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Experimental Analysis of Comparative Performance of Conventional and Matrix Aluminium Mesh Wire Absorber Solar air Heater

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ABSTRACT

In present work for increasing the performance of solar air heater on aluminium square meshed wire was inserted between both channels in which air is passing and get heated up. An experimental comparison of thermal performance of double pass solar air heater has been conducted by using aluminium mesh wire instead of a flat absorber. It improves the collector efficiency by increasing the air velocity and heat transfer coefficient between absorber plate and air. Research also includes the effect of mass flow rate, wire mesh in the bottom channel and top channel, temperature difference and thermal efficiency. The experiment evaluate that the presence of square wire mesh in the solar air heater rises the outlet temperature ,which furture increases the thermal efficiency and also shows substantial potentiality to heat air in both type solar air heater. In research it has been investigated that solar air heater with aluminium mesh wire (MSAH) has reasonably high performance to heat air compare with conventional solar air heater (CSAH). The maximum difference in temperature was found as 31°C for mass flow rate of 0.00527 kg/s in case of solar air heater with aluminium mesh wire matrix absorber which was about 19% higher compare with conventional solar air heater.
Keywords: Solar Air Heater, Fins, Thermal Efficiency, Matrix Absorber.

I. INTRODUCTION

In the study, a test of solar air heater was performed based on the heating of air by matrix and conventional solar air heater. Aim of our experiment increase in the thermal efficiency of the solar air heater, by using matrix absorber in conventional solar air heater. Conventional solar air heaters mainly consist of an absorber plate, transparent cover, insulated hot air ducts and air blowers in active systems but in matrix solar air heater over the absorber plate aluminium matrix absorber is attached. Different factors affect the Solar air heater efficiency such as collector dimensions, type and shape of absorber plate, glass cover, inlet temperature, wind speed, intensity of radiation and outlet temperature etc. Thermal efficiency of a solar air heater is generally considered poor because of low rate of heat transfer capability between absorber plate and air flowing in the duct. In order to make a solar air heater a more effective solar energy utilization system, thermal performance needs to be improved by enhancing the heat transfer rate from absorber plate to air flowing in the duct of solar air heater. One of the method for the enhancement of convective heat transfer by using aluminium wire matrix absorber on both side of absorber plate. By using this matrix wire heat transfer area of air increase so thermal efficiency increase.

II. METHODS AND MATERIAL

1. Literature Review

B. M. Ramani, Akhilesh Gupta et al [1] investigate that Double pass counter flow solar air collector with porous material in the second air pass gives higher thermal efficiency in comparison to double pass counter flow solar air collector without absorber matrix and conventional single pass solar collector. This can be due to the fact that the porous material provides very large surface area for heat transfer and hence the volumetric heat transfer coefficient is extremely high. Also, due to porous material, the solar radiations are absorbed by the successive layers of wire mesh assuming its absorption as the volumetric phenomenon as compared to surface phenomenon in case of the conventional collector where in solar radiations are absorbed by the absorber plate. Further, in the counter flow arrangement, air flowing in the first air passage picks up heat from the glass covers reducing their temperatures and then flows over the absorber plate/matrix. The heat energy extracted by the flowing air in the first pass from the glass covers is used to preheat it and also decreases the temperature of glass covers which in turn reduces the heat losses to the surroundings and hence the performance of such collectors have been found to be superior compared to conventional solar air collector where in air flows in one pass either above or below the absorber plate.

L.B.Y. Aldabbagh et al [2] investigated experiment on Single and double pass solar air heaters and compared with published results. The results of the study showed that a maximum of 83.65% efficiency can be obtained by using a porous media instead of an absorber plate in the double pass model proposed in this study. For the single pass the maximum efficiency obtained was 45.93% for air mass flow rate of 0.038 kg/s. The efficiencies were found to increase with increasing mass flow rate of the air in both cases. The obtained results showed that the temperature differences, DTs between the outlet flow and the ambient decreased opposed to the increasing mass flow rate of the air. In addition, obtained results showed for the same mass flow rate the collector temperature differences increased parallel to the increasing solar radiation, I. Solar air heaters are extensively used in low temperature energy technology; increasing importance of renewable energy, low thermal efficiency of conventional flat-plate solar air heaters, minimal use of materials compared to other solar heating systems and their extensive usage will continue to attract researchers to design more efficient solar air heaters.

K. Rajarajeswari et al [3] evaluate and establish Performance of the developed matrix air heater in drying application. The dryer proved efficient and economic for drying fruits. Experiments were conducted with 4 mm tomato slices having an initial moisture content of 90.62 % took 3 hours to bring down to a safe moisture level of 18.28 %, which is propitious for storage. Economic analysis showed that the cumulative present worth of annual savings for drying tomatoes over the life of the dryer was Rs. 28, 52, 503.00. The capital investment of the dryer was Rs. 1, 40,000.00 and the payback period of the dryer was calculated to be 1.05 years which is very short comparing the life time of the dryer.

M. A. Aravindh and A. Sreekumar [4] are design and test on a wire mesh solar air heater for drying application. It is tested with and without load and the variations in performance are studied. It is found that the highest temperature of 74ºC is attained when operated with load. Even though there is only little variation from solar and open sun drying, the quality of the product dried is comparatively much better. The natural colour of the product is retained in solar drying whereas in open sun drying, there is a discolouration. Also due to exposure to atmosphere, there is a risk of contamination due to dust and other materials, which can be completely eliminated in solar drying. 90% of the moisture content is removed in 5 hours, then the drying rate is constant because there will be some residual moisture in the sample.

Foued CHABANE [5] studied aims to analyze a thermal efficiency of SAH. The comparison of solar collectors with smooth plate and with baffle indicates that the efficiency of the solar air collector depends significantly on the solar radiation, the volume flow rate and the position of a baffle when is fixed on the duct of solar collectors. The efficiency of the collector improves by increasing the volume flow rate from 40m3/h to 80m3/h due to enhanced heat transfer to the air flow. The mean highest thermal efficiency (η = 58%) was obtained at a solar intensity of I = 937 W/m2 by fixing the baffle under the absorber plate at a volume flow rate of 80 m3/h and a tilt angle of 34.8°.

Chii-Dong Ho et al [6] this study provides an alternative design for wire mesh packed solar air heaters with recycling operations. Significant improvements on the heat transfer efficiency are achieved by application of the recycle-effect concept to solar air heaters to conduct recycling double-pass operations. The device performance of wire mesh double-pass solar air heaters with external recycle was investigated theoretically and experimentally with the aim of making economic sense with consideration of the hydraulic dissipated energy. The results show that the wire mesh packed solar air heater is economically feasible to improve the collector efficiency under recycling operation due to the promotion of turbulence intensity. This work indicates that a suitable selection of operating conditions for the new design of recycling wire mesh packed solar air heater could enhance collector efficiency with a reasonable hydraulic dissipated energy increase.

Amit Roy et al [7] Performance analysis of a single pass solar air heater shows that substantial increase in thermal efficiency can be achieved by utilizing square wire mesh in the absorber plate compared conventional solar air heater. The efficiency increases with increasing air flow rate though for higher air flow rate, difference in temperature between the outlet and inlet of the collector reduces. Also the temperature difference increases with increasing solar irradiation. The maximum temperature difference was found as 360C for a mass flow rate of 0.0116 kg/s in case of solar air heater with wire mesh which was about 39% higher compared to solar air heater without wire mesh. Maximum efficiencies obtained for the solar air heater with and without wire mesh were 54.6% and 29.24% respectively for air flow rate 0.0251 kg/s at a solar intensity of 1045 W/m2. It was also observed that power developed by SAH with wire mesh was 44.92% higher compared to SAH without square wire mesh.

Filiz Ozgen et al [8] conduced a experimental study to evaluate the energy efficiencies of three types of double-flow SAHs with aluminium cans under a wide range of operating conditions. According to the results of the experiments, the double-flow type of the SAHs with aluminium cans has been introduced for increasing the heat-transfer area, leading to improved thermal efficiency. The performance of double-flow type SAHs, in which air is flowing simultaneously over and under absorbing plate, is more efficient than that of the devices with only one flow channel over or under the absorbing plate because the heat-transfer area in double-flow systems is double. The optimal value of collector efficiency was obtained for type I at 0.05 kg/s mass flow rate. Testing results always yield higher efficiency values of the Type I (non-arranged cans) than that of the Type III (without cans) flat-plate collector.

2. Experimental Detail

2.1 Experimental Set-up

Double pass solar air heater has been designed and fabricated by 18mm thick plywood with 8mm insulation provided around a rectangular duct at outlet to minimized the heat losses

The comparison in the enhancement of heat transfer coefficient and thermal efficiency having two different type solar air heater one is conventional (flat plate type) and other one is flat plate with aluminium matrix absorber. The flow system consists of in three sections i.e. the entry section consists of (35×210mm), test section consists of (1470×210mm) and exit section is (170×210mm). Transparent glass cover sheets two sets(1740×210mm) is used as it allows shorter wavelength radiation to pass and restricts larger wavelength radiation to go back. The flow measuring orifice plate (diameter 25mm), control valve and centrifugal blower are connected by the 1000 mm long G.I. pipe line (diameter 40mm) in ordered.Six calibrated thermocouples (K-type) are attached with upper and lower surface of the absorber plate for measurement of plate average temperature, one thermocouple was use at inlet for measuring inlet temperature of air and one thermocouple was used at the outlet to measured outlet air temperature with the help of temperature indicator. A block diagram of experimental setup and cross sectional view of double pass solar air heater have been shown in fig 1.

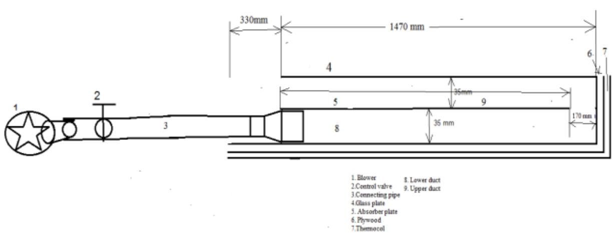


Figure 1. Schematic diagram of Experimental setup

2.2 Data Reduction

1. Mass Flow Rate of Air (m)

$$m = \rho A_c V_d$$

where,

ρ = Density of air (kg/m^3)

A_c = Cross-section area of duct (m^2)

V_d= Velocity of air in duct (m/s)

2. Friction Factor (f)

$$f=\frac{1}{2}\Delta P \frac{D_h}{\rho_a \times {V_d}^2}$$

where,

$\Delta P = P_i - P_o$

D_h= duct hydraulic diameter (m)

ρ_a= density of air (kg/m^3)

3. Nikurande-Karman Equation to friction factor(f)

$$f=0.046Re^{-0.2}$$

4. Thermal Efficiency(η_{th})

$$\eta_{th}=\frac{mc_p\Delta T}{I \times A_s}$$

where,

m = mass flow rate of air (kg/s)

c_p= specific heat at constant pressure (J/kg°C)

ΔT = duct air temperature dif

I = Intensity of solar radiation (W/m^2)

A_s= surface area of transparent glass (m^2)

5. Performance Factor (PF)

$$PF = \frac{Nu_b/Nu_s}{(f_b/f_s)^{1/3}}$$

where,

Nu_b= Nusselt no. of baffles absorber plate

Nu_s= Nusselt no. of Smooth absorber plate

f_b= Friction factor of baffles absorber plate

f_s= Friction factor of Smooth absorber plate

6. Mean temperature of plate (T_S)

$$T_S = \frac{T_1+T_2+T_3+T_4}{4}$$

Where T_1, T_2 ,T_3 and T_4 are surface temperature of absorber plate at different location.

2.3 Experimental Procedure

In order to compare the result of the MSAH duct with porous surface and CSAH duct with smooth absorber plate operating under similar flow conditions was also tested.

We are performing an experiment from 10:00 am to 04:00 pm every day in September at the campus of Radharaman Institute of Technology and science, Bhopal, MP, India. The photos of experimental setup are shown in figure. At day of experiment firstly we are clean the setup from the dust by the help of blower. Then after we are arranged the ducts at 23° by the help of table. Check all the connection of thermocouple wire and extension wire. Then set the manometer at vertical passion and measure the pressure difference at variable speed of blower i.e. 15m/sec, 21m/sec and 27m/sec at outlet of blower (diameter 20mm) in both setups. Then we are record the radiation intensity at 23^0 by the help of pyranometer. Measure ambient temperature by the help of hygrometer and write down it. Then start the blower and record all thermocouple reading after some time when reading is stable in both setup. Then change the speed 21m/sec, 27m/sec and record all above parameters. This process repeat in every hour.

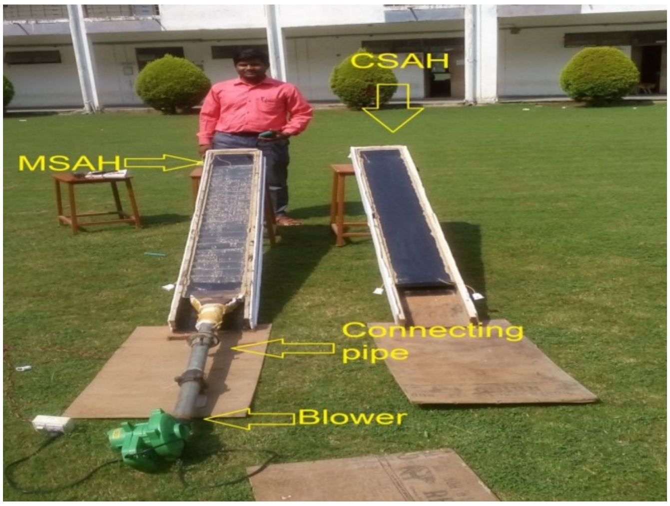
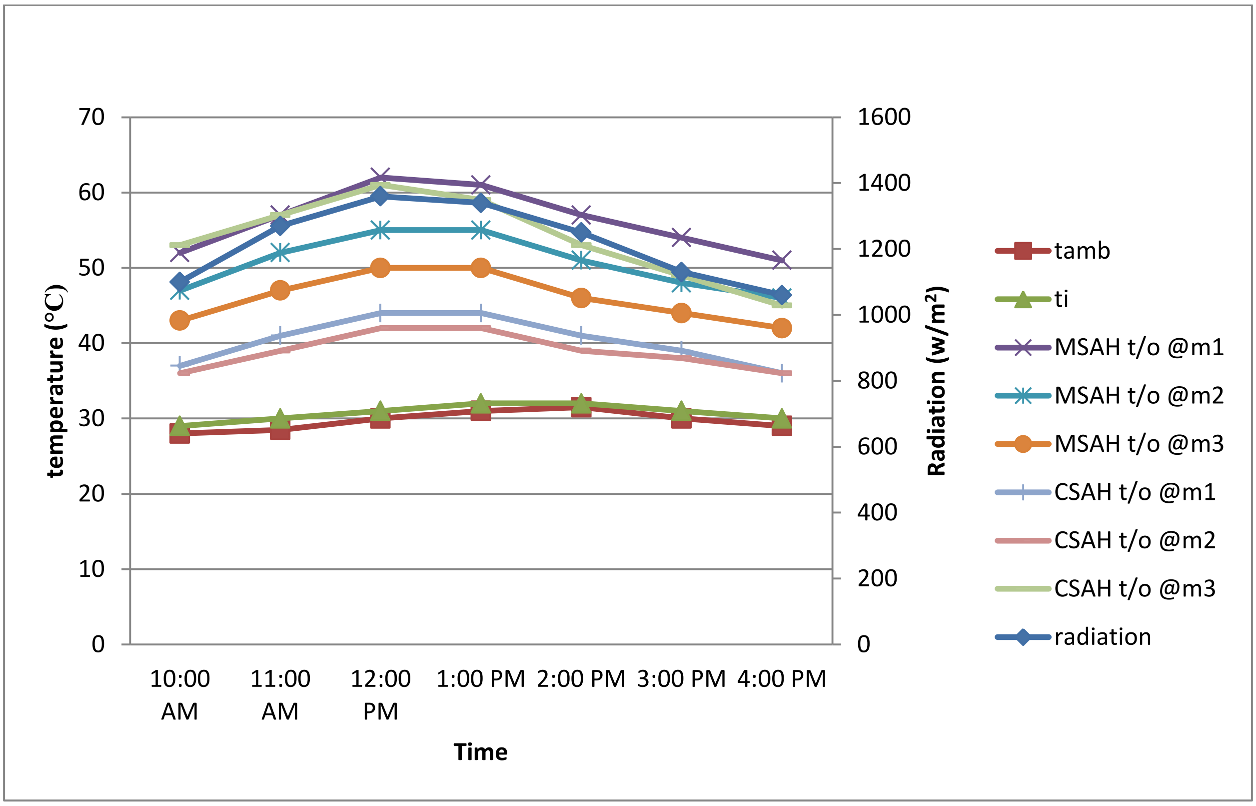


Figure 2. Pictorial view of experimental setup

III. RESULTS AND DISCUSSION

3.1 Comparative variation of temperature with time and radiation

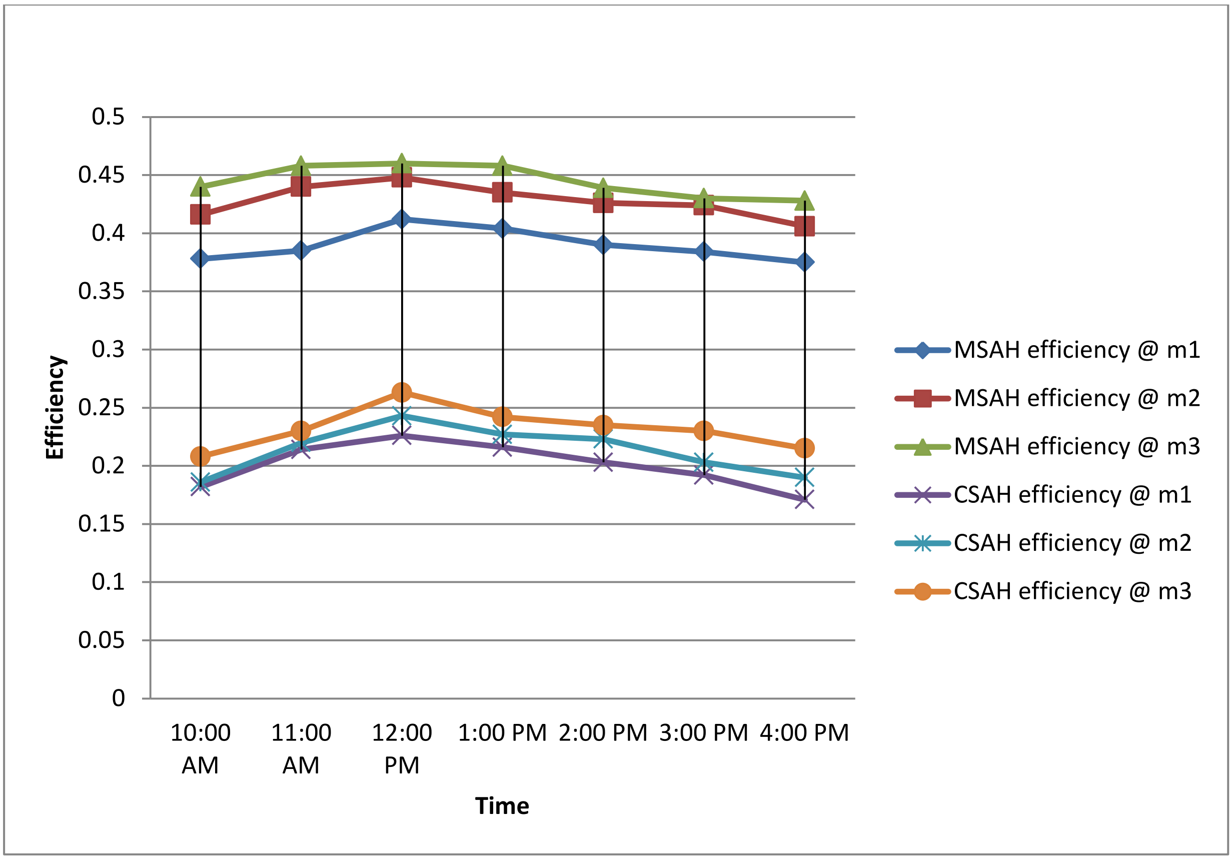
Comparative variation of temperature with time and radiation are shown in graph. Maximum value of outlet temperature is 62°C in matrix solar air heater and 44°C in conventional solar air heater at 12:00 PM. The use of matrix absorber increases the outlet temperature 3°C to18°C in different mass flow rate.



Graph 3.1 Comparative variation of temperature with time and radiation

3.2 Comparative variation of thermal efficiency with time

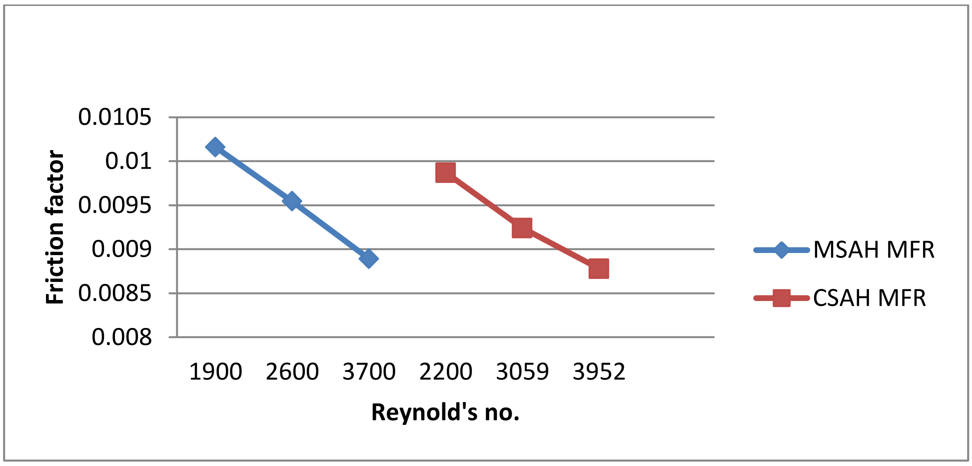
Comparative variations of thermal efficiency with time are shown in graph. Maximum thermal efficiency are found 46% in matrix solar air heater and 26.3% in conventional solar air heater at 12:00 PM in mass flow rate of 0.00946kg/s. By using the matrix absorber the thermal efficiency increases 14% to 19% compare with conventional solar air heater at different mass flow rate.



Graph 3.2 Comparative variation of thermal efficiency with time

3.3 Comparative variation of friction factor with Reynolds number

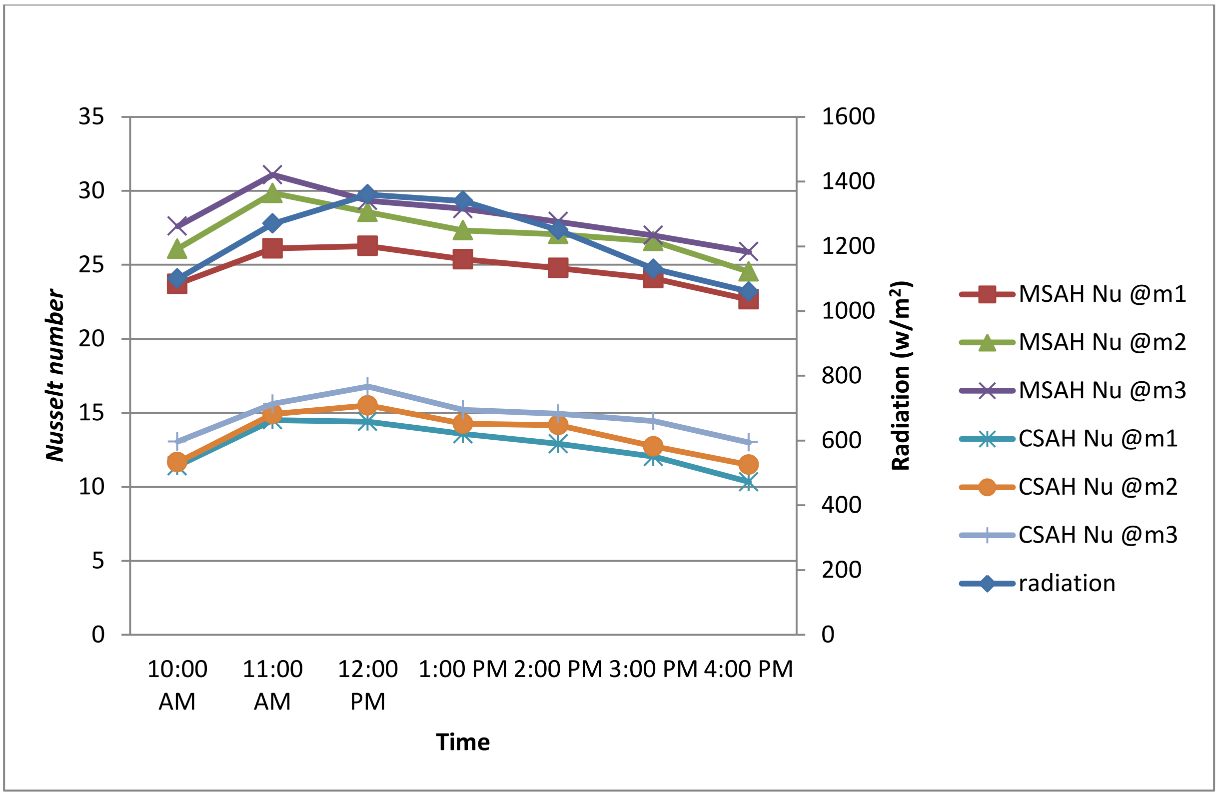
Comparative variations of friction factor with Reynolds number are shown in graph. When we are using matrix absorber so pressure is decreases so friction factor increases. Friction factor increases approx 0.000291.



Graph 3.3 Comparative variation of friction factor with Reynolds number

3.4 Comparative variation of Nusselt number with time

Comparative variations of Nusselt number with time are shown in graph. Maximum Nusselt number are found 31.07 in matrix solar air heater at 11:00PM and 16.77 in conventional solar air heater at 12:00 PM in mass flow rate of 0.00946kg/s When we are using matrix absorber so Nusselt number increases 8 to 20 compare to conventional solar air heater at different mass flow rate.



Graph 3.4 Comparative variation of Nusselt number with time

IV. CONCLUSION

An experimental analysis on performance of conventional and matrix absorber solar air heater having the air flow on absorber plate has been made for air mass flow rate of about 0.00527kg/s to 0.00946 kg/s. Intensity of solar radiation was changed time to time and maximum value was found at 12:30 PM in cleaned day. A direct performance comparison of the solar air heater with aluminium mesh wire matrix absorber and smooth plate solar air heater shows that,

1. The thermal efficiency of the aluminium mesh wire matrix absorber solar air heater is about 14-19% higher than the conventional solar air heater, highest thermal efficiency is at the high mass flow rate.
2. Thermal efficiency is increases with increasing the mass flow rate in both solar air heaters.
3. Outlet air temperature is decreases with increasing the mass flow rate in both solar air heaters.
4. It was observed that with the use of aluminium mesh wire matrix absorber the heat collection rate was increases which further enhanced the heat transfer.
5. Investigation also results in the difference of 10C in ambient and inlet air temperature.
6. Maximum outlet temperature obtain on aluminium mesh wire matrix absorber solar air heater was 62^0C and on conventional solar air heater is 440C.

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