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To Analysis Efficiency of Solar Air Heater with Discrete V Shape Roughness Geometry on an Absorber Plate

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ABSTRACT: Artificial roughness applied on the absorber plate is the most efficient method to improve thermal performance of solar air heaters. Experimental investigations appropriate to distinct roughness geometries shows that the enhancement in heat transfer is accompanied by considerable rise in pumping power. Solar air heater is used to heat air but it has low thermal efficiency because of low thermal conductivity between air and absorber plate. Thermal efficiency of solar air heater can be improved by creating artificial roughness on absorber plate which causes higher temperature to absorber plate and hence maximum thermal losses occurs to atmosphere.

KEYWORDS: Artificial Roughness, Heat Transfer Coefficient, Absorber Plate, Solar air heater

I. INTRODUCTION

Energy has strong socio-economic and environmental linkages. Most of the environmental problems that confront mankind today are connected to the use of energy in one-way or another. There is a discernible human influence on global climate. The human benefits of energy production; supply and consumption frequently have an environmental downside that may in turn affect human health and quality of life. These ill effects related to increased energy use have risen considerably with increasing energy demand in recent decades. Some of the problems accompanying energy supply include soil, water, air, noise pollution, ozone depletion, greenhouse gas effects, risks of nuclear energy use, genetic disorders, large-scale destruction of landscapes due to the extraction of fossil-fuels, maritime pollution, ecological consequences of hydropower projects leading to massive interference with ecosystems, catastrophic accidents like Chernobyl, etc. The rapid increase of energy usage and the fast depletion of fossil fuels have made it mandatory to look for alternative energy resources to meet the energy demands of the future.

Solar energy is available freely, omnipresent and an indigenous source of energy provides a clean and pollution free atmosphere. The simplest and the most efficient way to utilize solar energy is to convert it into thermal energy for heating applications by using solar collectors. Solar air heaters, because of their inherent simplicity are cheap and most widely used collector devices. The efficiency of flat plate solar air heaters has been found to be low because of low heat transfer coefficient between the absorber plate and the flowing air, which increases the absorber plate temperatures, leading to higher heat losses to the environment. Hence, different modifications are suggested and applied to improve the heat transfer coefficient between the absorber plate and air. One of the methods is installation of turbulence promoters in the form of artificial roughness on the underside of the absorber plate. Such artificial roughness produces the turbulence and breaks the laminar sub layer due to this more heat transfer archived. Solar air heaters are being used for many applications at low and moderate temperatures. Some of these are crop drying, timber seasoning, space heating, chicken brooding and curing / drying of concrete / clay building components. Han et al.[9] seen the effect of artificial roughness on heat transfer and friction factor for two opposite roughened surfaces. Verma and Prasad [13] studied the effect of protruding wires on friction factor, heat transfer coefficient and plate efficiency factor of a solar air heater, Sahu et al.[15] experimentally investigated the heat transfer coefficient by using 900 broken transverse ribs on absorber plate of a solar air heater, Gupta et al. [11] experimentally investigated the effect of relative roughness height

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(e/d), Aharwal et al.[17] carried out result of inclination of rib with respect to flow direction and Reynolds number (Re) on the thermo hydraulic performance of a roughened solar air heater for transitionally rough flow region.

II. CONCEPT OF ARTIFICIAL ROUGHNESS

Artificial roughness is basically a heat transfer enhancement technique by which thermo hydraulic performance of a solar air heater can be improved. The thermal efficiency of solar air heater is generally poor due to low heat transfer coefficient 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. So there is a need to break the laminar sub layer. Artificial roughness, provided on the underside of the absorber plate, creates local wall turbulence. Secondary recirculation flows further enhance the convective heat transfer. Flows from the core to the surface reduce the thickness of boundary layer and secondary flows from the surface to the core flow promote mixing. Energy for creating turbulence has to come from a blower and excessive turbulence results in greater power. Therefore, it is desirable that the turbulence must be created only in the region very close to the heat transferring surface, so that the power requirement may be reduced. This can be done by keeping the height of the roughness element small in comparison with the duct dimension. Although there are several parameters that characterize the arrangement and shape of the roughness are

1. Relative roughness pitch (p/e): Relative roughness pitch (p/ e) is defined as the ratio of distance between two consecutive ribs and height of the rib.
2. Relative roughness height (e/ D): Relative roughness height (e/ D) is the ratio of rib height to equivalent diameter of the air passage.
3. Angle of attack (α): Angle of attack is inclination of rib with direction of air flow in duct.
4. Aspect ratio: It is ratio of duct width to duct height. This factor also plays a very crucial role in investigating thermo-hydraulic performance.

III. EXPERIMENTAL SETUP

The experimental setup consist of entry section, exist section, plenum, a flow measuring orifice-meter and centrifugal blower with control valve as shown schematic view of experimental setup in fig.1. The wooden rectangular duct of internal dimensions 1750mm \times 300mm \times 30mm which consist of an entrance section, a test section and exist section of length 500 mm, 1000mm and 250mm respectively in accordance with the recommendation of ASHARE standard 93-77. The entry lengths are taken as $5\sqrt{WH}$ and exit section length is taken as $2.5\sqrt{WH}$. The entry section length is provided for uniform development of flow the inlet of the test section. The test section of length 1000 mm provided for the testing of smooth and artificially roughened plates. In order to provided the insulation and minimize the heat losses, the thickness of the plywood base of duct is 12 mm and side wooden wall thickness is 30 mm. The exit section and plenum are attached to minimize the pressure losses from sudden reduction in area of the outlet. A circular pipe is used to pass the air from the plenum to the orifice meter. After that flow control Electronic regulator is used. The air sucked by the induction blower extreme right end. When the air is passes over the absorber at the extreme rights end. When the air pass over the absorber plate of 1 mm thickness is used for testing. A glass cover is provided so that the solar radiations fall on the upper side of aluminum plate. The thermocouple are provided measuring air as well as temperature of the plate. Thermocouple are calibrated against a reference temperature of 0⁰ C using Standard and exit section The mass flow rate is measured by the orifice meter with U-tube manometer which is calibrated using standard pitot tube. The coefficient of discharge (Cd) of orifice meter is 0.62. One simple type of two transparent basins. The manometer contains two manometric fluids one is methyl alcohol and other is kerosene of different specific gravities and immiscible with each other and with fluid for which pressure difference is to be measured.

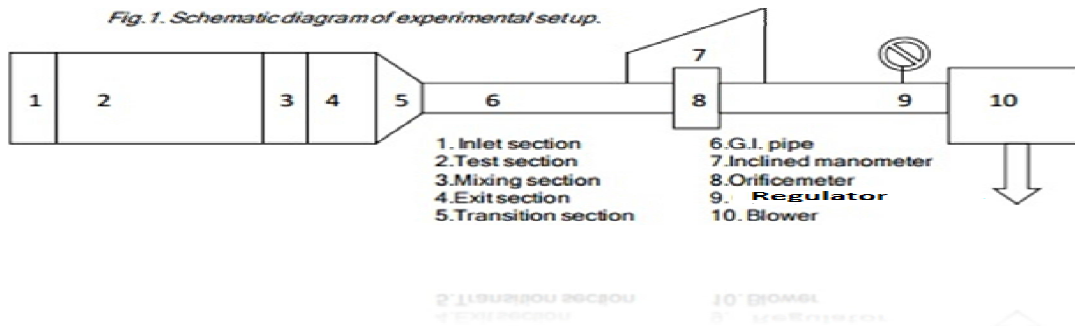
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Fig. 3.1 Schematic Diagram Of Experiment Setup



IV. RANGE PARAMETER OF V SHAPE ROUGHNESS

Table shows the roughness geometry of circular multi arc shaped ribs, which has investigated under present investigation.

Parameters	Value
Relative roughness pitch (p/e)	12mm
Rib height (e)	5 mm
Duct aspect ratio (W/H)	10
Reynolds number (Re)	3000-6000
Angle of attack (α)	90 ⁰
Hydraulic diameter D _h (mm)	54.50
Total Length (mm)	1000

V. EXPERIMENTAL RESULTS

1. REYNOLDS NUMBER V/S THERMAL EFFICIENCY :

Following results have been obtained from the experiment. The variation of Thermal Efficiency with Reynolds number is shown in Fig 5.1. It is seen that the value of Thermal Efficiency increases with increases in Reynolds number. The value of Thermal Efficiency is varies from 40 to 90 in the range of Reynolds number 3000-6000. The maximum value of Thermal Efficiency is observe for rib with gap roughness arrangement.

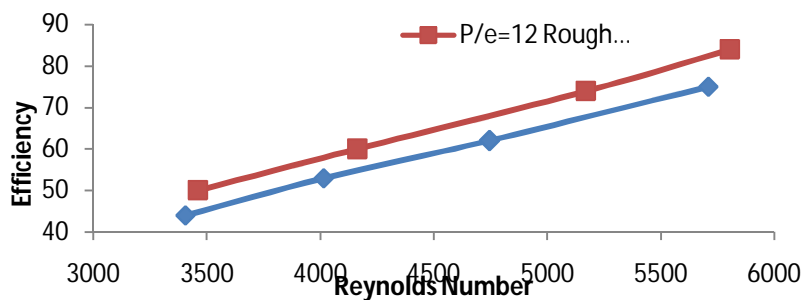


Fig.5.1 Variation of Thermal Efficiency with Reynolds Numbers

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2. Reynolds number V/S Heat Transfer Coefficient

The variation of Heat transfer coefficient with Reynolds number is shown in Fig.5.2. It is seen that the value of Thermal Efficiency increases with increases in Reynolds number. The value of Heat transfer coefficient varies from 20 to 80 in the range of Reynolds number 3000-7000. The maximum value of Heat transfer coefficient is observed for rib with gap roughness arrangement. This may be due to the fact that the presence of gap produces more turbulence, which enhances heat transfer.

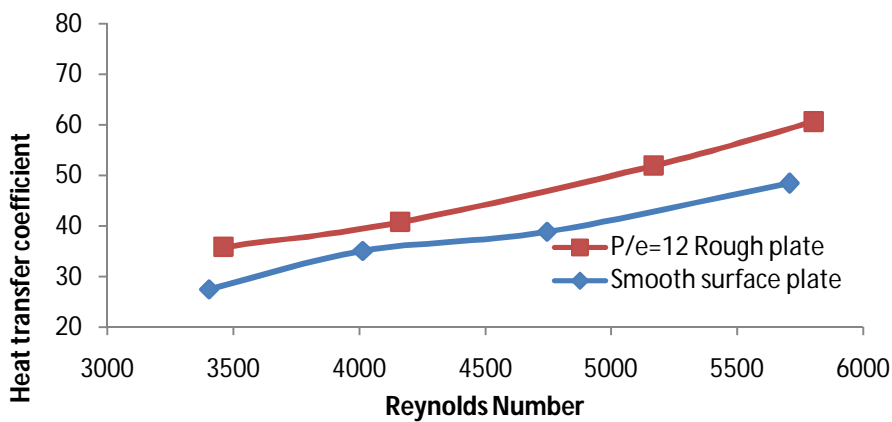


Fig 5.2 Variation of Heat Transfer coefficient with Reynolds Numbers

3. Reynolds number V/S Heat Transfer

The variation of Heat Transfer with Reynolds number is shown in Fig 5.3. It is seen that the value of Heat Transfer number increases with increases in Reynolds number. The value of Heat Transfer number varies from 90 to 190 in the range of Reynolds number 3000-7000. The maximum value of Heat Transfer number is observed for Discrete V shaped roughness arrangement. This may be due to the fact that the presence of gap produces more turbulence, which enhances heat transfer.

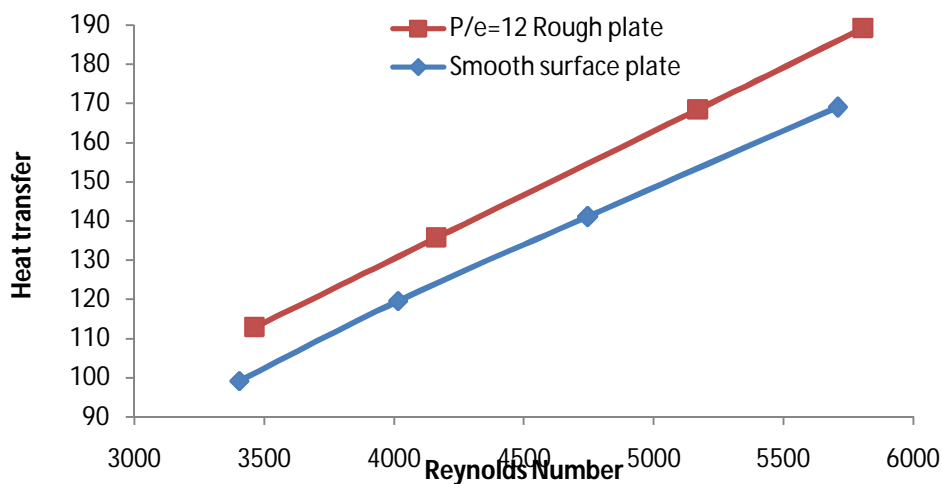


Fig 5.3 Variation of Heat transfer with Reynolds Numbers

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4. Reynolds number V/S Nusselt Number

The variation of Nusselt number with Reynolds number is shown in Fig. 5.4 It is seen that the value of Nusselt number increases with increases in Reynolds number. The value of Nusselt number is varies from 50 to 120 in the range of Reynolds number 3000-6000.

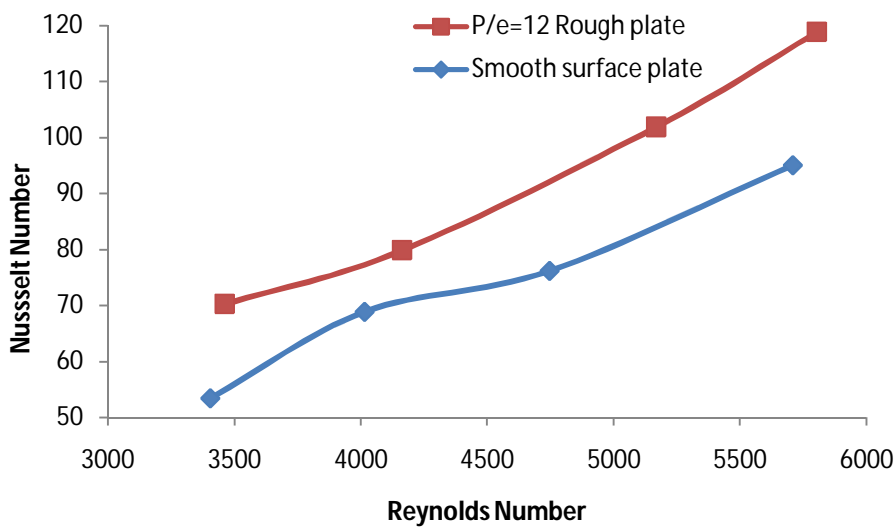


Fig 5.4 Variation of Nusselt Number with Reynolds Numbers

5. Thermal Efficiency Vs Actual heat transfer coefficient

The variation of Thermal efficiency with Actual heat transfer coefficient is shown in Fig. 5.5 It is seen that the value of Thermal efficiency increases with increases in Actual heat transfer coefficient. The value of Thermal efficiency is varies from 40 to 90 in the range of Actual heat transfer coefficient 20 to 70. The maximum value of Thermal efficiency is observe for V shaped roughness arrangement. This may due to the fact that the presence of gap produce more turbulence.

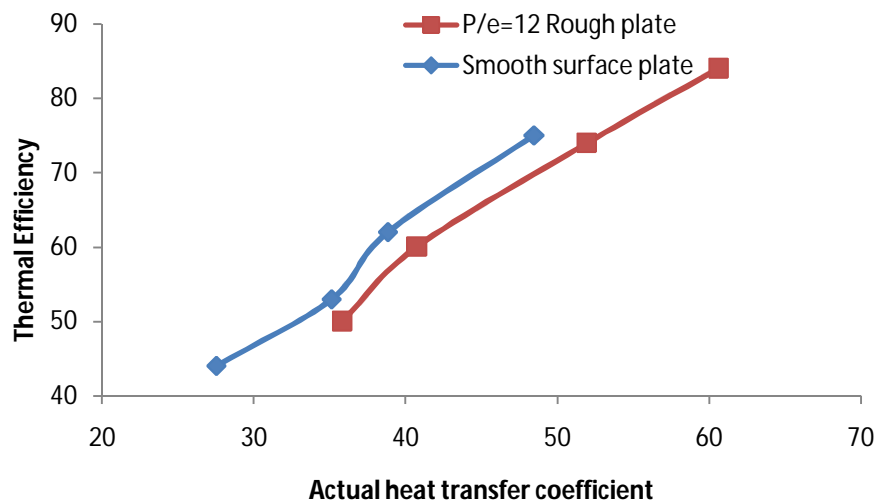


Fig. 5.5 Thermal Efficiency Vs Actual heat transfer Coefficient

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VI. CONCLUSION

The following conclusion can be drawn from experimental work –

1. The heat transfer coefficient (h) of rough plate increases compare to smooth plate.
2. It is found that thermal efficiency (η) of rough plate is a greater than smooth surface.
3. The Nusselt number (Nu) is also greater than smooth plate.

Finally observe that Nu , h and η for rough has higher values than smooth surface, therefore rough surface is better heat transfer aspect than smooth surface.

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