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Estimation and Analysis of Energy Efflux for Variable Configuration of Solar Air Heater

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Abstract *:*In modern times, there is hard need of utilizing non-conventional sources for meeting energy demands. Solar heating power generation is one of the novel concepts which is widely used for power generation. Solar Air Heater (SAH) is a device that generates electricity by using solar energy. The radiation is absorbed by the heat and converted into heat energy on the absorbing surface and is transferred to the liquid flowing through the collector. It has been seen that the solar heat transfer rate is affected by ribs, insulation, glass, fluid channels, heat sink panels and tilt angle. Also, it was revealed through review of literature that heat transfer rate of flow is best estimated by using artificial roughness on the surface. The main aim of the research is to estimate the variation of solar heat transfer rate with respect to change in time and configuration of collector with different roughness geometries of the flat plate solar heating system. Flat heat sink plates and circular heat sink plates were designed to achieve the maximum thermal performance of the solar water heater and then thermally measured, and then examined according to the heat transfer and friction characteristics of the solar wind water heater tube.

Index Terms **- Configuration, efflux, flat plate collector, friction, heat, insulation, reflector, roughness, solar air heater**

I. INTRODUCTION

1.1 Solar Energy

Solar energy is the first energy source found in nature. It not only provides heat or light energy, but is also responsible for life on earth. The sun is the source of other energies. Many harvestings equipment and facilities are installed and operating to use solar energy, so this large amount of energy is often used in the largest possible way, thus reducing the consumption of non-continuous supply. The use of solar energy depends on its properties, which are its electrical properties. Its density and variability over space and time are important for planning solar energy devices.

1.2 Solar Thermal Collector

Solar thermal collectors are mainly used to generate electricity and power. These collectors come in various configurations but flat plate collector is widely used.Flat Collector (FPC), forms the basis of solar energy harvesting systems and is designed to operate at temperatures from ambient to 60°C or medium temperature from ambient to 100°C.Flat plate collectors provide heat for a long time at low temperature. cost. The flat plate collector is an electronic circuit that converts the electrical energy of solar radiation into the efficiency of the working fluid (liquid or air). The advantage of using mounting plates is that they can collect both light and different electrical currents. It works with high performance, low maintenance and installation cost with long service life. It has been seen that solar collectors have a low convective heat constant between the air and the absorber plate on account of the boundary layer formation on the absorber plate

II. LITERATURE REVIEW

Before beginning our research, comprehensive literature survey was done. Enormous amount of literature is available on the comparative analysis between with and devoid of surface roughness. In the first paper investigation of flat plate, v-corrugated and finned air collectors was initially performed by[1].It was concluded that Efficiency of v-corrugated collector was greater than flat plate collector efficiency and Efficiency of flat plate collector was greater than and the v-corrugated.[2] experimentally investigated the effect of external recycle on the performances of flat-plate solar air heaters with internal fins attached and concluded that efficiency enhancement Was 65.28% at air flow rate of 0.01kg/s.[3] did experimental performance of single and double pass solar air heater with fins and steel wire mesh as absorber. It was concluded that efficiency was increased with increasing the air flow rate. Use of Absorber-steel wire mesh layers increases the efficiency of double pass air heater than single pass air heater for the same mass flow rate.[4]got comprehensive performance evaluation and parametric studies of single pass solar air heater with fins and baffles attached over the absorber plate and concluded that increase in the outlet temperature and efficiency and increasing the number of fins and baffles width reduces the effective efficiency.[5] studied the performances of the friction factor and the heat transfer for a solar air heater by using U-shaped ribs.The results proposed that the value of Reynolds number 3800 enhanced the Nusselt number by 2.3 times and friction factor by 2.5 times as compared to the smooth absorber plate. The results were compiled to derive the correlation for the values of the friction factor and the heat transfer coefficient.[6] studied the inclined ribs of square cross section. In this experiment, he studied the effect of the gap between the roughness ribs.

He showed that the heat transfer rate has increased from 2.3 to 2.6 times that of the smooth absorber plate and thus produced the correlation for solar air heater having square wire ribs.[7] did the experiment on the broken ribs for the enhancement of the various performance parameters of the solar air heater the broken ribs were at 90° to the air flow thus offering a blockage to the air. The results showed that the heat transfer rate has been increased by 1.3 to 1.5 times as compared to the smooth absorber plate under the similar conditions.[8] investigated the inclined ribs at various angles which showed that the heat transfer is more optimised at 60° inclination angle and the friction factor is maximum at the angle of 70° and generated correlation for the heat transfer and the friction factor for the solar air heater.[9] experimental investigation on the inclined ribs at 60° angle with a varying pitch and height of the rib. He reported the performance parameters of the solar air heater were optimized as compared to the smooth plate. He made the correlation between the various characteristics of the solar air heater.[10] studied the solar air heater by working on the discrete inclined ribs the inclination angle taken is 60°. He reported that heat transfer coefficient has been enhanced. Considering this enhancement in the heat transfer coefficient he proposed the correlation for the solar air heater having discrete inclined ribs.[11] studied the experiments on the combination of inclined and transverse ribs in the solar air heater duct. He studied and reported that for this type of roughness ribs. The optimum results can be achieved at a pitch value of 8 and roughness height value of .03. He optimised his result for the heat transfer and the friction factor.[12] experimentally worked on heat transfers coefficient friction factor in a rectangular duct, when a roughened discrete V-rib absorber plate is used in the solar air heaters, the results found are more efficient than that of smooth absorber plate with result that the Nusselt number has shown a huge hike at a gap position of 0.65 which is up to 3 times more than the smooth absorber plate.[13] experimentally investigated the expanded wire mesh roughness experimentally and reported its correlation and inferred that the Nusselt number and friction factor values were 4 to 5 times to the smooth absorber plate under the similar conditions.[14] studied the dimple shaped geometry of the roughness sheet and optimised the results for the friction factor and heat transfer coefficient. He reported that the favourable values of heat transfer were achieved at relative roughness height of 0.037 and the relative roughness pitch of 10 in the solar air heater duct.[15] study the effect of relative roughness height and pitch on the friction factor and the heat transfer in turbulent flow. He studied this experimentation to enhance the performance parameters of the solar air heater. He used wire protrusions on the GI plate as a roughness rib. The roughness ribs were vertical i.e. at 90° to the flowing air.[16] Experimental study of [17] revealed the inclined ribs and reported that the results are much more optimised and shows a huge increase in the heat transfer rate. This also showed that the turbulence in the flowing air is also much more than that of the vertical/perpendicular ribs and studied the effect of discrete W-shaped ribs and its effects on the friction factor and heat transfer characteristics the results reported that the Nusselt number was increased by 2.1 times and the friction factor was optimised by 2.7 times as compared smooth absorber plate when the angle of attack kept at 60°[18] worked on a solar air heater to study the effect of embedded wedge-shaped roughness fins. He prepared the data and derived correlations including coefficient of friction and heat transfer. The adopted Reynolds number ranges from 3000 to 18000, the change in roughness height is from 0.015 to 0.033, and the change in relative roughness pitch is from 12.12 to 60.17, and the results show that the heat transfer is much greater compared to the flat absorber. bowl.[19], the effect of ribbed artificial roughness on the heat transfer and friction coefficient of solar air heater ducts was studied.The report states that the Nusselt number increased 2.5 to 3.5 times compared to a smooth plate.[20] experimentally investigated the geometry of arcuate roughness and its influence on the heat transfer coefficient and friction coefficient of a rectangular duct solar air heater. As a result, it was found that the friction coefficient and heat transfer coefficient increased by 1.75 times and 3.6 times, respectively, compared to the flat absorber plate. The arc angle was 0.333 and the relative roughness height was 0.042.[21] studied the heat transfer friction factor characteristics of the solar air heater with a protrusion type roughness. The experiment was carried out with a wide range of Reynolds number ranging from 4000 – 20000. Relative short wave length 18.7 – 37.5 and the relative long wave length 25.0 – 37.5mm. The relative roughness height and the duct aspect ratio values were taken as 0.03 and 10 respectively.[22] studied the experimentation of the solar air heater to enhance the performance parameters. He worked on V-shaped roughness ribs on a huge range of Reynolds number varying from 2500 to 18000. He also varied the roughness height ranging from 0.02 to 0.034 and the angle of attack ranging from 30° to 90°

On the basis of the above discussed literature, it was found that the plane absorber plate and circular shape with aluminium wire geometry has not been used by any of the researchers till date. Therefore, this experimental study was conducted to determine the effect on the roughness of the flat absorber plate and circular shape using aluminum wire.

III. EXPERIMENTAL SET UP

The solar air heater is used for preheating the air. Its setup is shown. A solar heater is a solar device that collects solar energy and then focuses it on a rough surface, first heating it and then transferring the heat to the air through the duct pipes when it is cold. A schematic diagram and photographic view of the experimental setup is shown in Fig1

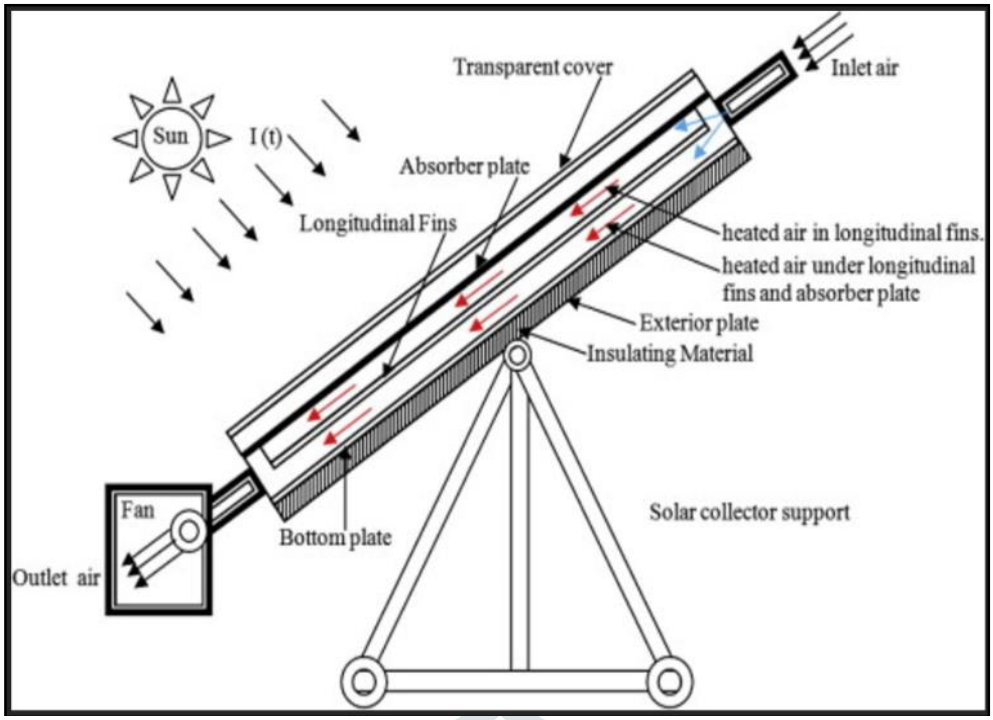

Fig.1 Experimental set-up

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Table 1. Solar Device Specifications

S.No	Item/Components	Dimension
1	Inner Sheet (MS)	2x1 m
2	Thickness of MS sheet	16gauge
3	Rockwool inserted within sheet	50mm both sides
4	Insulation sheet (Al) Thickness	0.5 mm
5	Absorber sheet thickness	0.75 mm
6	Glass covering on top thickness	8mm
7	Thermocouple range	50-200°C
8	Angle of inclination of assembly	45°C

3.1 Roughness production on plates

Aluminum sheets are used to fix roughness shapes to them. The 0.75mm flat absorber sheet adopts a circle and is made of 0.05mm size aluminum paper. The roughness is applied to different sizes of wafers so that the wafers could be different for different tests. The roughness geometry was corrected with the help of fevicol SR 998. It is easily available in the market and is not expensive. This adhesive is ideal for this purpose because it has excellent thermal properties, ensuring it remains stable in the tube when heat directly affects the paper.

3.2 Rockwool insulation

Rockwool insulation alludes to a kind of insulation that is produced using real shakes and minerals. An extensive variety of items can be produced using rockwool, because of its incredible capacity to piece sound and heat.

Fig 2.Rockwool Insulation

The desirable attributes of a protecting material are: low warm conductivity, stability at high temperature (upto 200°C), no degassing upto around 200°C,self-supporting element without inclination to settle, simplicity of use, no commitment in erosion. Rockwool have been used as insulation material in this project due to its better self -supporting feature. Rock-wool of thickness 100 mm is used to insulate underneath of the collector and 50 mm around the wall of collector.

3.3 Aluminium sheet

Rockwool insulation is covered with aluminium sheet of thickness 0.5mm in order to protect the blow of insulation.

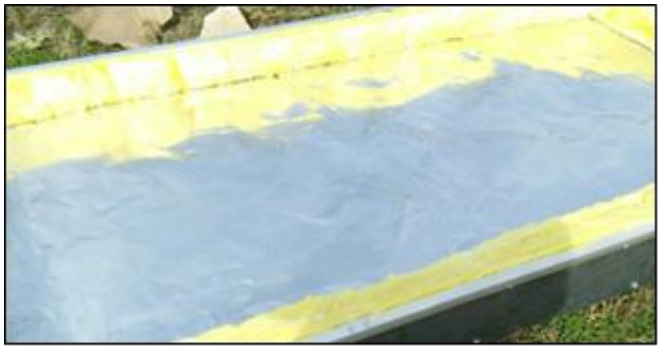


Fig 3. Aluminium Sheet

Sheet metal is metal formed by an industrial process into thin, flat pieces.It is one of the fundamental forms used in metal working and it can be cut and bent into a variety of shapes. Aluminium is also a popular metal used in sheet metal due to its flexibility, wide range of options, cost effectiveness, and other properties.

3.4 Glass (Cover plate)

Fixing the glass of 8mm and the distance of the glass and the absorber plate is 2 inches. The most basic factor for the cover plate material are the quality, toughness, non-degradability and sunlight based transmittance. Glass has been widely used for glazing purpose in solar collectors because it can transmit as much as 90% of incoming short wave solar irradiation while transmitting virtually none of the wave radiation emitted outward by the absorber plate.

Fig 4. Glass

Toughened or tempered glass is used due to its proven durability and stability against UV radiation. Also, it is strong enough to sustain breakage from thermal cyclic as well as natural events. Glass of 8 mm thickness is used as glazing cover in this experimental study. The whole glass is supported by the aluminium frame, which is then attached to the collector casing.

3.5 Reflector

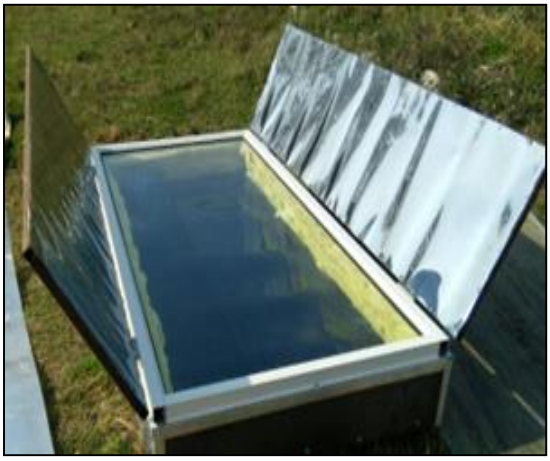


Fig 5.Reflector

Reflector is a device that causes reflection (for example, a mirror or a retro reflector) Reflector is attached with the glass and the angle of the reflector is 45°

Fig 6. System standing at an angle 45

3.7 Thermocouple

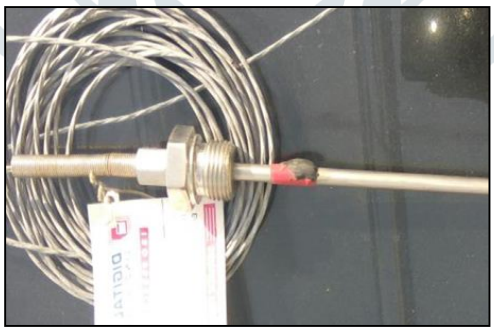


Fig 7. Thermocouple

A thermocouple is an electrical device consisting of two different electrodes that produce electric current at different temperatures. Due to the thermoelectric effect, thermocouples produce a temperature and this voltage can be interpreted as a temperature. The thermocouple is a widely used thermometer. temperature measurement using a K type thermocouple, the temperature range is -50°F to 200°F.The selector switch is the controller and display device for temperature measurement. The thermocouples are placed equidistant from each other so that we have balanced temperature values. The values are to be evaluated separately for the plate temperature and for the air temperature.

3.7 Air blower

Fig 8. Air Blower

Air Blower Blowers are turbomachines which convey air at a desirable high speed (and in like manner at a high mass flow rate) but at a moderately low static mass. The primary motivation behind fans is to move large amounts of gas or vapor at eye-watering speeds. The weight gain of the fan is very small, only a few millimeters of water depth is required. The static size of the blower is slightly higher, 1000mm above the water column; this must overcome the weight loss as the oil passes through the gap.

Solar Power Meter

Fig 9. Solar Power Meter

Solar power meter is a device that converts the energy from sunlight into electrical energy. Basic solar power systems use lenses or mirrors and tracking systems to focus large areas of sunlight into small beams. Photovoltaic cells use the photovoltaic effect to convert light into electric current.

3.9 Data Logger

A data logger (also datalogger or data recorder) is an electronic device that records data over time or in relation to location either with a built-in instrument or sensor or via external instruments and sensors.

Fig 10. Data Logger

Increasingly, but not entirely, they are based on a digital processor (or computer). They generally are small, battery powered, portable, and equipped with a microprocessor, internal memory for data storage, and sensors. Some data loggers interface with a personal computer, and use software to activate the data logger and view and analyze the collected data, while others have a local interface device (keypad, LCD) and can be used as a stand-alone device.

IV. Results and Observations

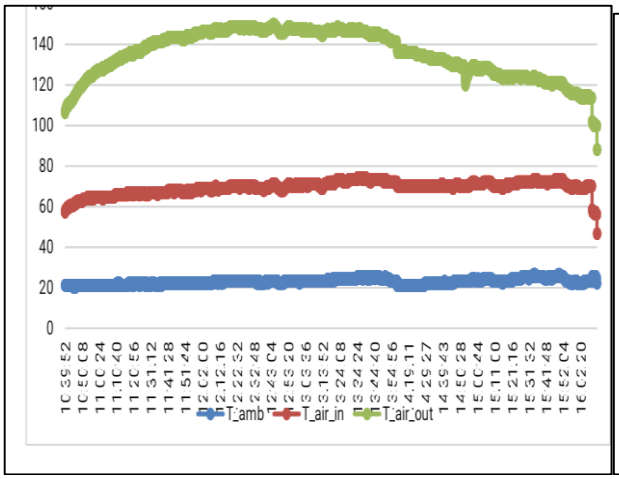
Data from Data logger was analysed and compiled for seven consecutive days. The data depicts the variation of temperature of solar plate collector with the passage of time

Table 2. Variation of temperature on solar plate collector with time

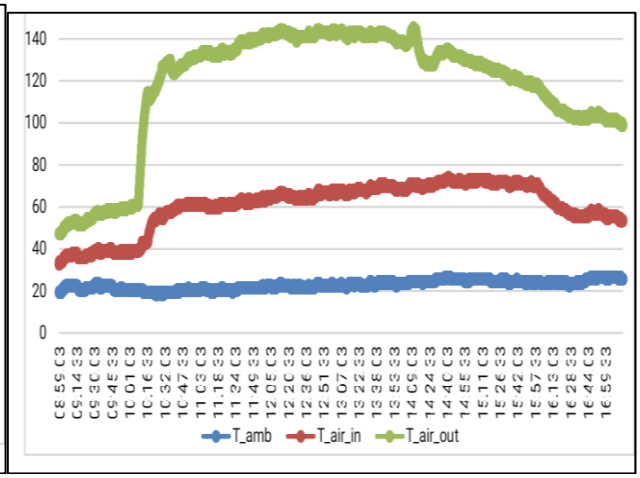
Time	T_{amp}	Inlet T_{air}	Outlet T_{air}
10:00 am	20	52	103
11:00 am	21	61	137
12:00 pm	22	66	143
1:00 pm	22	67	151
2:00 pm	22	70	142
3:00 pm	22	69	133
4:00 pm	23	68	121

This variation was studied for consecutive five days and then graphs were plotted from the data acquired through data logger device. Then energy efflux rate variation with or without reflector was studied and graphs were plotted accordingly.

4.1 Variation of Temperature with time for consecutive five days



Day 1



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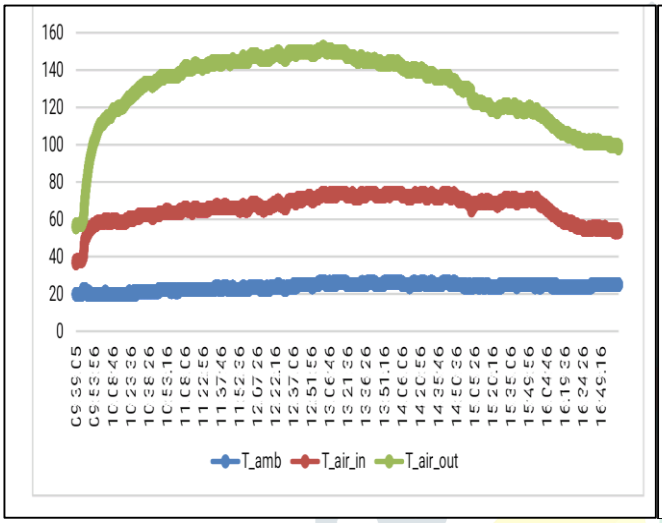

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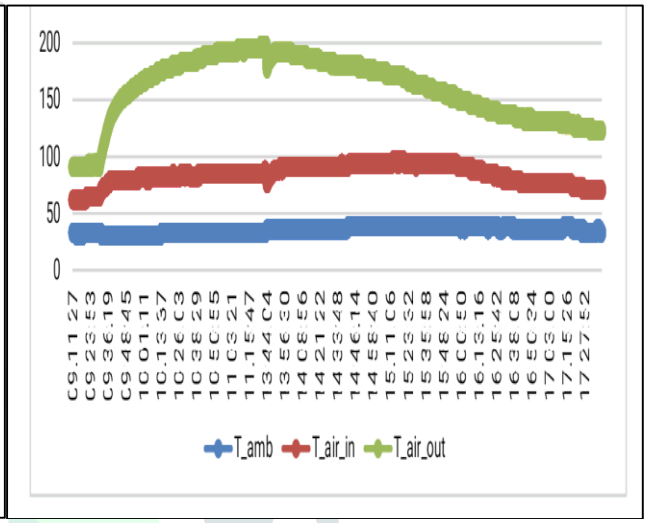

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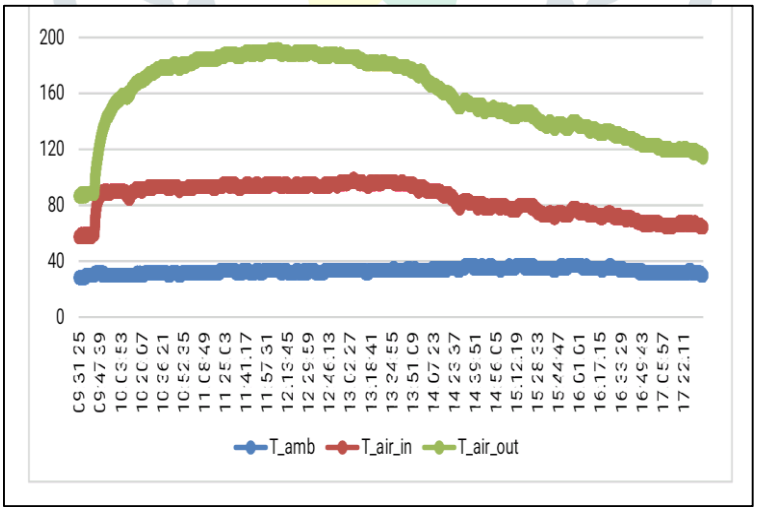
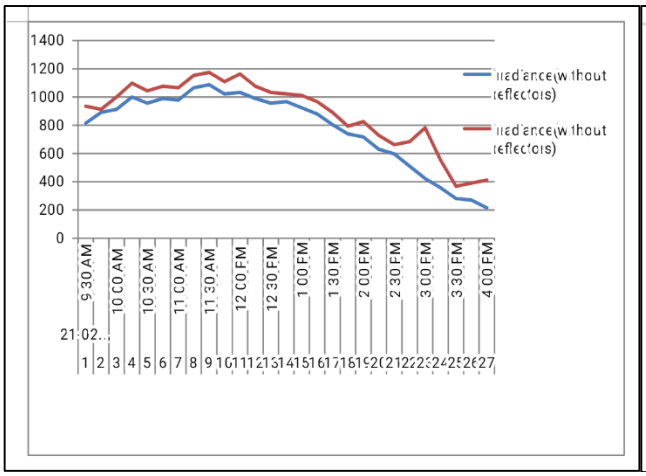


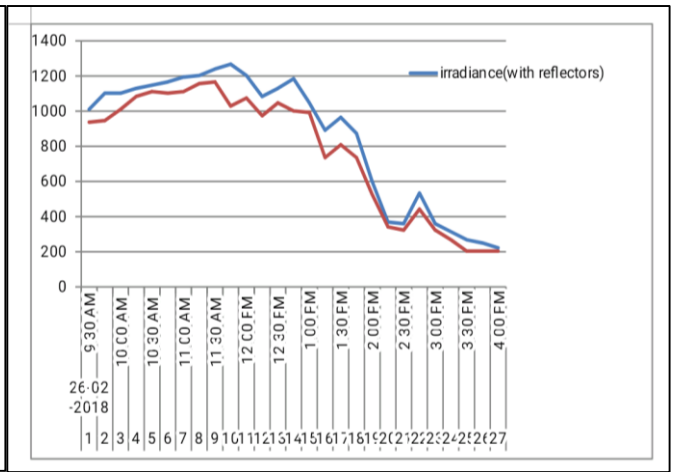
Day 5

Fig.11. Variation of Temperature of Surface of collector for five days

4.2 Varaiation of Energy Efflux with time with and without reflectors



Day 1



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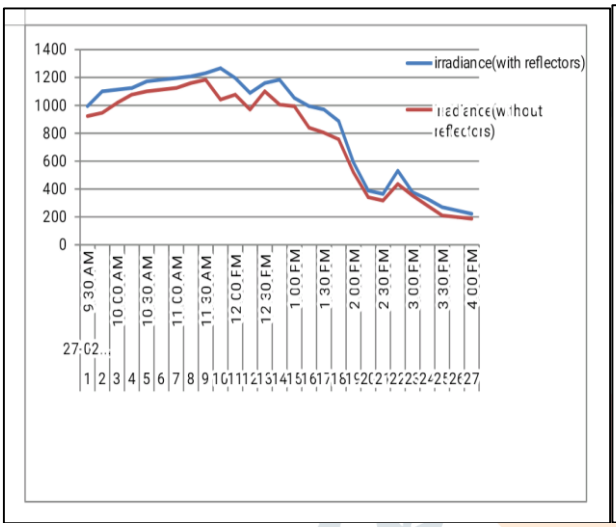
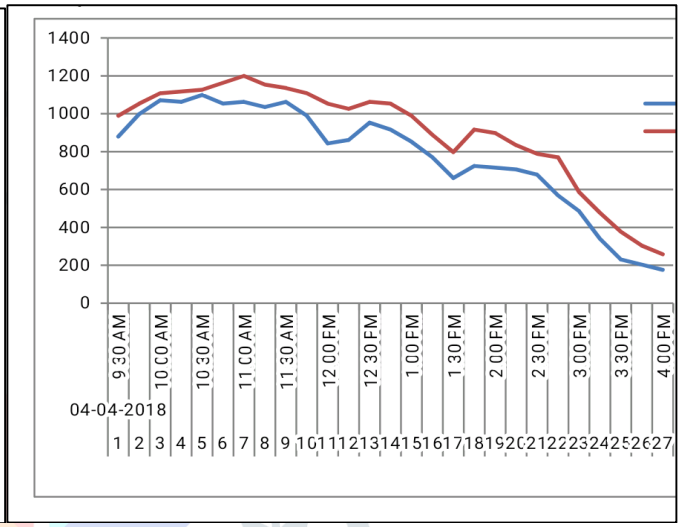
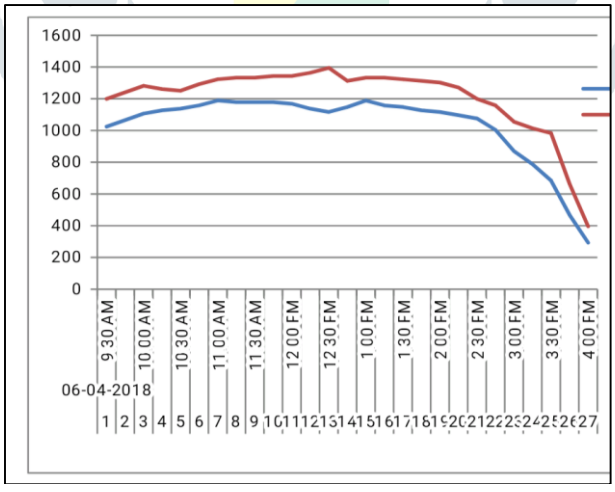


Day 3



Day 4



Day 5

Fig.12. Variation of Energy efflux rate from collector for five days

V. CONCLUSION

This research paper is an attempt to review the heat transfer and friction factor characteristics of roughened solar air heater. Performance enhancement of the roughened ducts was thoroughly studied. In addition to it, the effect of the flat absorber plate and circular shaped roughness ribs on the absorber plate on energy efflux rate was analyzed. The investigation resulted revealed that the heat transfer and the friction factor were enhanced. Various conclusions that can be drawn are given below:

- Many types of roughness geometries are there, which can be used to enhance the heat transfer and friction factor coefficient of the solar air heaters.
- Roughness geometry can be created on the absorber plate by gluing the ribs on the plate and punching or protrusion. Generally done by fixing or gluing aluminium sheet on the absorber plate.
- General types of roughness geometries discussed and studied in literature are V-type, discrete V-type, wire mesh type, dimple forming etc.
- Providing angle and proper pitch to the ribs, results in more turbulence in the flowing air, which ultimately results into higher heat transfer and friction factor coefficient.
- The thermo-hydraulic performance has been found optimum in cases when roughened absorber plate is used.

VI. Future Scope

The research work focused on energy efflux rate variation with surface roughness of absorbing plate. The research may be extended in future for following

- The energy analysis can be done, so that its losses can be determined and can be minimized.
- Combination of more than one roughness geometries can be investigated to study its characteristics.
- The cost effectiveness can be studied to make the investigation cheaper.

VII. Acknowledgment

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