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Performance enhancement of double pass solar air heater with metallic wiry sponge insert by DOE

[1]Vimal Prajapati, [2]Umang Soni, [3]Mandhata Yadav

[1]ME Thermal student, Mechanical department, Spit, basana,
[2]Assistant Professor, Mechanical department, GEC, patan,
[3]Assistant professor, mechanical department, SPIT, Piludara,

Abstract: *this research study is performing to enhance the performance of the double pass solar air heater. DOE method full factorial array L9 is designed for this and performs the observation for two factors at 3 levels. 15, 18 and 21 number metallic wiry sponges inserted into the double pass solar air heater and 10mm, 20mm, 30mm of H2O pressure difference at inlet is designed. The maximum efficiency 88% of the double pass solar air heater is observed with 10mm pressure difference at orifice and 21 numbers of metallic wiry sponges inserted. The efficiency enhancement is higher because of it gives a huge heat transfer area and high thermal conductivity of S.S.*

INTRODUCTION

Energy crisis and global warming was lead to find an alternative way to overcome the above worsening situation. Renewable energy plays a major solution and thereby 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. To harness the solar energy, Collectors are used and for low temperature application side flat plate collectors are used. In solar air heater, solar energyis collected by means of an absorbing plate and the collected heat energy is transferred to heat transferring medium such as air.

1. **Collector-** A typical solar air heater heating collector is made up of wood, galvanized iron sheet, or concrete. Inner surface is blackened coating to absorb the maximum solar radiation during the day period. Inclination is provided to receive maximum solar radiation, this collector put at northern facing to collect the maximum solar radiation.

2. **Glass cover** – Glass is put on the for allowing the maximum solar radiation inside the solar air collector, to minimize convective heat loss from absorber plate.

3. **Absorber plate –** Main element of solar air heater. And absorb the maximum possible amount of solar radiation.

4. **Insulation** –Outer side walls is insulated with different insulation materials such as puff, thermocol wood, fiber glass wool, etc. to reduce heat transfer by conduction.

Basic Types of Solar Air Heaters:

The solar air heater is basically divided in two types as following:

a. **Passive type solar air heater:**

In this type of solar air heater is simple in manufacturing and easy to maintenance. Side walls of these are made up of galvanized iron sheet, wooden sheet, or concrete. Inner surface of walls are blackened coating, absorber plate with black painted put inside the box to absorb the maximum solar radiation and for batter heat transfer to the fluid. Inclination is provided to receive a maximum solar radiation during a day period. Glass cover is provided to make it air tight basin and transparent top layer to allowing the solar energy inside the box and reducing the heat losses. Also insulation is provided around the periphery of the side wall to reduce the heat loss from the side walls.

b. **Active solar radiation:**

In this type of solar air heater external power sources are provided for forced convection or to heat the air. These types of solar air heaters are consume an electricity or external power.

Design of experiment

The aim in general:

to extract as much as possible information from a limited set of experimental study or computer simulations. It is used to maximize the information content of the measurements / simulations in the context of their utilization for estimating the model parameters and selection of the points where response should be evaluated.

Method applied for model design with:

- Experimental data
- Simulation data

Method applied for model fitting

- Objective functions
- Constraint functions

DOE allows the simultaneous investigation of the effect of a set of variables on a response in a cost effective manner. DOE is superior to the traditional one variable at a time method, which fails to consider possible interaction between the factors.

Problem definition:

There are lots of work has been already done to improve the efficiency of the solar air heater but due to its lower efficiency and higher installation cost for same capacity, it is not commercialize global in the market. The double pass solar air heater gives more efficiency as compared to the single pass solar air heater. So, it is necessary to reduce the cost of solar air heater and increase the efficiency of the DPSAH with optimizing the parameter with the help of DOE.

Objectives and goal:

The main objective of this Research study is to make the solar air heater commercially applicable and in low cost. By this concept combine effect of metallic wiry sponge and DOE Method applying for going to optimize the parameter and increase the efficiency of the double pass solar collector in the same absorber plate area. Reduce the cost of active solar air heater by using the inexpensive and easily available material and also reduce the complexity with for less skill operation.

Methodology:

Whole Experimental setup will made from galvanized iron sheet/ mild steel sheet of 1.5mm. The side walls of the solar air heater will be covered with the help of puff / glass wool insulation. Experimental setup will design with the help of software and developed as per our requirements in it. Absorber plate and absorber material will be defined and implement in the experimental setup. All the sides and absorber plate surfaces were painted with black paint to absorb maximum solar radiation during the day. Axial fan/blower with control valve was fitted to forced circulation and controlling of air flow. Generate an orthogonal array for Experiment and make a No. of set of Runs for Experiment with two different parameters (Pressure Drop and No. of Metallic Wiry Sponge on Absorber Plate) at three levels and compared to the simple absorber plate results. All the data will be measured in the sunny days. Results will be measured with the help of measuring instruments such as solar radiation meter (pyranometer), Temperature indicator, thermocouple, and manometer. Mathematical calculations determine for find out the efficiency of the double pass solar air heater.

2.1 LITERATURE OF SURVEY

For this review the following research study has been observed and reviewed: Review on literature on experimental investigation on solar air heater and DOE to find the Thermal efficiency and heat transfer enhancement used different porous media, thermal energy storage material, obstacles etc. So many researchers were finding different review give us below.

[1] **Aldabbagh, L. B. Y., F. Egelioglu et al.** (2010) investigated on **experimentally performed a thermal analysis of single and double pass solar air heaters with steel wire mesh layers are used instead of a flat absorber plate**. 10 steel wire mesh layers were fixed in second duct parallel to the glazing. They studied an effect of mass flow rate of air on the outlet temperature and thermal efficiency. This researcher fount that the efficiency with increase with increasing the mass flow rate

for the range of the flow rate used in this study between 0.012 and 0.038 kg/s. And for the same flow rate, the efficiency of the double pass is found to be higher than the single pass by 34 to 45%. So proven that double pass solar air heater was more efficient compare that single pass solar air heater. Moreover, the maximum efficiencies obtained for single pass and double pass air collector are 45.93% and 83.65%. Shown Figure below simple diagram and arrangement of steel wire mesh layers inside the air channel.

[2] **S. S Krishnananth et al.** (2013) work on **Experimental analysis on double pass solar air heater with thermal energy storage.** Double pass solar air heater was fabricated and integrated with thermal storage system. Paraffin wax used as thermal energy storage system and this paraffin wax placed inside the aluminum capsules was used phase changing energy material. These capsules placed inside the channel at different location. So they was study of experimental analysis at different configuration such as 1) flat absorber plate 2) capsules above the absorber plate 3) capsules below the absorber plate 4) capsules above the back plate. This four configuration used on double pass solar air heater and they was find that capsules placed above the absorber plate was more efficient compare to other configuration. They was also observed that, the solar air heater with paraffin wax as energy storage material delivers comparatively high temperature air throughout the day. The efficiency is also higher during evening hours.

[3]Abdallah Salah et al. (2009) presented on **effect of various absorbing materials on the thermal performance of solar stills.** They used Different types of absorbing materials to examine their effect on the yield of solar stills. These absorbing materials are of two types: coated and uncoated porous media (called metallic wiry sponges) and black volcanic rocks. This solar steel contains black coated and uncoated metallic wiry sponge made from steel quality AISI 430. This researcher found that an uncoated metallic wiry sponge has the highest collection during day time compare to metallic wiry sponge and black volcanic rocks. They found that the overall average gain in the collected distilled water taking into the consideration the overnight water collections were 28%, 43% and 60% for coated and uncoated metallic wiry sponges and black rocks respectively.

[4] **RahelehNowzari, L.B.Y. Aldabbagh at al.**(2014) represented an **experimentally performed a thermal analysis of single and double pass solar air heaters with partially perforated cover**. They studied on the thermal performance of the single and double pass solar air heaters with normal glazing and with quarter perforated cover experimentally. The solar air collector was tested with two different perforated covers in which the holes made on one cover had the center-to-center distance of 20D (6 cm) and on the other cover it was 10D (3 cm), where D (0.3 cm) was the hole diameter. Simple they was finding that thermal efficiency of the double pass always more than single pass solar air heater by 5-22.7% for the 0.037 kg/s mass flow rate. At the same mass flow rate they were found maximum thermal efficiency of the single and double pass solar air heaters with normal glazing are 55.52% and 60.18%.While the double pass solar air heaters have 60.49% and 57.60% maximum thermal efficiency with 10D and 20D perforated covers, respectively. So this researcher fount that, the efficiency of the solar air heater with 10D perforated cover is slightly higher than one with 20D perforated cover for both single and double pass.

[5] **Paisarn Naphon et al.** (2005) worked on **numerically analysis of heat characteristics and performance of double pass flat plate solar air heater with and without porous media**.They develop mathematical models which describe the heat transfer characteristics of the double-pass flat plate solar air heater and these are derived from the energy conservation. They found thermal conductivity of porous media has significant effect on the thermal performance of the solar air heater. They found that porous material used high thermal conductivity because the heat transfer rate depends directly on the thermal conductivity. And also they observed that, they found thermal conductivity of porous media has significant effect on the thermal performance of the solar air heater.

[6] P. T. Saravanakumar et al. (2012) presented Numerical study and thermal performance of the Flat plate solar air heaters with and without Thermal storage system.The mathematical models described that the heat transfer of the plate solar air heater are derived from the energy equation. The results obtained from the model are validated by comparison with experimental data. They found that the thermal conductivity of thermal storage material has significant effect of thermal performance of the solar air heater. And also they observed that the solar air heater with the thermal storage material gives 5 - 10% higher collector efficiency than that of without thermal storage material.

[7] **Hikmet Esen** et al. (2008) work on experimentally investigated the energy and exergy analysis for a double-flow flat plate solar air heater with and without obstacles. Four types of absorber plates made of stainless steel with black chrome selective coatings were used (Fig. 2.7). The dimensions and plate thickness for all four collectors were 1250 x 800 mm and 1mm, respectively. Single glazing with 5 mm thickness was used. It was observed that the obstacles created the turbulence and reduced the dead zones. The shapes of tested obstacles were presented in the study. The measured parameters were the inlet and outlet temperatures, the absorbing plate temperature, the ambient temperature, and the solar radiation. Following analysis of the results, optimal value of efficiency was found to be when the absorbing plate was in the middle level of flow channel for all operating conditions. It was also found that the double-flow collector equipped with obstacles appeared significantly better than that without obstacles. It was shown that the type III (the one which was staggered with leaf shaped obstacles) absorber plate always yielded higher efficiency than the Type I (flat plate). An energy analysis for the experimented collector was also performed. The results showed that the largest irreversibility occurred at the flat plate (without obstacles) collector in which collector efficiency is the smallest.

Experimental Setup

The experimental setup will be designed to measure the effect of metallic wiry sponge inserted in the double pass solar air heater. The experimental setup has been fabricated from the galvanized iron sheet of 16” gauge (1.6mm), the reduced draft has been provided to the equally air distribution at the inlet and outlet section. The absorber M.S. plate is put at the middle of the solar air heater and all inner surfaces with absorber plate coated black paint to absorb the maximum solar radiation. Adjustable inclination stand has been designed to measure the effect of different inclination angles of solar air heater. For batter comparison there are two set up will fabricated of same dimensions. Absorber plate area is designed to measure the effect is $0.5m^2$. Forced draft fan is placed at the inlet of the DPSAH. 4mm clear glass is placed at the top of the air heater to reduce the heat loss.

Figure 1 Experimental Setup

L9 Array for Observation

Pressure difference_1	No. of MWS_1	Pressure difference	No. of MWS
1	1	10	15
1	2	10	18
1	3	10	21
2	1	20	15
2	2	20	18
2	3	20	21
3	1	30	15

3	2	30	18
3	3	30	21

Results & Discussion

All resultant data for this concept of metallic wiry sponge used in solar air heater has been carried out in typically sunny days in month of April - May. Where in Maximum Solar Radiation arrived at 995W/m^2 and The Experiment has been carried out from 10:00 AM in morning to 04:00PM in Evening. All data has been measured with required Instrumentation. Solar Radiation has been measured with the help of Pyrano-meter bulb type digital solar meter. Wind velocity and mass flow rate of air outlet has been measured with the help of anemometer, all Temperatures have been measured with the help of J-type Thermocouple and value has been indicated in the j-type digital indicator. Flow rate has been regulated with the help of control valve at 10 mm. 20mm, 30mm pressure difference.

Effect of Efficiency Vs Time Vs different No. of MWS

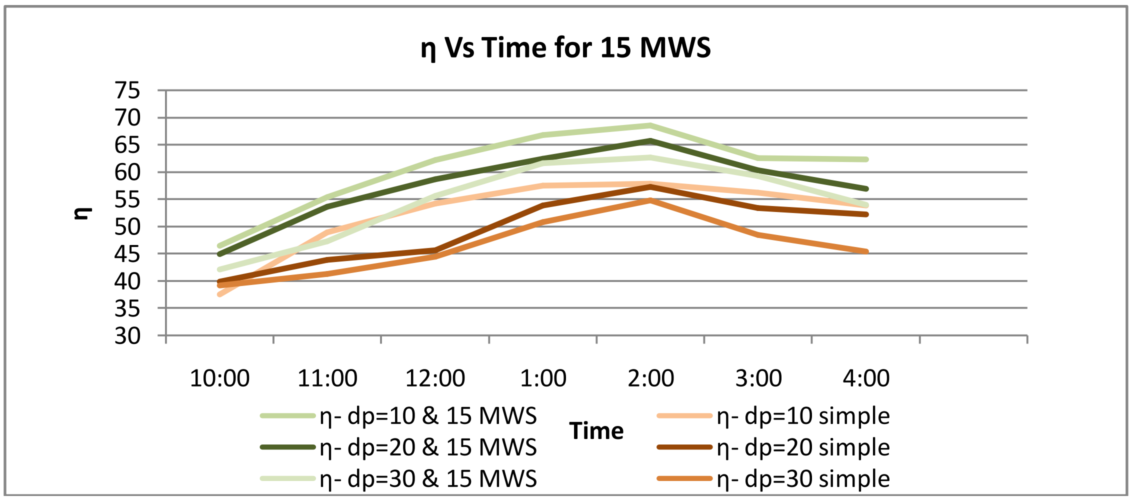

Figure 2 Efficiency Vs Time for 15 MWS DPSAH

The above figure 2 shows the observation chart for efficiency of double pass solar air heater. It has been observed that maximum 68% is achieved with the 15 Metallic wiry sponges at 10mm pressure difference and it is gradually decreased 65%, 58% respectively with pressure difference 20mm and 30mm. Maximum efficiency in simple DPSAH is observed as 59% at 10mm pressure difference and it is gradually decreased 58%, 45% respectively for 20mm and 30mm pressure difference.

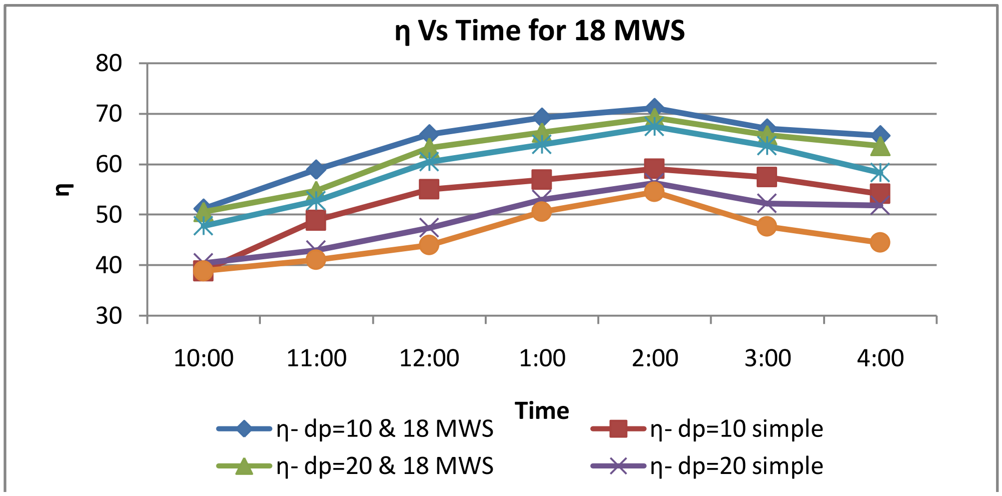

Figure 3 Efficiency Vs Time 18 MWS DPSAH

The above figure 3 shows the observation chart for efficiency of double pass solar air heater. It has been observed that maximum 70% is achieved with the 18 Metallic wiry sponges at 10mm pressure difference and it is gradually decreased 68%, 64% respectively with pressure difference 20mm and 30mm. Maximum efficiency in simple DPSAH is observed as 60% at 10mm pressure drop and it is gradually decreased 59%, 56% respectively for 20mm and 30mm pressure difference.

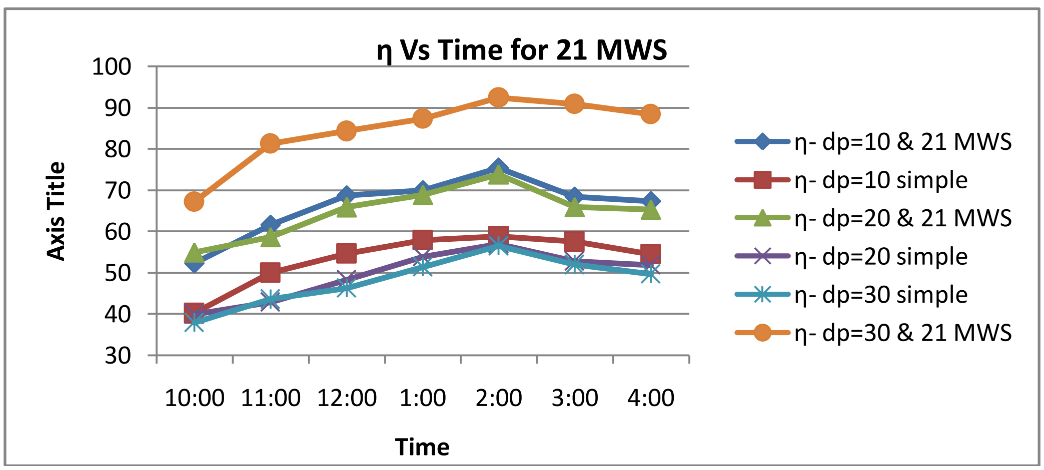

Figure 4 Efficiency Vs Time 21 MWS DPSAH

The above figure 4shows the observation chart for efficiency of double pass solar air heater. It has been observed that maximum 91% is achieved with the 21 Metallic wiry sponges at 10mm pressure difference and it is gradually decreased 68%, 67% respectively with pressure difference 20mm and 30mm. Maximum efficiency in simple DPSAH is observed as 59% at 10mm pressure drop and it is gradually decreased 58%, 57% respectively for 20mm and 30mm pressure difference.

Conclusion

From the above results it has been observed that the metallic wiry sponge gives higher efficiency as compared to the simple absorber plate type double pass solar air heater. Efficiency has been gradually decreased in both the type of double pass solar air heater with increasing pressure difference from 10mm to 30mm.also it has been observed that the efficiency of the double pass solar air heater is increased with increasing number of metallic wiry sponge from 15, 18, and 21. The maximum efficiency of 71% got in 21 metallic wiry sponges double pass solar air heater with 10mm pressure difference. The lowest efficiency 46% maximum has been observed in simple double pass solar air heater with 30mm pressure difference.

Future scope

Increase the number of metallic wiry sponge in the double pipe solar air heater and optimize the results with larger array design, which gives better accuracy.
The effect of inclination angle on MWS double pass solar air heater will helpful to increase the efficiency of the solar air heater

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