a baffled solar air heater with external recycle." Energy Conversion and Management 88 (2014): 239-250.