International Journal of Thermal Technologies
E-ISSN 2277 – 4114

Available at http://inpressco.com/category/ijtt/

Research Article

Performance Analysis of Solar Air Heater using CFD Simulation

Ambreesh Prasad Shukla†*, Rakesh Kushwaha†, Bhupendra Gupta† and Anand Bisen‡

†Department of Mechanical Engineering, Jabalpur Engineering College, Jabalpur-482011, India
‡Mechanical Engineering, KNPC, Jabalpur, India

Received 02 Jan 2018, Accepted 05 March 2018, Available online 10 March 2018, **Vol.8, No.1 (March 2018)**

Abstract

Solar energy has emerged as one of the alternate to conventional sources of energy. Solar air heaters are one of the important devices to utilize solar energy. But, poor heat transfer coefficient is one of the major problem in solar air heater. In this research article, an attempt is made to increase heat transfer coefficient of solar air heater by putting Hollow bodies over the absorber plate. These resulted in increase in heat transfer coefficient, efficiency and increase in outlet temperature of air simultaneously.

Keywords: *Solar Air Heater, Heat Transfer Coefficient, Efficiency, CFD Simulation.*

1. Introduction

The sun is a huge source of energy. Every day the sun radiates an enormous amount of energy called solar energy. Major application of solar energy include solar water and air heating, solar drying of agricultural products, salt production by evaporation of sea water, solar distillation on a community scale, solar cookers, solar engines for water pumping, food refrigeration, photo-voltaic conversion, solar furnace, heating and cooling of buildings, solar thermal power generation, high temperature application for industrial process heating etc. It can be generally classified as thermal and electrical applications.

(i) Electrical utilization

Devices used in photovoltaic conversion is called solar cell. When solar radiation falls on this semiconductor device, it is directly converted into DC electricity. Two important steps are involved in the principle of working of a solar cell. These are (1) Creation of pairs of positive and negative charges (called election-hole pairs) in the solar cell by absorbed solar radiation. (2) Separation of the positive and negative charges by a potential gradient within the cell. For the first step to occur, the cell must be made of a material which can absorb the energy associated with the photons of sunlight.

(ii) Direct thermal utilization

This is the most popular utilization of solar energy. In this, usually there is a collection device, which is directly exposed to the solar radiation. This can be an absorbing type or concentrating type. In the former case, there is a dark surface exposed to sun, which absorbs radiation. This absorbed energy is then transferred to a working fluid, which is in contact with the absorber.

Flat-plate collectors are used for direct thermal utilization of solar energy. It has an absorber plate over which solar energy falls and after passing through one or more glass covers absorbed energy is partly transferred to a liquid, flowing through tubes, which are either fixed to the absorber plate or forms an integral part of it. This energy transfer is the useful gain.

Solar Air Heater: Compared to other solar collectors, solar air heaters (SAH) have some distinct advantages. The mode of heat transfer from the absorber plate and the working fluid is the main difference between liquid flat plate collectors and air heaters. The air heaters eliminate the need to transfer heat from the working fluid to another working fluid.
Air is being directly used as the working substance, the system is less complicated and is compact. The corrosion problem, which can become serious in solar water heater, is completely eliminated in solar air heaters. Hence light gauge steel or aluminium plates can easily be used. Hence, a solar air heater appears to be inherently cheaper and can last longer.

Components of Solar Air Heaters

(i)Absorber Plate: The material of absorber plate should have good thermal conductivity, sufficient tensile and compressive strength and should be corrosion resistance. Copper is generally preferred

*Corresponding author: **Ambreesh Prasad Shukla**
DOI: https://doi.org/10.14741/ijtt/v.8.1.2

because of its extremely high conductivity and resistance to corrosion. Collectors are also constructed with materials like aluminium, steel, Galvanized Iron (GI) sheets and various thermoplastics and metal ions.

(ii) Cover Plate: Cover plate or plates through which the solar energy must be transmitted is also extremely important part of solar air heater. Purposes of cover plates are,

(a) To transmit maximum amount of solar radiation possible to the absorber plate.

(b) To minimize the loss from the absorber plate to the environment.

(c) To shield the absorber plate from direct exposure to weathering.

(iii) Insulation: Insulations are provided to reduce heat loss from the absorber plate due to conduction or convection. Generally used insulating materials are glass wool or rock wool. Absorber plate should be insulated beneath and or in the side, depending on the type of design used. Important requirement of an insulator is that it should be heat resistant.

2. Literature Review

Vipin B Gawande, A.S. Dhoble have performed experimently and CFD investigation of heat transfer in solar air heater with L-shaped ribs (Vipin B. Gawande *et al,* 2016). Guang ping Cheng, Lixi Zhang has performed Numerical simulation of solar air heater with V groove absorber used in HD desalination. Alsanossi M. Aboghrar, B.T.H.T. Baharudin experimentally investigates outlet temperature and efficiency of Solar Air heater (SAH). Raed Abed Mahdiab, H. A. Mohammed, K. M. Munisamya Experimentally and Numerically Investigated the Combined Convection Heat Transfer and Fluid Flow around Circular Cylinder through Rectangular and Trapezoidal Open-Cell Aluminum Foams. Dr. Bhupendra Gupta, Jitendra Kumar Waiker, Gopal Prasad Manikpuri, Brahman Singh Bhalavi experimentally study to investigate the effect of mass flow of Air on thermal performance and pressure drop through the collector. V. Tyagi, A. K. Pandey, S. C. Kaushik, S. K. Tyagi experimentally studies performance of a solar air heater with and without phase change material (PCM). D.V.N. Lakshmi, Apurba Layek, P. Muthu Kumar planned to investigate the energy and exergy of solar air heater by placing trapezoidal corrugated absorber. Suman Saurav, M. M. Sahu have been carried out an experiment to improve heat transfer and thermal efficiency of solar air heater by providing artificial roughness. Chii-Dong Ho, Hsuan Chang, Chun-Sheng Lin, Chun-Chieh Chao and Yi-En Tien have been study on performance of a solar air heater with recycling as well as wire mesh packed. Rajendra Karwa and Kalpana Chauhan have been study on performance evaluation of solar air heaters having v-down discrete rib-roughness on the absorber plate.

To increase the efficiency of solar air heater, and also the outlet temperature of air at the same time, we have to increase the heat transfer from absorber plate to air. We know that from the newton's law of cooling (applied to convective heat transfer) the heat transfer between the fluid and solid plate can be increased by either increasing heat transfer coefficient, or by increasing the heat transfer area. From above discussion we can say that in order to increase the heat transfer between the absorber plate and air, we can do it by producing turbulence, and can also be done by increasing the area of absorber plate. But we cannot increase the turbulence beyond certain limit because excessive turbulence results in huge pressure drop. At the same time we cannot increase the area of absorber plate beyond certain limit because increase in absorber plate area also results increase in pressure drop.

In this research paper we had performed a CFD simulation of solar air heater having rectangular bodies inside using ANSYS 16.0 software. Solar air heater without bodies i.e. simple solar air heater is considered as Case-A and Solar air heater with rectangular hollow bodies is considered as Case-B. The parameter used for CFD simulation and results obtained from simulation are discussed in next section of this paper.

3. CFD Simulation

In order to simulate solar air heater with bodies and compare their results with simple solar air heater, two 3 dimensional fluid domain were created using ANSYS DESIGN MODELER. After this they were meshed using ANSYS MESHING software. ANSYS FLUENT were used to solve these fluid domains with defined boundary conditions. Results obtained from these simulations were discussed in subsequent section of this paper.

4. Results & Discussions

Figure 1(a) & 1(b) shows the variation of Temperature of Absorber Plate at different points (T1, T2, T3, and T4) along with Inlet and Outlet Temperature of Air with respect to heat input. Maximum temperature of absorber plate for Case-A is 395°K and for Case-B is 402.7°K.

Figures 2(a) & 2(b) show the variation of temperature raise for Case-A and Case-B with change in heat input. Maximum temperature raise for Case-A is 22.58°C and for Case-B is 32.11°C at heat input of 450 watts.

Figure 3shows the comparative variation of temperature raise for Case-A and Case-B with respect to heat gain. Increase in temperature raise for Case-B with respect to Case-A is 9.53°C.

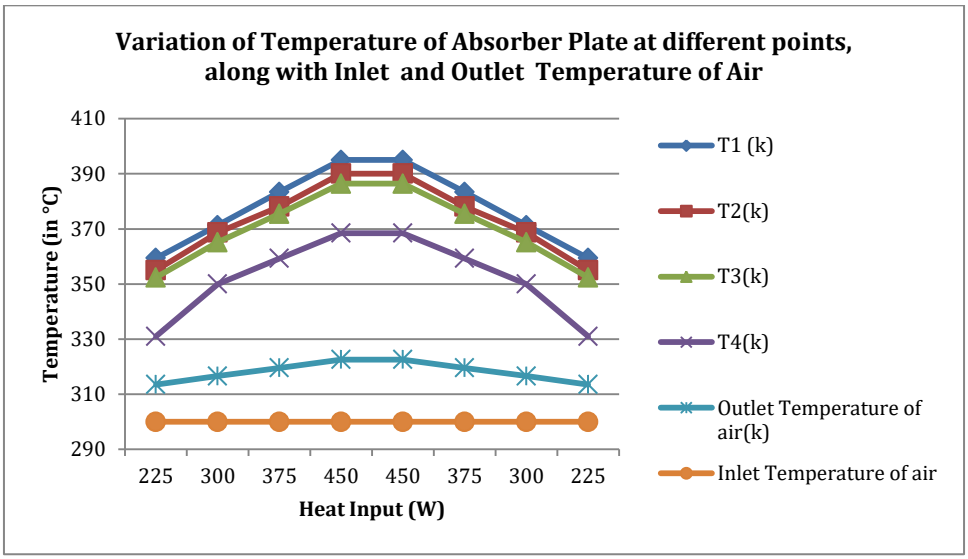

Fig. 1 (a) Case-A

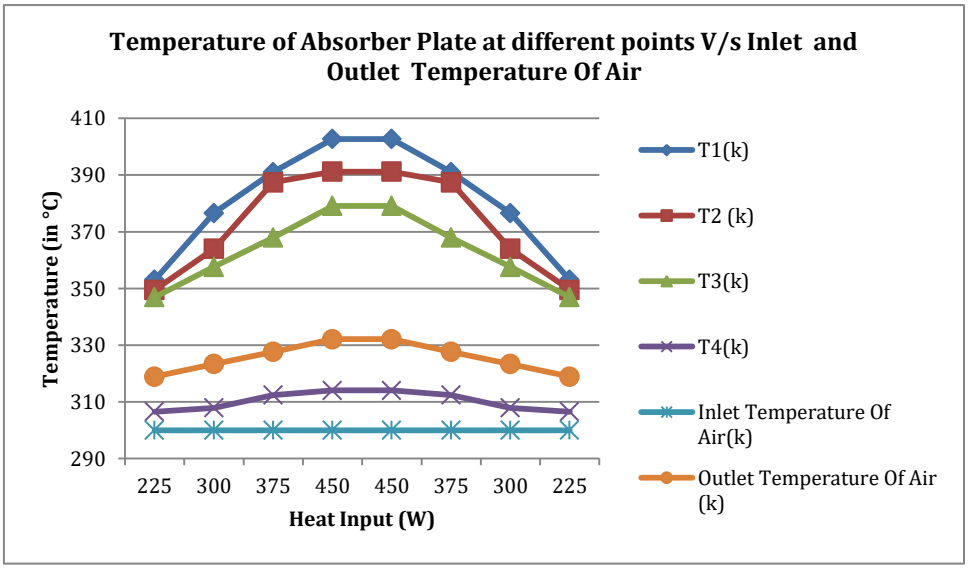

Fig. 1 (b) Case-B

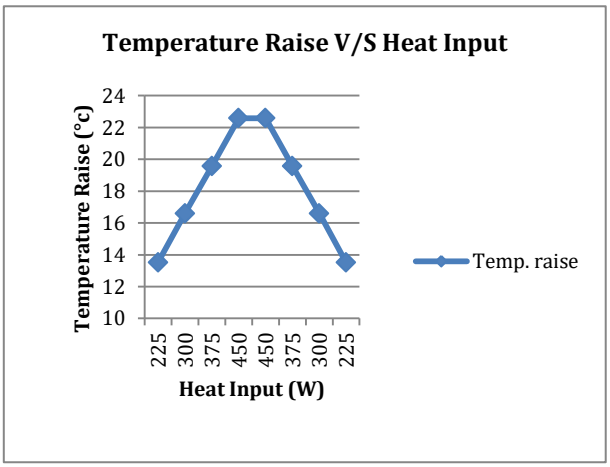

Fig. 2 (a) Case-A

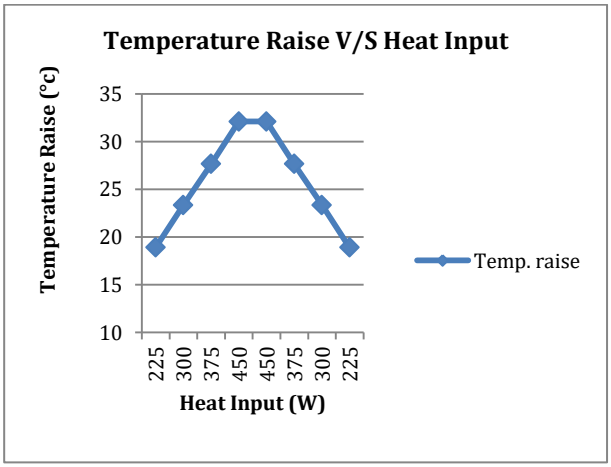

Fig. 2 (b) Case-B

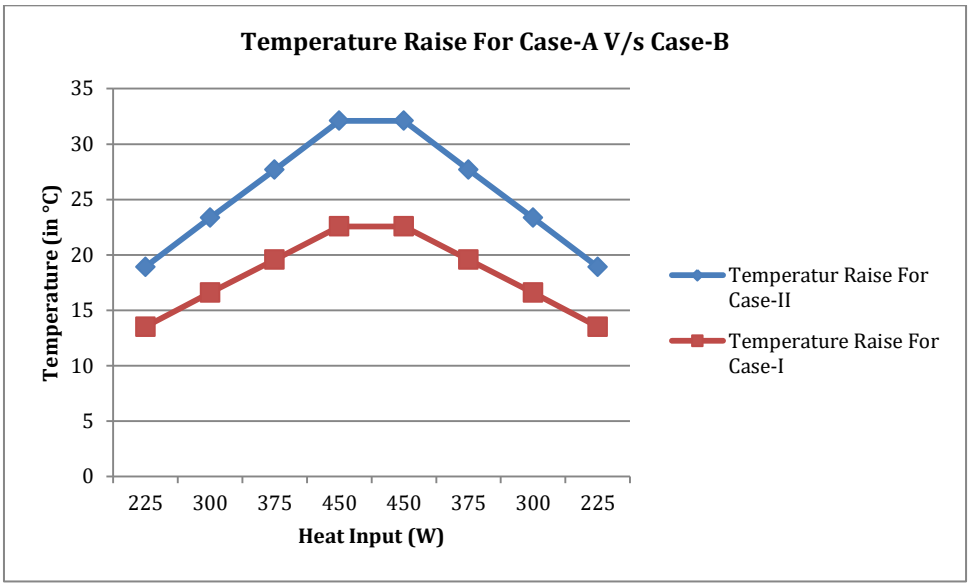

Fig.3 Comparison of heat input Vs temperature raise

Conclusions

1) Temperature at outlet for Case-B is 332.11°k while for case-A is 322.58°k.
2) Temperature raise for Case-B is 32.11°C and for Case-A is 22.58°C.
3) The reason for such increment in outlet temperature of air and also in temperature raise is presence of hollow bodies.
4) Due to presence of such rectangular hollow bodies heat transfer area is increased.
5) Along with increased in area of heat transfer due to presence of the bodies turbulence is also increased. Due to turbulence, laminar sub layer which formed adjacent to absorber plate is dissolved. This results in increased in heat transfer coefficient.
6) Thus we can conclude that it is advantageous to put rectangular hollow bodies inside the solar air heater

References

Vipin B. Gawande, A.S. Dhoble, D.B. Zodpe, Sunil Chamoli,(2016), Experimental and CFD investigation of convection heat transfer in solar air heater with reverse L-shaped ribs, Solar Energy, 131,275–295.

Guang ping Cheng, Lixi Zhang, (2011), Numerical simulation of solar air heater with V-groove absorber used in HD desalination, Desalination Publications, 28,239-246.

Alsanossi M. Aboghrara, B.T.H.T. Baharudin,(2017), Performance analysis of solar air heater with jet impingement on corrugated absorber plate, Case studies in thermal engineering,10,111-120.

Raed Abed Mahdia, H. A. Mohammed, K. M. Munisamy, (2013), Improvement of convection heat transfer by using porous media and nano-fluid, IJSR,2,34-47.

Dr. Bhupendra Gupta, Jitendra Kumar Waiker, Gopal Prasad Manikpuri, Brahman Singh Bhalavi, (2013), Experimental analysis of single and double pass smooth plate solar air collector with and without porous media, AJER, 02,144-149.

V. Tyagi ,A. K. Pandey , S. C. Kaushik , S. K. Tyagi, (2012), Thermal performance analysis of a solar air heater with and without phase change material (PCM),Journal of Thermal Analysis and Calorimetry,107,1345-1352.

D.V.N. Lakshmi , Apurba Layek, P. Muthu Kumar,(2017), Performance analysis of energy and exergy of solar air heater by placing trapezoidal corrugated absorber, Energy procedia,109, 463-470.

Suman Saurav, M. M. Sahu, (2013), Heat transfer and thermal efficiency of solar air heater having artificial roughness, IJRSE, 2, 99-109.

Chii-Dong Ho, Hsuan Chang, Chun-Sheng Lin, Chun-Chieh Chao and Yi-En Tien, (2015), Performance analysis of a solar air heater with recycling as well as wire mesh packed, Energy procedia, 75,403-409.

Rajendra Karwa and Kalpana Chauhan, (2010), Performance evaluation of solar air heaters having v-down discrete rib-roughness on the absorber plate, Energy, 35,398-409.