IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

An Experimental Analysis Of Domestic Double Pass Solar Air Heating System For Different Absorber Plates

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ABSTRACT

Solar Air Heater (SAH) is device which is mostly used to heat air in cold climates .That heated air a lots of application including warming building ,agricultural producer etc. In present work an experiment has been done to see how a Solar Air Heater (SAH) can be made more effective. This study examines the thermal performance of a Solar Air Heater (SAH) with a W- discrete, V – discrete, and a plain absorber plate at various mass flow rates. Outlet air temperature and thermal efficiency were two experimental outputs that were evaluated to confirm the performance. At a mass flow rate of 0.049 kg/s, the W – discrete absorber plate SAH was found to have a maximum thermal efficiency of 83%, which is respectively 39.83% and 30.16% greater than the W - discrete and V- discrete SAH. This study showed that for the parameter under consideration, flow configurations with W – discrete and V- discrete solar plate outperform and smooth plate SAH in terms of thermal performance. The angle at which air strike V – discrete absorber plate is 60◦, where as the air has to strike two 60◦ angled plate for the case W-discrete absorber plate. As the friction factor has high value for two 60◦ in (W- discrete solar plate).The thermal performance of absorber plate with W- discrete is high.

Key Word: Solar air heater, W-discrete V-discrete, thermal-efficiency, Outlet air temperature

1.0 INTRODUCTION

Energy is necessary in various ways to carry out our everyday activities, and it is the foundation for a long and healthy existence. There is a constant demand for energy as a result of industrialization in order to achieve long-term economic success [1].Fluctuating oil consumption and pollution from transportation vehicles [2].Compelled to use natural gas as an environmentally beneficial fuel [2–6]. However, because the supply of conventional energy utilized in residential and commercial applications is diminishing, renewable and unconventional energy are essential for meeting the energy needs of those sectors. Governments all across the world also enact laws to promote the use of environmentally friendly energy sources. [7] Solar energy is the sun's radiant light and heat, a promising renewable source to meet energy demand. The Earth's surface receives approximately 10,000 times more energy than today's energy requirements. The atmosphere and clouds absorb 15%-20% of the radiation, reducing it. Solar air heaters convert this energy into heat, making them inexpensive, easy to fabricate, and suitable for moderate and low temperature applications [8].

2.0 LITERATURE REVIEW

Examined double pass packed bed solar air heaters (SAH) with encapsulated PCM on absorber plate capsules in square and circular geometries. Four absorber plates with inline and staggered grid arrangements were attached and the intensity of solar radiation increased before noon and decreased after noon. The efficiency of SAH increased with mass flow rate, with square capsules being more efficient Many of Researchers have reviewed the previous works. For example Gadi Raju et.al [9] a study than cylindrical encapsules. Square encapsules in staggered and inline grid arrangements increased efficiency by 9.16% and 23.88%, respectively.

Kottayat Nidhul, et.al [10] this study provides a comprehensive description of various rib types in SAH, highlighting improvements in heat transfer but insufficient pressure reduction. It also discusses energetic performance analysis, rib influence on energy gain, and the effects of multiple ribs and gaps on SAH's overall performance.

Faraz Afshariet al. [11] a gap in the rib allows faster primary and secondary flow passage, reviving delayed flow beyond reattachment point and reducing recirculation zone. The study improved thermal performance of a TSAH by incorporating multiple tabulators and modeling their effects using CFD technique.

Tarek Kh. Abdelkader et al. [12] this Experimental test rigs were created using turburlators for better heat transfer rate. The maximum instantaneous heater efficiency reached 72.41%, with experimental and numerical average temperature differences ranging from 9.16-14.54 C Artificial roughness in SAH improves quality by creating local wall turbulence and increasing convective heat transfer coefficient.

Aamir Imtiyaz et al. [13] this investigation used a solar selective coating made of 4% CNTs/CuO black paint on a roughened aluminum SAH Nusselt Number and Friction factor depend on Re, e/D, P/e, rib shape, and Duct form. Roughness height should be slightly higher than transition sublayer thickness, and sloping ribs improve effectiveness.

Dongxu Jin et al. [20] Investigate flat and v-corrugated plate solar air heaters with built-in PCM as thermal energy storage material, comparing them with and without PCM. This study investigates heat transfer and fluid flow in a solar air heater duct with V-shaped ribs. It calculates Nusselt number, friction factor, and flow structure based on rib geometrical characteristics.

3.0 MATERIALS AND METHOD

Two Solar air heaters are designed and fabricated Viz. W discrete and V discrete with plain plate. It has a rectangular channel which is having a two passes and solar radiation which gives the equivalent heat on plate provided a sun with concentrators outside, a device for measuring pressure, a device for temperature measurement and a blower .A rectangular channel or box which is designed a double passes solar air heater, verify friction factor and heat transfer characteristics over the absorber plate. The whole set up fabricated from wood has a rectangular shaped double passes channel. Absorber plate G.I material (galvanized iron) and painted a black colour, sheet of thermocouple used as insulator in a rectangular box. The dimensions of the rectangular channel are as follow.

L×B×H 1500 mm × 700 mm × 70 mm

3.1 Experimental Setup

3.1.1 Solar Air Heater Duct

The fabrication of the duct is done by a wooden plank which is rectangular in cross section. The duct dimension is 1500 mm × 700 mm × 70 mm. The aspect ratio of the duct calculated is 45.45. The test section length is 1200 mm. The bottom portion of the duct is fabricated of thick plank of wood with 5 mm thick plywood affixed on it and the other two sides is fabricated of 19 mm thick plank of wood.

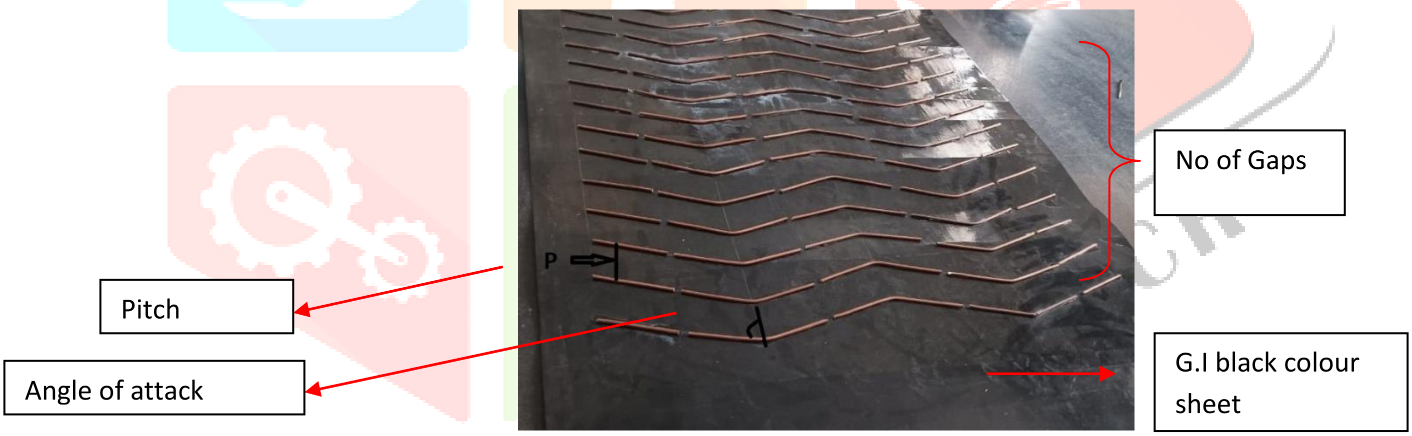


Figure.1 Absorber plate of W- discrete Double pass Solar Air Heater

3.2.2 Schematic Diagram of System

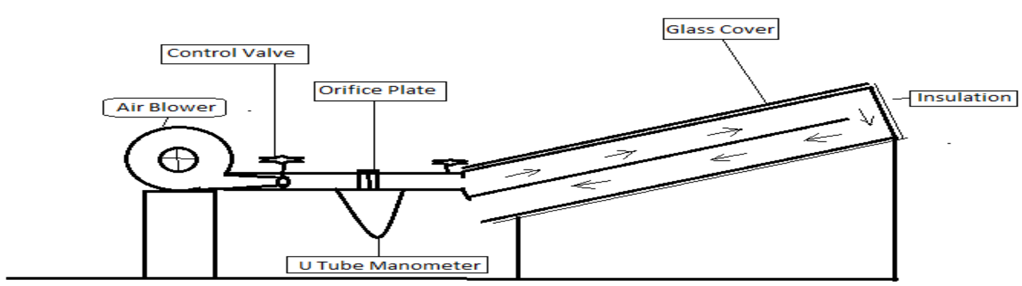


Figure.2 Schematic diagram of Double Pass Solar Air Heater

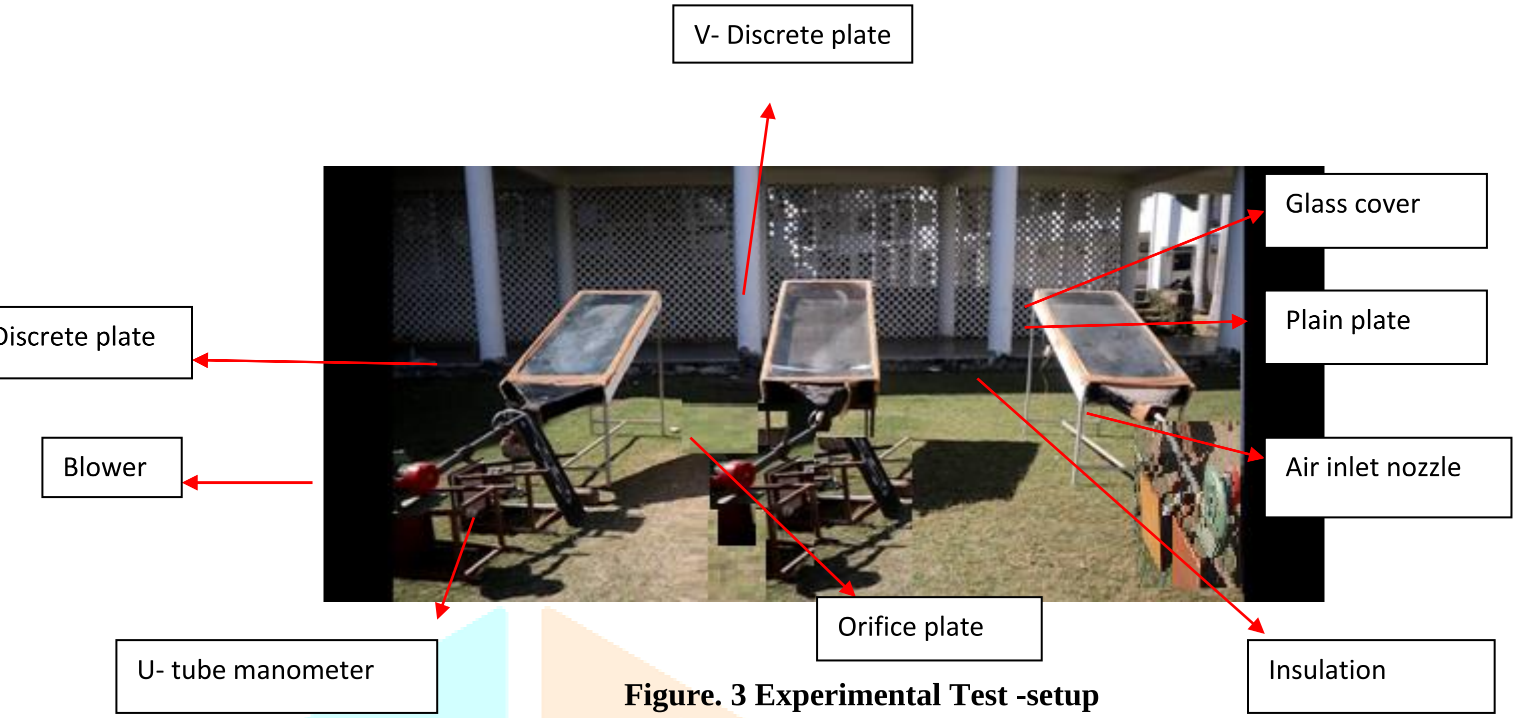


Figure. 3 Experimental Test -setup

4.0 EXPERIMENTAL DATA REDUCTION

The data includes thermocouples reading and different mass flow rates (m). This data have been recorded air inlet temperature and air outlet temperature at a top of absorber plate to the bottom of absorber plate ,a data obtained in steady condition .The data obtained from experiment has been used to calculate heat transfer rate(Q), Nusselt number (Nu) , friction factor (f),and Reynolds number (Re).The following equation has been used to determine the Q ,Nu ,f and Re.

4.1.1 Average temperature

The average flow temperature $\mathbf{T_f}$ is the measure value of inlet temperature and outlet temperature of test section

By using the following equation.

$$\mathbf{T_f = \frac{T_i + T_O}{2}}$$

4.1.2 Average temperature of the absorber surface (T_P)

Using the following equation, the average flow temperature T_f is a measurement of the temperature at the section's inlet and outflow.

$$\mathbf{T_p = \frac{T1+T2+T3+T4+T5+T6}{6}}$$

4.2 Mass flow rate

Mass flow rate,(m) has been determine from the pressure drop measurement across the orifice plate.

$$m = C_d \, Ao \sqrt{\frac{2\rho(\Delta p_o)}{1-\beta^4}}$$

4.3 Air velocity in the duct (V)

Air velocity in duct measured by following equation,

$$V = \frac{m}{\rho WH}$$

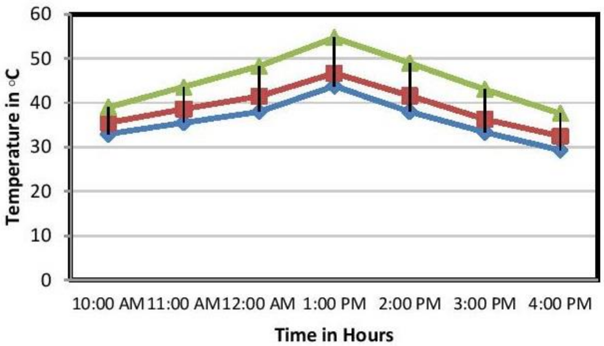
4.4 Reynolds number

The value of Reynolds number was measured by using equation,

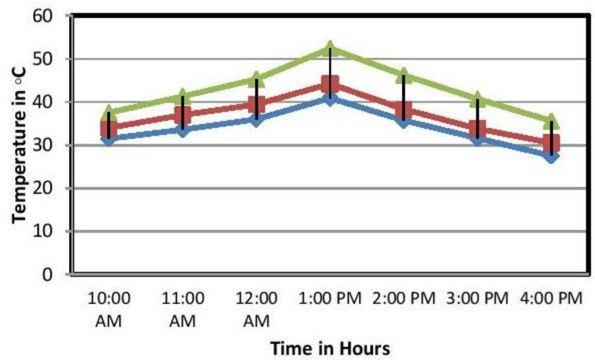
$$R_e = \frac{\rho V D_h}{\mu}$$

5.0 RESULTS AND DISCUSSION

It was observed that the maximum temperature of double pass Solar air heater. The temperature and experiment were conducted at Radharaman Institute of Technology & Science Bhopal; location (23.2599°N, 77.4126°E) The



(Figure. 4)



(Figure. 5)

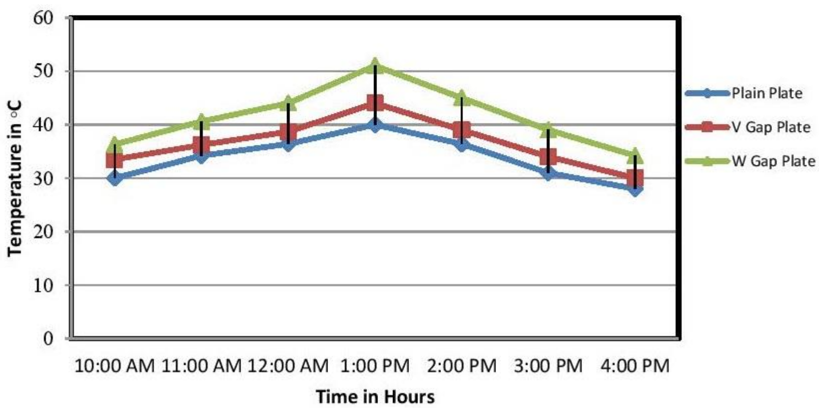


Figure. 6

Variation in Temperatures of Different Solar Air Heaters at (Figure. 4) m_1, (Figure. 5) m_2, and (Figure. 6) m_3

SAH performance was compared with and without ribs in the hot and muggy Bhopal area of MP, India. Three subsections are included in the presentation of the results: incident solar radiation in the first, temperature distribution in the second, and SAH's thermal efficiency in the third. Losses from ancillary equipment, such as blowers and valves, are ignored.

Figure (4) shows the outlet temperature vs standard local time on the testing day (3) for various solar air heaters at mass flow rate (m_1=0.025). The outlet temperature rose from morning to midday and then began to fall towards evening. The main reason for the trend was variation in solar radiation with time.

The output temperature increased as the mass flow rate of air increased for all the three solar air heaters with the different types of absorber plates (plain plate, V – Gap plate, W-Gap plate).

Maximum outlet temperature was found out for Plain plate, V – Gap plate and W-Gap plate with the values of 38.7^{0}C, 41.8^{0}C and 50.2^{0}C respectively at 01 PM. Minimum outlet temperature for above three solar air heater was calculated to be 28.6^{0}C, 31.3^{0}C and 35.4^{0}C respectively at 10 PM. Again the reason was amount of solar radiation falling of the air heaters.

Figure (5) shows the outlet temperature vs standard local time on the testing day (3) for various solar air heaters at mass flow rate (m_2=0.037). The outlet temperature rose from morning to midday and then began to fall towards evening. The main reason for the trend was variation in solar radiation with time.

The output temperature increased as the mass flow rate of air increased for all the three solar air heaters with the different types of absorber plates (plain plate, V – Gap plate, W-Gap plate).Maximum outlet temperature was found out for Plain plate, V – Gap plate and W-Gap plate with the values of 38.7^{0}C, 41.8^{0}C and 50.2^{0}C respectively at 01 PM. Minimum outlet temperature for above three solar air heater was calculated to be 28.6^{0}C, 31.3^{0}C and 35.4^{0}C respectively at 10 PM. Again the reason was amount of solar radiation falling of the air heaters.

Figure (6) shows the outlet temperature vs standard local time on the testing day (3) for various solar air heaters at mass flow rate (m_3=0.049). The outlet temperature rose from morning to midday and then began to fall towards evening. The main reason for the trend was variation in solar radiation with time.

The output temperature increased as the mass flow rate of air increased for all the three solar air heaters with the different types of absorber plates (plain plate, V – Gap plate, W-Gap plate).Maximum outlet temperature was found out for Plain plate, V – Gap plate and W-Gap plate with the values of 38.7^{0}C, 41.8^{0}C and 50.2^{0}C respectively at 01 PM. Minimum outlet temperature for above three solar air heater was calculated to be 28.6^{0}C, 31.3^{0}C and 35.4^{0}C respectively at 10 PM. Again the reason was amount of solar radiation falling of the air heaters.

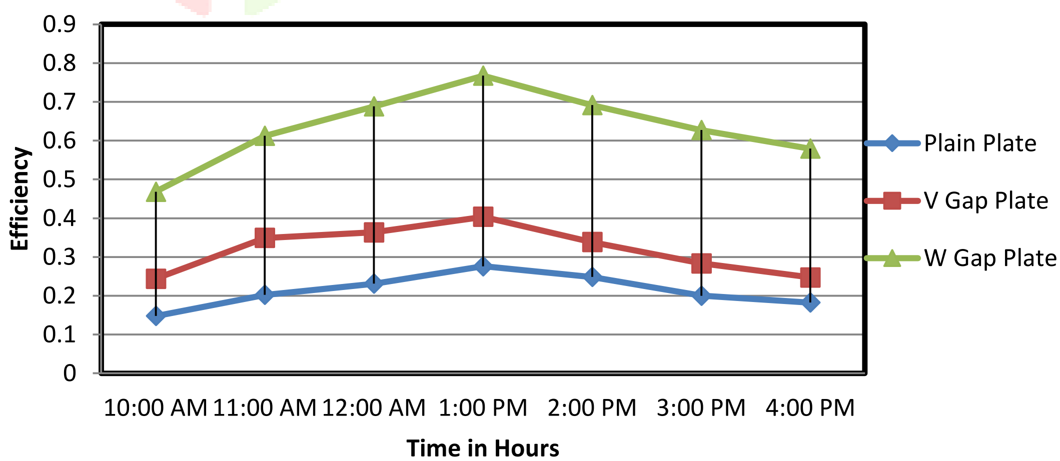


Figure 7 Variation in efficiencies with respect to time for different absorber plates

Figure (7) shows the outlet efficiency vs standard local time on the testing day (3) for various solar air heaters at mass flow rate (m_3=0.049). Maximum outlet efficiency was found out for Plain plate, V – Gap plate and W-Gap plate with the values of 25.95٪ ,34.45٪ and 74.09٪ respectively at 01 PM. Minimum outlet efficiency for above three solar air heater was calculated to be 14.27٪ , 22.71٪ and 45.43٪ respectively at 10 PM. Again the reason was amount of solar radiation falling of the air heaters.

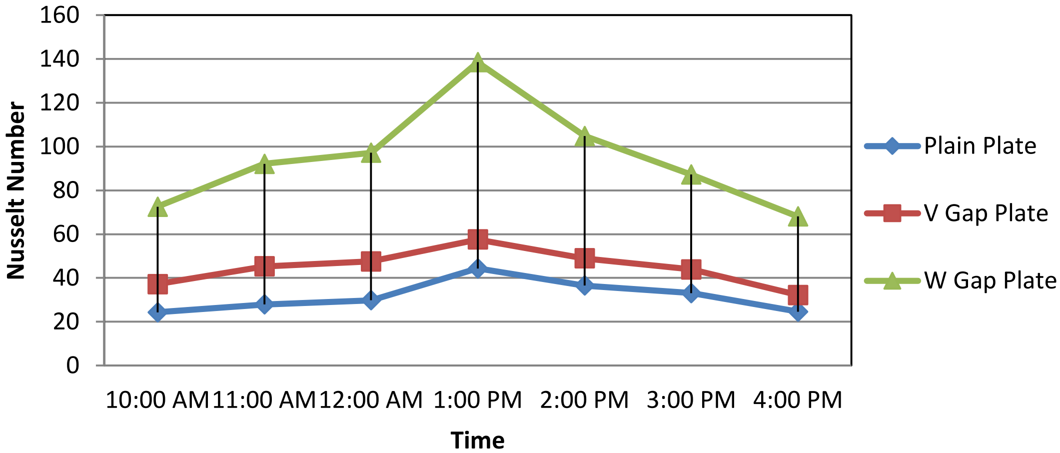


Figure 8 Variation in Nusselt number with respect to time for different absorber plates

Figure (8) shows the outlet Nusselt number vs standard local time on the testing day(3) for various solar air heaters at mass flow rate (m_3=0.049). The outlet Nusselt number rose from morning to midday and then began to fall towards evening. The main reason for the trend was variation in solar radiation with time.

The output efficiency increased as the mass flow rate of air increased for all the three solar air heaters with the different types of absorber plates (plain plate, V – Gap plate, W-Gap plate).

Maximum outlet Nusselt number was found out for Plain plate, V – Gap plate and W-Gap plate with the values of 33.0393 , 44.8949 and 108.6062 respectively at 01 PM. Minimum outlet Nusselt number for above three solar air heater was calculated to be 19.6965 ,32.1388 and 69.0440 respectively at 10 PM. Again the reason was amount of solar radiation falling of the air heaters.

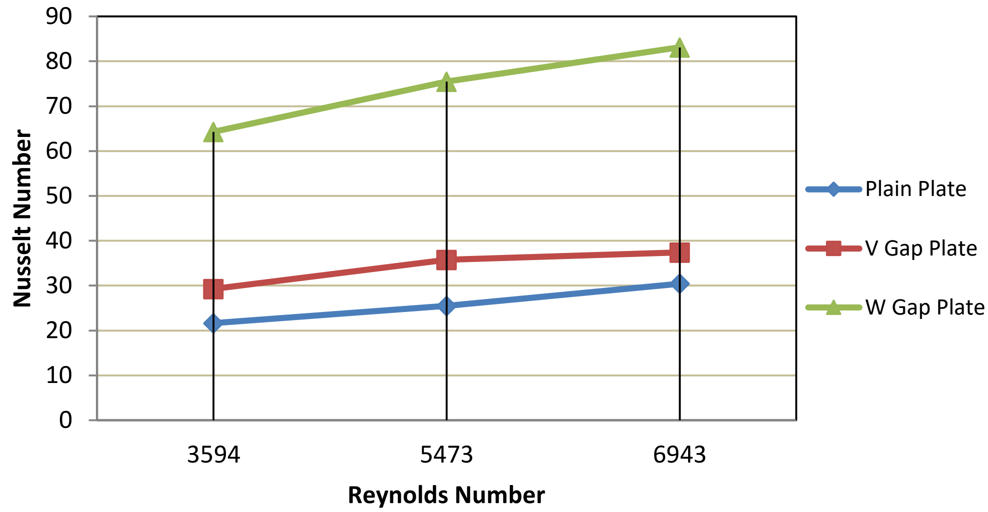


Figure 9 comparisons between Nusselt number &Reynolds number for different absorber plates

In figure (9) for W-discrete plate Nusselt number increases at higher rates as compared to other two plates with variation in Reynolds number .For V- discrete plate Nusselt number becomes nearly same for higher values of Reynolds number.

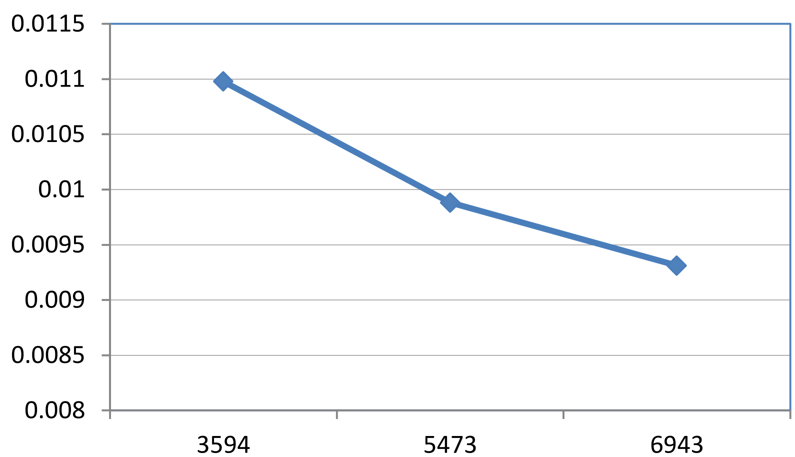


Figure 10 Effect of Reynolds number on friction factor

Figure (10) Shows variation in friction factor with Reynolds number. It can be seen that as Reynolds number increases the values of friction factor decreases, the reason can be at higher velocities the flow separation layer has fixed dimension leading to fixed values of friction factor.

CONCLUSION

The work on "W – discrete," “V – discrete” and "plain plate" has been done to compare the performance of the three rib geometries for solar air heaters. From the current investigation the following results can be drawn:

(i) Efficiency of W – discrete double pass solar air heater at mass flow rate 0.049 kg /s is 64 % is higher than V – discrete. Efficiency of V-discrete is 49 % higher than plain plate of double pass solar air heater , at mass flow rate 0.037 kg/s is 40.76% and 26.74% and also mass flow rate 0.025kg/s is 42.78% and 21.54 %

(ii) The Nusselt number for solar air heaters varies with mass flow rate, rising from morning to midday and falling as the evening approaches. The output efficiency increases with higher mass flow rate. Maximum value of Nusselt numbers were observed to be 33.0393, 44.8949, and 108.6062 at 01 PM, while minimum numbers were 19.6965, 32.1388, and 69.0440 at 10 PM.

(iii) Outlet air temperature is inversely proportional to mass flow rate for all the three solar air heaters. Was noted m_1 (0.025kg/s), m_2 (0.037 kg /s) and m_3 (0.049kg/s) mass flow decreased a temperature is increased.

(iv)Thermal efficiency increases as mass flow rate does. From m_1 (0.025kg/s) to m_2 (0.037), the efficiency of a W –discrete double pass solar air heater is found to grow by 19.87 %, and from m_1 (0.025kg/s) to m_3 (0.049 kg/s), it increases by 38.81%,

(v) For V- discrete double pass solar air heater air heaters efficiency increased by 9.46% - 16.01%. And for simple double pass solar air heater efficiency increased by 6.94%-11.18%..

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