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Experimentation on Solar Air Heater with V Shaped Artificial Roughness

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ABSTRACT:In this paper the effort has been made to increase the thermo hydraulic performance and heat transfer enhancement of air which is pass through solar air heater provided with artificial roughness having the Relative roughness pitch (p/e) of 1.428 , Relative roughness height (e/D) of 1.75 , Aspect Ratio of 10 and Angle of attack (α) is 120° .The mass flow rate of air which is send to collector is ranges from 0.002 kg/s – 0.004 kg/s. The Reynolds number varies from 40,000 – 64,000. The test conducted for the solar air collector at various tilt angle of 10° , 20° , 30° with a velocity of 20 m/s and 25 m/s. The effective efficiency has been computed based on the experimentally determined values for the range of parameters considered. Further an attempt has been made to optimize the thermal efficiency for the system under similar conditions.

KEYWORDS:Artificial Roughness, Relative Roughness Pitch, Relative Roughness Height, Aspect Ratio, Angle of Attack.

I. INTRODUCTION

Solar air heater is one of the basic equipment through which solar energy is converted into thermal energy. The solar air heater has an important place among solar heat collectors. Solar air heater is a device to produce hot air for any industrial or farmer level drying applications by using freely available Sun, without using any conventional fuels like electricity, diesel, LPG, firewood, coal, etc., But It could be coupled with an existing conventional drying systems like Tray driers, Tunnel Driers, Conveyor Drier, FBD drier and bin drier operated by conventional fuels to save fuel consumption.

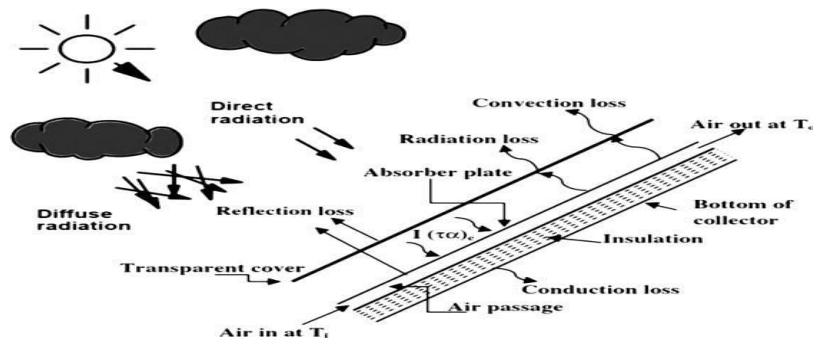


Figure 1. Solar Air Heater

1.1 ARTIFICIAL ROUGHNESS

Artificial roughness is basically a heat transfer enhancement technique by which a thermo hydraulic performance of solar air heater can be improved. The thermal efficiency of solar air heater is generally poor due to low heat transfer co-efficient between the absorber plate and the air flowing in to the duct due to the formation of laminar sub layer on the absorber plate which acts as heat transferring surface.

1.1 Geometrical Parameters

The basic dimensionless geometrical parameters that are used to characterize roughness are as given below

- Relative roughness pitch (p/e)
- Relative roughness height (e/D)
- Angle of attack (α)

- Aspect ratio

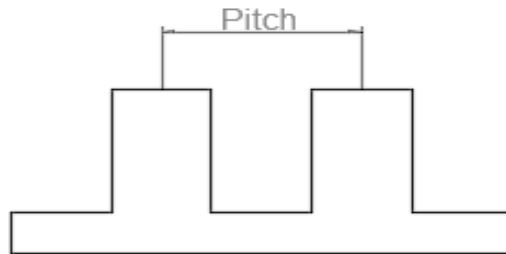


Figure 2. Relative Roughness Pitch

Relative Roughness Pitch: Relative roughness pitch (p/e) is defined as the ratio of distance between two consecutive ribs and height of the rib.

Relative Roughness Height: Relative roughness height (e/D) is the ratio of rib height to equivalent diameter of the air passage.

Angle of Attack: Angle of attack is inclination of rib with direction of air flow in duct.

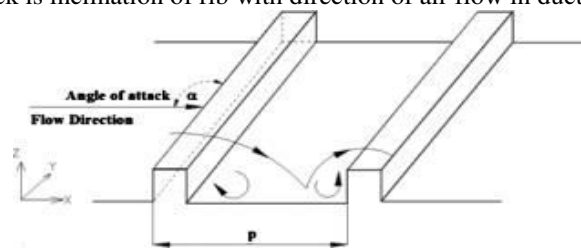


Figure 3. Angle of Attack

Aspect Ratio: It is ratio of duct width to duct height. This factor also plays a very crucial role in investigating thermo-hydraulic performance.



Figure 4. Aspect Ratio

II. RELATED WORK

In this chapter, an extensive review of literature in the area of solar air heater system, with special reference to thermal storage materials, natural and forced convection SAH systems, energy and exergy analysis, ANN modelling techniques, is presented. There are several schemes that can be implemented to enhance the thermal performance of the energy collection devices. These methods, along with their enhancement potential are discussed in this chapter.

Ali Najah Al-Shamani et al. (2014) Numerical study of heat transfer due to turbulent flow of nanofluids through rib-groove channel have been investigated. The continuity, momentum and energy equations are solved by the finite volume method (FVM). Four different rib-groove shapes have been examined. Four different types of nanoparticles, Al_2O_3 , CuO , SiO_2 , and ZnO with different volumes fractions in the range of 1–4% and different nanoparticle diameter in the range of 25–70 nm, have been also studied. The computations are performed under constant temperature over a range of Reynolds number (Re) 10,000–40,000. Results indicate that the Trapezoidal with increasing height in the flow direction rib-trapezoidal groove has the best heat transfer rate and high Nusselt number.

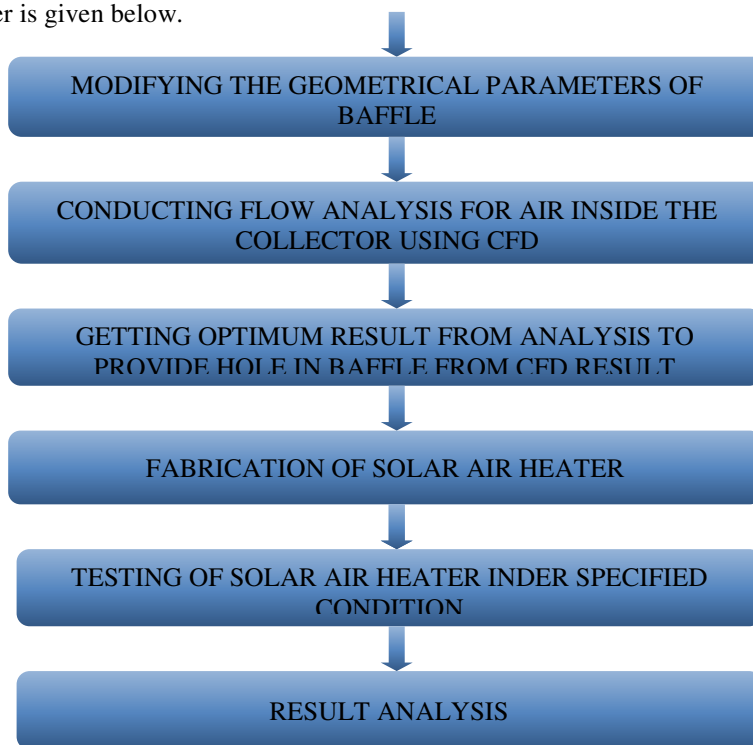
Anil Kumar Patil et al. (2017) the thermal performance of solar air heater can be improved by the application of artificial roughness on the underside of absorber surface. An attempt has been made to compare the performance of solar air heater having different types of roughness geometries based on correlations proposed in the literature. Thermo-hydraulic performance parameter (η), thermal efficiency (η_{th}), thermal efficiency improvement factor (TEIF), effective efficiency (η_{eff}), and exergetic efficiency (η_{ex}) are evaluated to gauge the performance of different roughness geometries.



Anil Singh Yadav et al. (2014) The use of an artificial roughness on a surface is an effective technique to enhance the rate of heat transfer to fluid flow in the duct of a solar air heater. Correlations for heat transfer and friction factor, developed by various investigators for artificially roughened solar air heaters have been reported in this article. The effects of various rib parameters on heat transfer and fluid flow processes are also discussed. Circular fins are mostly used to absorb solar radiation and send that heat to air, by this the air can easily slip due to hitting at its polished semi circular face at its flow direction. Net structure is used as a roughened surface for air flow to improve heat enhancement by our project's assumed height (70mm) .Plane wall structured baffle is mostly used as roughness shape. Due to plane shaped baffle, air cannot diffuse itself inside the collector. Aluminium is preferred for absorber plate and baffle, because copper has embrittlement property. Embrittlement property causes brittleness of absorber and baffle and reduces the life time of the same. Design of absorber and baffle plate using copper is not economical one. From the literature survey find out the enhance the heat transfer by providing V- Type diffuse shape at collector's inlet baffle. Create more turbulent action of air inside the collector to receive more radiation by dropping of velocity using diffusing process of air. Provide more holes at baffle in a same pitch for flow of air pass through baffle. improve the efficiency of collector by using reduce the gap between baffle tip and Glass cover, because due to providing more space between baffle hot air can settle at top of collector and take some risk and needs more external force to blow out. Provide single perfect glazed glass cover to avoid more reflection and improve the transmittivity of radiation from atmosphere to collector.

III. METHODOLOGY

The main objective of our project is to fabricate Solar Air Heater by providing V – Type baffle fixed on absorber plate to enhance the rate of heat transfer and improve the efficiency of the collector. The flow chart of our project to improve the heat transfer is given below.



IV. EXPERIMENTAL RESULTS

This Experiment consists of the following parts such as given below

- Blower
- Gate valve
- Solar collector



- Thermocouples
- Air hose



Figure 5. Experimental Setup

Construction

Blower: Blower is an electro mechanical device which produces high pressure air than the normal atmospheric pressure to blow the air in to require applications. Centrifugal blower is used to blow air in to collector.



Figure 6. Centrifugal Blower

Gate valve: A gate valve, also known as a sluice valve, is a valve which opens by lifting a round or rectangular gate/wedge out of the path of the fluid. Gate valves are used to permit or prevent the flow of liquids, and are typically for on/off control rather than flow regulation.

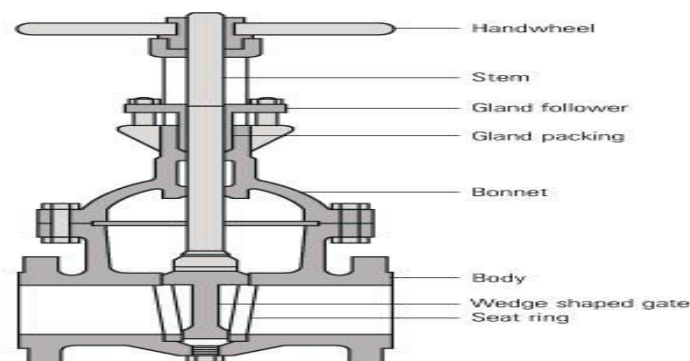


Figure 7. Gate Valve

Solar collector: A solar collector is a device that collects and/or concentrates solar radiation from the Sun. These devices are primarily used for active solar heating. Solar air collector can heat the air flow inside the air by using absorber and baffle plates.



Figure 8. Solar Collector

DESIGN PARAMETERS OF SOLAR COLLECTOR:

The Following are the design parameter which should be considers before design the solar collector. They are as given below:

Heat transport system: Heat obtained by solar energy is passed in to collector by perfect glazed glass cover. Then the heat at top surface of glass cover is passed to absorber plate and baffles by radiation. The air passing through the collector receives heat from glass’s bottom surface, baffle and absorber by convection. The heat transfer from absorber plate to baffle is done by conduction.

Selective surface: Selection of surface is one of the important parameter to design the solar collector. The Non-Reflection blackened paint is used to apply on surface of absorber and baffle plates. Because, as per Stefan – Boltzmann law of radiation black body absorb more heat than other. Aluminium is used as material for design the absorber plate and baffles. Aluminium has low thermal conductivity than copper, but aluminium has more life time and economic one.

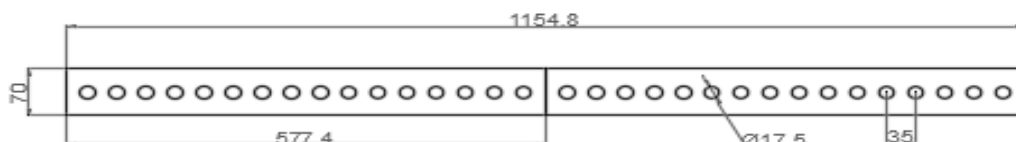
Number of covers: Perfect glazed single glass cover is used as top cover in project, because it has more transmittivity & absorptivity and less reflectivity to the collector. The Glass cover has a thickness of 5mm is used at top.

Spacing / sizing of collector: For any collector energy obtained from solar radiation is mainly depends upon its size. More energy can be obtained by providing large size collector, if the collector size is less the energy attainment will be less. 1m Width, 1.5m Length and 100 mm high collector is used in the project to collect more heat energy to heat the air.

Baffle arrangement

The test is conducted for the various set of baffles having hole diameter of 17.5mm, 35mm & 52.5mm fixed on the absorber plate as given below:

>17.5mm diameter holed baffle set



Digital Thermocouple: A Thermocouple is a sensor used to measure temperature. Thermocouples consist of two wire legs made from different metals. The wires legs are welded together at one end, creating a junction. This junction is where the temperature is measured. When the junction experiences a change in temperature, a voltage is created.

4.1 Experimentation Conducted without baffles in Absorber plate:

When the experimentation was conducted without baffles the efficiency is about ranges from 46.2 % to 51.8 %. The temperature and radiation plot of the readings are as given below

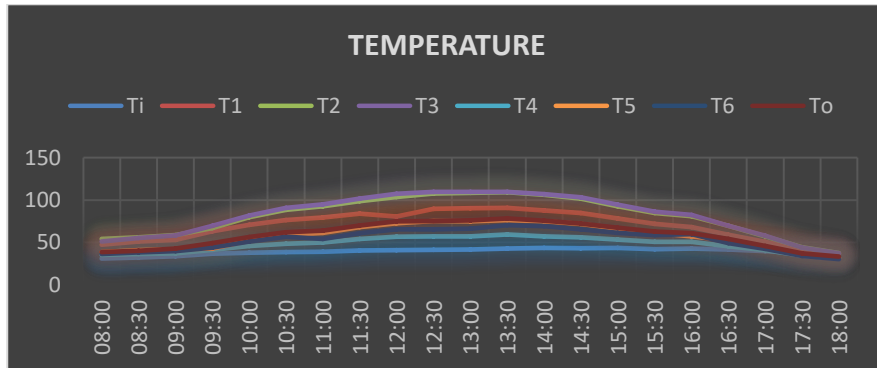


Figure 10. Time vs Temperatures

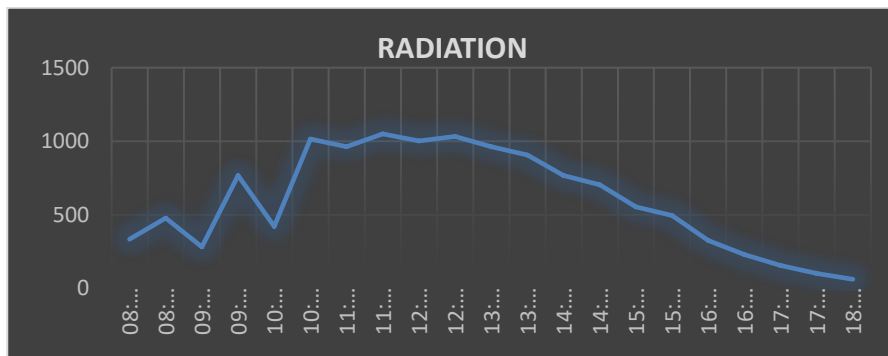


Figure 11. Time vs Radiation

4.2 Experimentation Conducted with baffles in Absorber plate:

When the experimentation was conducted without baffles the efficiency is about ranges from 58.1 % to 62.4 %. The temperature and radiation plot of the readings are as given below

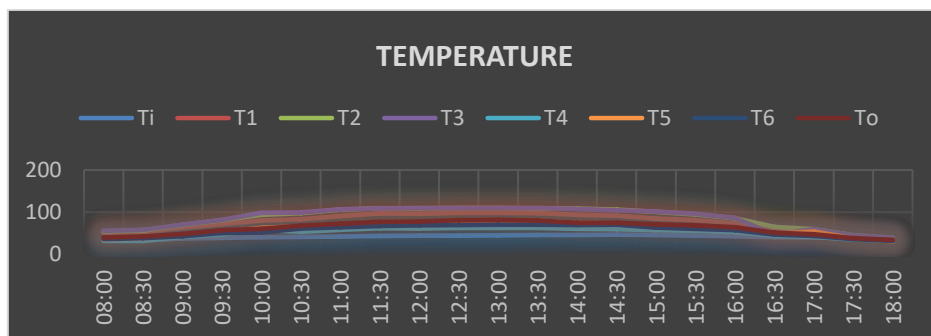


Figure 11. Time vs Temperature

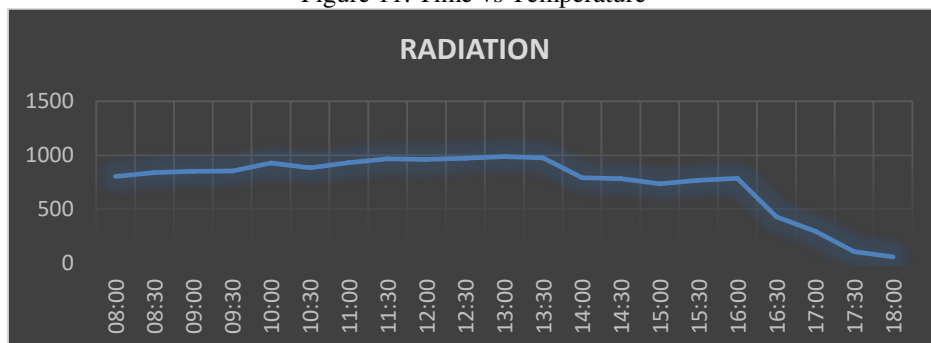


Figure 12. Time vs Radiation

Baffle hole size vs Useful energy gain:

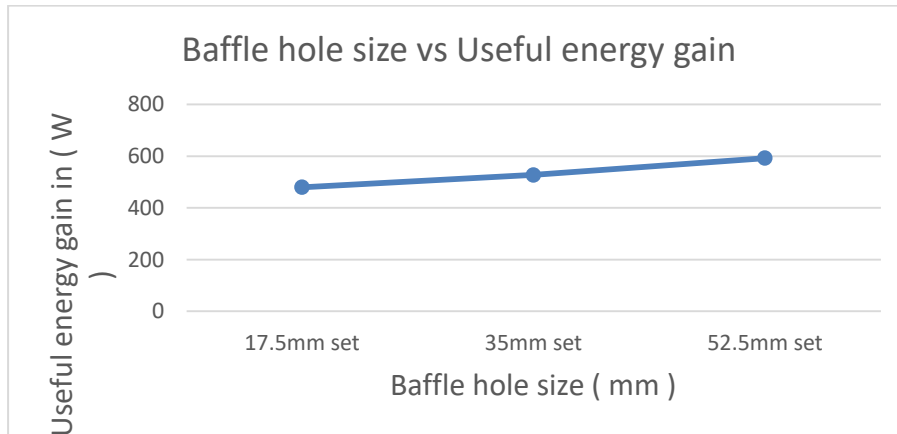


Figure 13. Baffle hole size vs Useful energy gain

Figure 13. Shows the amount of Useful energy gain with respect to the size of hole in baffle which is fixed on absorber plate.

- For 17.5mm hole baffle set the amount of heat gain is about 479.57W
- For 35mm hole baffle set the amount of heat gain is about 527.78W
- For 52.5mm hole baffle set the amount of heat gain is about 592.7W

Baffle hole size vs Efficiency:

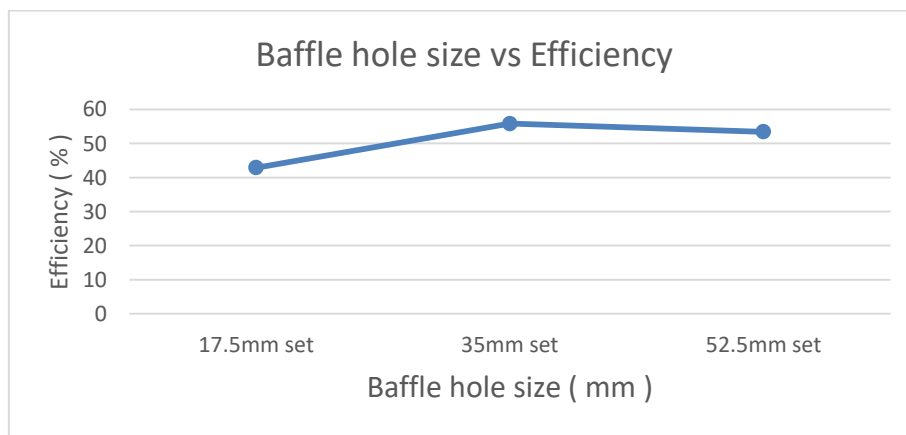


Figure 14 Baffle hole size vs Efficiency

Fig 14. Shows the Efficiency of Solar Collector with respect to the size of hole in baffle

- For 17.5mm hole baffle set the Efficiency is about 42.92 %
- For 35mm hole baffle set the Efficiency is about 55.86 %
- For 52.5mm hole baffle set the Efficiency is about 53.44 %

V. CONCLUSION

The performance analysis of the solar air heater with Artificial Roughness has been obtained. Baffles having the height of 70mm provided with various sizes of holes are used as artificial roughness fixed on absorber plate to improve the performance of the solar air heater. The test is conducted for the various hole diameter provided in the baffle such as 17.5mm, 35mm & 52.5mm. There is a considerable Enhancement in the effective efficiency of solar air heaters having Baffle type of roughness elements. Solar air heaters having baffles as roughness element is found to have better effective efficiency in the higher range of Reynolds number.

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