Effect of Reynolds Number and Angle of Attack on Heat Transfer Coefficient of Solar Air Heater using Inclined Square Shaped Ribs on the Absorber Plate

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Abstract— An experimental investigation has been carried out to study the heat transfer coefficient by using artificial roughness in the form of specially prepared square shaped inclined roughness on the absorber plate of an air heater. The roughened surface is uniformly heated while the remaining three walls are insulated. These boundary conditions corresponds closely to those found in solar air heaters. The experiments having Reynolds number ranging from 3000 to 8000.the angle of attack of flow on roughness=150,300,450,600is used in the experiment. The heat transfer data obtained is compared with the data obtained from smooth duct under similar geometrical conditions.

Key words: Solar Air Heater, Artificial Roughness, Heat Transfer Co Efficient

I. Introduction

In heat transfer air is usually used as a working fluid in various types of power exchange system. It also plays a significant role as the hot air the absolute recipient of energy. The flat plate collectors is supirer for heat the air, but in compare to liquid solar collectors. The major application of this solar air heater is not been developed in world wide. The air is commonly used as a working fluid flat plate collector, in that case eliminates the essential for heat ex-changer. It usually in use to transfer the heat from water to air into an liquid flat plate collector.

The most important variation among liquid flat plate and air collectors is one of the mode of heat transfer among the absorber plate & heat transfer fluid. The finest form of liquid flat collector is commonly use of fin type in structure, the absorbed heat is transferred to the liquid tubes by conduction. In air collectors, the air flow can be contact with entire absorbs the air by flat plate surface. The conductivity of the plate is of little meaning as well no decay of the absorber plate and aluminum plates can be easily used. The solar air heater naturally cheaper, The advantage of the solar energy is it is available in naturally reduce its cost and also it is a renewable energy.

The law of solar air heater is almost same as to liquid flat plate collector. The air is distributed in make with contact of black radiation surface, which is commonly overlay by one or more number of apparent covers to reduce the heat loss. In convenient and technical reason , the store heat is usually transferring to pebble bed once it not required; night air heating is consuming by passing cool air throughout the warm pebble bed.

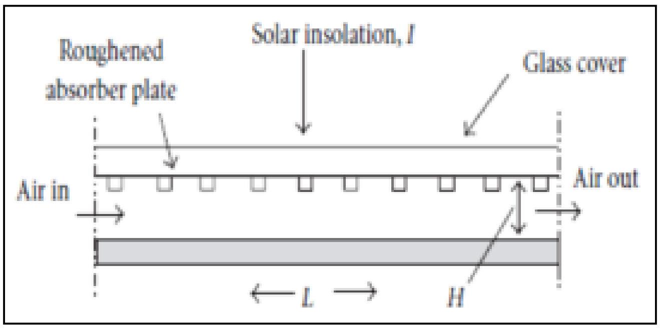

Fig. 1: typical solar air heater with extended surface

Figure 1 shows the typical solar air heater with roughened absorber plate with glass cover on the top where air is flowed into the apparatus the heat is transferred from the absorber plate with roughened surface to air.

The main difference between liquid flat plate collectors and air collectors is the mode of heat transfer between the absorber plate and the heat transfer fluid. In the best type of liquid flat plate collector, which generally makes use of a fin type construction, heat absorbed is transfer to liquid tubes by conduction. Therefore, a sheet of high thermal conductivity is required to work as an absorber plate in the case of liquid flat-plate collectors. For air collectors, where the air stream can be in contact with the complete absorbing surface, the plate conductivity is of small importance. Also, there is no corrosion of the absorber plate and hence light gauge steel or aluminum plates can easily be used. Hence, a solar air heater appears to be inherently cheaper and can last longer. Unlike liquid flat-plate collectors, the system is not pressurized and therefore, light gauge metal sheets can be used. In solar-air heaters leakage is also not big problem, unlike in liquid collectors. Sometimes even waste materials and other buildings can be used for designing air heaters. Air collectors require less plumbing and there is no danger of freezing. The relative simplicity of air systems is attractive to persons who wish to build their own system, but as with all systems of collecting, storing, and using the sun's energy, their precise design is difficult. Most of such systems, except the simplest of systems, must be designed by someone, knowledgeable in simple mechanics and heat surface need not be metal. Since, in many collector designs air comes in contact with the same surface to another, as is the case with the absorber plate for liquid collectors. Almost any blackened surface which is heated by the sun will transfer heat to air when the air is blown over it. This heat transfer mechanism opens up numerous possibilities for absorber surfaces.

II. LITERATURE REVIEW

A. *Sahu and Bhagoria [1]*

They varied the pitch for 90^0 transverse ribs roughness on the absorber plate, they absorbs its effects on the thermal characteristics of the solar air heater. They conducted these experiments for the Reynolds number range of 3000-12000, pitch of the ribs from 10-30mm, height of the roughness is 1.5mm. They observed Nusselt Number increases quickly at a lower Reynolds Number and it remains constant for maximum values of Reynolds Number. The maximum heat transfer obtained at the pitch of 20 mm. Experimental results gives, when using roughened surface on the absorber plate increases the heat transfer co-efficient 1.25-1.4 times compared to the smooth rectangur duct. And also increases the thermal efficiency of the solar air heater in the range of 51-83%.

B. *Momin, Saini, and Solanki [2]*

They conducted experiments by using V-shaped roughened ribs on the duct, they investigates Nusselt number increases when friction factor decreases with increases the Reynolds number. They use relative roughness height of 0.034 and α=60, V-shaped ribs increases the Nusselt Number values by 1.14 & 2.30 times more than the inclined ribs & smooth plate at a Re=17034.

C. *Bhagoria, Saini and Solanki [3]*

They use wedge shaped ribs on the solar air heater duct. The use of wedge shaped ribs obtains more enhancements in Nu about 2.4 & 5.3 times compared to smooth duct. The higher Nusselt number obtained at a e/d_h=7.57 and again it decrease with increasing the e/dh values from 7.57 to 12.12. The friction factor decreases continuously when e/d_h increases from 5.67 to 12.12.

D. *Pongjet Promvonge [4]*

They conducted the experiments to investigate the friction loss behavior of the channel. They use multiple 60^0 V-baffles. They also use three different baffle blockage ratio of 0.10, 0.20, & 0.30 and baffle pitch spacing ratio of 1, 2, & 3. The Reynolds Number ranges from 5000-2500.This experiments results gives, when using V-baffles increases the Nussels number and thermals enhancement factor compared to the smooth channel. The use of V-baffle with a blockage ratio of 0.10 increases more thermal enhancement factor of 1.87 at a lower values of Reynolds number

III. EXPERIMENTAL SETUP

Fig. 2: Experimental set up

Fig2 shows the schematic set up of heat transfer and pressure drop in a rectangular channel. The overall length of the rectangular channel is 2400mm, width is 200mm and height is 30mm. In that test section has a 1200mm, air entry section is 400mm and air exit section is 800mm.The high pressure blower is fitted with the circular pipe to the rectangular channel. The glass wool is inserted under both inlet and exit rectangular channel to reduce the heat loss to environment. Dimmer start is used to adjust the power input like voltage and current and also it maintains a uniform heat flux on the absorber plate. The control valve is mounted in between the exit section and blower to control the rate of air flow. The pressure drop across the orifice is measured by using U-Tube mercury manometer. The 10 Electric bulbs are used as a artificial heating source, each bulbs carries 60W so we get 600W of power from that bulbs. The 10 bulbs are placed on the flat surface of the chimney shaped rectangular door at 400mm height from above the absorber plate. We are used aluminum plate as a absorber plate is of length 1200mm, 200mm width and 0.4mm thickness. Aluminum Ribs are used for the artificial roughness on the absorber plate of different thickness like 1.18mm,0.87mm and 0.68mm.The schematic diagram of the aluminum absorber as shown in the below fig.

Fig. 3: aluminum absorber plate with roughness

The Twenty screw type Chromium-nickel thermocouples of (J-type) was used to measure the air as well as surface temperature at different location. In that 12 thermocouples were fixed on the absorber plate to measure the surface or plate surface temperature, 6 thermocouples were placed inside the rectangular channel where the air flow to measure the air temperature up to the test section and remaining 2 thermocouples were inserted at the air inlet and air exit section to measure the inlet and exit air temperature respectively.

IV. INSTRUMENTATIONS

A. *Pressure Drop*

The pressure drop across the orifice is measured by the U-tube mercury manometer; the diameter of the orifice plate is 20mm.

B. *Temperature Measurements*

The temperature of both air and surface measured by using J-type thermocouple at different location in the equipment, then twelve thermocouples are placed on one side of the absorber plate and six were placed inside the air flow rectangular channel and two were inserted at inlet and exit channel. These are all temperatures are displayed on the digital thermometer.

V. EXPERIMENTAL PROCEDURE

Before conducting the experiment first we should check weather all the equipment is in proper working condition. Also check weather connection of all instruments is in correct way. Then after all these, switch on the main plug and adjust the dimmer starts for a power input to maintain the uniform heat flux, it takes 1hr to heat the absorber plate after that switch on the blower to suck the air from atmosphere and flow over a roughened geometry to absorb heat from the plate, mixes both air and heat by using equidistant baffles placed in the exit section ,when it reaches constant air flow throughout the duct then note down the air and surface temperature and also at the time we take manometer reading for pressure drop across the orifice for different valve opening like 25%,50%,75%,100%.Then repeat the procedure for different power input . The parameters are needed to note down while conducting the experiment for future calculation work i.e. Inlet and exit air temperature to calculating the average bulk mean temperature for different properties of air. Surface temperature of the absorber plate. Pressure drop across the orifice orifice by using U-tube mercury manometer.

VI. DATA REDUCTION

Head developed (H) by air calculated by the relation by using density of mercury and air

$$H = x\left\{\frac{\rho_m}{\rho_a} - 1\right\} \ldots\ldots 6.1$$

Actual Discharge calculated by using area of orifice plate and area of pipe velocity,

$$Q = c_d * \frac{A_1 * A_2 * \sqrt{2gH}}{\sqrt{A_1^2 - A_2^2}} \ldots\ldots 6.2$$

Velocity of air, mass flow of air evaluated by using bellow relation

$$V_f = \frac{Q}{A_d} \ldots\ldots 6.3$$

$$m = \rho air * A_f * V_f \ldots\ldots 6.4$$

The Reynolds number based on the channel hydraulic diameter is given by,

$$R_e = \frac{\rho * V_f * d_h}{\mu} \ldots\ldots 6.5$$

Heat gained by the air is computed by inlet and exit temperature of air.

$$Q_{conv} = m * C_p * (T_0 - T_i) \ldots\ldots 6.6$$

From above result and average surface plate temperature and bulk mean temperature heat transfer coefficient evaluated From heat transfer coefficient Nusselt number

$$h = \frac{Q_{conv}}{A_p(T_s - T_b)} \ldots\ldots 6.7$$

$$N = \frac{h d_h}{k} \ldots\ldots 6.8$$

VII. RESULTS AND DISCUSSIONS

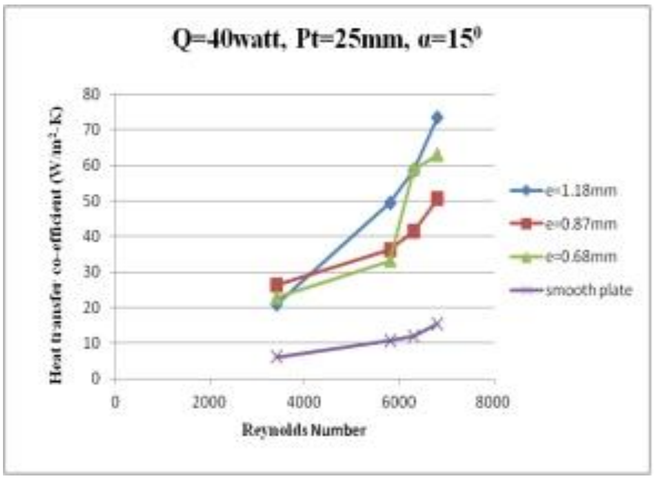

Fig. 4: shows The HTC for a constant α=15^0, Pt=25mm and power input (Q) =40watts and for also various Reynolds number (Re) and roughness height (e)

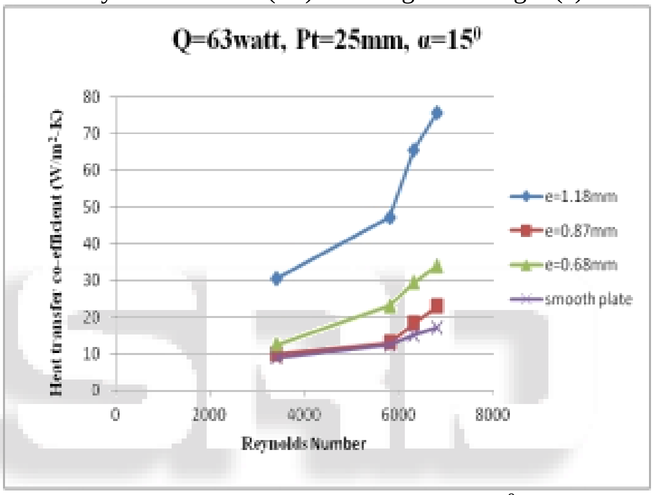

Fig. 5: shows The HTC for a constant α=15^0, Pt=25mm and power input (Q) =63watts and for also various Reynolds number (Re) and roughness height (e).

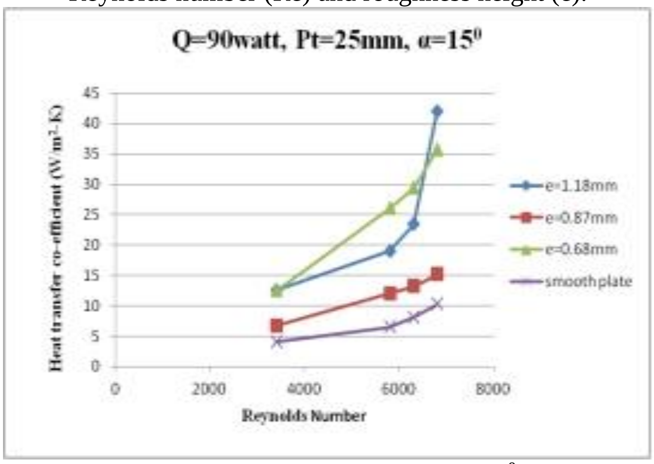

Fig. 6: shows The HTC for a constant α=15^0, Pt=25mm and power input (Q) =90watts and for also various Reynolds number (Re) and roughness height (e).

– The use of angle of attack α=45^0, various roughness height (e) and constant pitch Pt=25mm, the obtained heat transfer co-efficient varies from 7.01 W/m^2-K to 72.07 W/m^2-K for various Reynolds number (Re) and power input (Q).

- The use of angle of attack $\alpha=30^0$, various roughness height (e) and constant pitch Pt=25mm, the obtained heat transfer co-efficient varies from 6.33 W/m^2-K to 65.08 W/m^2-K for various Reynolds number (Re) and power input (Q).
- The use of angle of attack $\alpha=15^0$, various roughness height (e) and constant pitch Pt=25mm, the obtained heat transfer co-efficient varies from 6.99 W/m^2-K to 75.62 W/m^2-K for various Reynolds number (Re) and power input (Q).
- The highest heat transfer co-efficient obtained at an Angle of Attack $\alpha=15^0$, invariable Pt=25mm, used for e=1.18mm and Reynolds number (Re), power input (Q).
- The use of angle of attack $\alpha=45^0$, various roughness height (e) and constant pitch Pt=25mm, the obtained Nusselt number varies from 13.8 to 143.23 for various Reynolds number (Re) and power input (Q).
- The use of angle of attack $\alpha=30^0$, various roughness height (e) and constant pitch Pt=25mm, the obtained Nusselt number varies from 12.47 to 127.65 for various Reynolds number (Re) and power input (Q).
- The use of angle of attack $\alpha=15^0$, various roughness height (e) and constant pitch Pt=25mm, the obtained Nusselt number varies from 12.96 to 148.88 for various Reynolds number (Re) and power input (Q).
- The highest Nusselt number obtained at an Angle of Attack $\alpha=15^0$, invariable Pt=25mm, used for e=1.18mm and Reynolds number (Re), power input (Q).

VIII. Conclusion

On the origin of current investigational study on heat transfer of flow of fluid during solar air heater channel artificially roughened by means of special Roughness Height (e), Reynolds Number (Re),at room Temperature of 26°among various angle of Attack (α) ,the subsequent conclusion are prepared.

The highest heat transfer co-efficient i.e. 75.62 W/m2-K obtained at an Angle of Attack $\alpha=15^0$, invariable Pt=25mm, used for e=1.18mm and Reynolds number (Re) from 3400-6800 on room temperature of 26^0C , power input Q=63W are nearly compare to the smooth plate. Because of increase in swirl intensity caused by increase in turbulent kinetic energy and turbulent dissipation rate with the increase in Reynolds number.

The highest Nusselt number i.e. 148.88 obtained at an Angle of Attack $\alpha=15^0$, invariable Pt=25mm, used for e=1.18mm and Reynolds number (Re) from 3400-6800 on room temperature of 26^0C , power input Q=63W are nearly compare to the smooth plate. Because of Reynolds number increases thickness of the boundary layer decreases and hence convective resistance decreases as a result increase the nusselt number.

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