International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in; editorijoer@gmail.com

Vol.5., Issue.3, 2017
May-June

REVIEW ARTICLE

ISSN: 2321-7758

A REVIEW ON THE INVESTIGATION OF SOLAR AIR HEATER WITH SPIRAL COIL HORIZONTAL ROUGHENED ABSORBER PLATE

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ABSTRACT

The purpose of using solar air collectors is to raise the atmospheric air temperature to a temperature which can be used for various low and medium temperature applications. Collector, absorber and airflow arrangement are the most important components in the solar air collector. The performance of the collector depends on its heat loss and the absorber area that is in contact with the airflow. This study involves the mathematical modelling of the effect of horizontal spiral roughness. Artificial roughness in the form of spiral coil on the absorber plate is another technique to enhance the rate of heat transfer to flowing fluid in the roughened duct of solar air heater. Various artificial roughness geometries have been reported in the literature by investigators, for determining the effect of various roughness geometries on heat transfer enhancement and friction characteristics in roughened duct of solar air heater. The parameter p/de, e/de and Re are the main factors for enhancing the heat transfer coefficient for spiral coil horizontal solar air heater.

INTRODUCTION

Solar air heater is widely used because it is simple in design, and easy to fabricate, easy to maintain and it required cheap material for construction. The main problem with these systems is low rate of heat transfer from absorber plate to flowing air. Researchers have attempted to improve the performance of solar air heater by focusing intensive studies on design and operating parameter.

Many researchers have attempted to increase heat transfer rate from absorber plate to flowing air by adding fins on absorber plate. Several studies have been done by providing the roughness on absorbing plate. Some researchers have used packed bed material where as in several different studies corrugated surface mainly V corrugated, cross corrugated have been used.

Many researchers have used recycle of flowing air with different duct. Owning to increase frictional losses higher pump work is required which puts further restriction on increasing surface roughness to improve heat transfer rate from absorber plate to flowing air.

In order to balance the quality of energy gain and friction losses the exergy analysis is done.

The exergy analysis has proven to more powerful tool to design and optimize the performance of energy system. In the present work an attempt has been made to perform energy and eXergy analysis of solar air heater at different mass flow rate of air.

DIFFERENT ENHANCEMENT TECHNIQUES

1. **Honeycomb collector**: Honeycomb substance is transparent to solar irradiation, allowing for energy to enter the collector and heat

the absorber plate. However, it creates a layer of air that cannot circulate, thus dramatically reducing losses related to convection – the major reason for energy losses and lower efficiency of flat plate collectors at high temperature differentials. In addition, the polymer blocks back radiation in the infrared, thus further reducing energy losses.On the surface of the Honeycomb Collector is a proprietary "transparent insulation technology", shaped like a honeycomb, which allows sunlight to pass through to heat the collecting surface while suppressing heat losses from convection and conduction at the same time. This design is said to be very energy-efficient, enabling the sun's energy to easily enter the collector while keeping energy losses to a minimum, even with large temperature differences between the ambient air and that inside the collector itself.

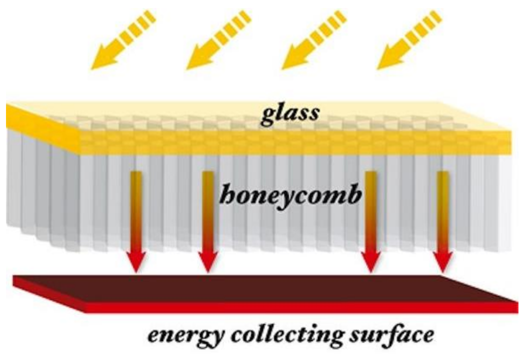

Fig.1: honey comb collector

2. Double exposure collector: Double exposure evacuated solar flat plate collector system mainly consist of 5 important parts and they are solar collector, evacuated glass box, adjustable frame, evacuated tank and the tracking system with mirrors. The assembly of solar collector and the glass box is mounted on the adjustable frame. The adjustable frame is so made that the tilt angle of solar collector can be changes from 20o to 45o. The adjustment is given to analyze the better flow rate on different tilt angles that are 20o, 30o & 45o. The tracking system is placed below the solar collector plate in such a way that the reflected solar radiations from the mirrors placed over the tracking system will incident on the solar collector plate. The tracking system is manually adjustable.

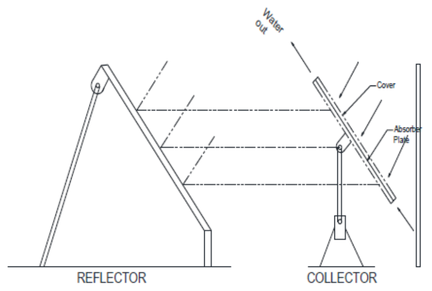

Fig.2: double exposure collector

3. **Thermal trap collector:** The “thermal trap effect” in semi-transparent material and the trapping system in the conventional flat-plate collectors with two, three or four glass or plastic covers with air-gaps in between are analysed under a common heading of “thermal trap collectors”. In general, a thermal trap collector consists of one or many slabs of semitransparent material of finite thickness with air-gaps in between, and an ideal withdrawal mechanism at the base of the trapping system to withdraw all available energy. This approach makes a comparative study of the two types of collectors possible, and provides data to design the appropriate withdrawal mechanism and operating condition. The two-layer methyl methacrylate thermal trap collector has, in general, a better performance than the corresponding single or three and four-layer systems. But at high withdrawal efficiencies of about 60 per cent, the single layer methyl methacrylate shows its uniqueness and becomes competitive with the two-layer system. But the three and four-layer “glass” thermal trap collectors perform better than the corresponding single and two-layer ones, with the three-layer system having an overall better performance. The number of slabs in addition to thickness are important parameters in the study of the performance of thermal trap collectors.

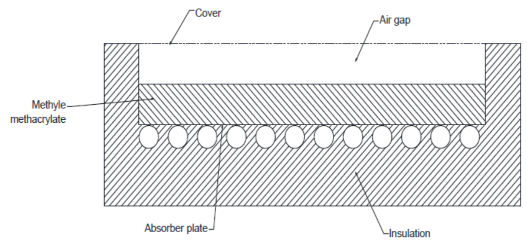

Fig.3: thermal trap collector

4. **Two pass collector:** Multi-pass solar air collectors with heat transfer surface enhancement to have efficiencies between 60-70%. The use of double pass solar air collector with heat transfer surface enhancement has better performance than the conventional single-pass collector. The performance of double pass solar air collector with a single cover is found to be most cost-effective, as compared to the other design. Double-pass designs perform better than the single pass solar air collector and reported an increase of 10-15 % in collector efficiency. One way to achieve considerable improvement in collector efficiency is to use an extended heat transfer area by using corrugated surfaces, matrix type absorber, compound honeycomb collector, box-type absorber, porous media and finned absorber. In the present study, the main concern is to study experimentally on the efficiency of the double-pass solar air collector with staggered fins.

5. **Double flow type collector:** The system thermal efficiency increases by 5% after using porous media in the lower channel than the double flow without porous media. At the same time the pressure drop will be increased, thus increasing the pumping power expanding by about 3-4 times. The cost of solar energy; the annual cost of the collector/the annual thermal energy gain in double flow duct double duct flat plate collector with porous media is less than the annual thermal energy gain in double flow duct double duct flat plate collector without porous media due to the higher useful energy gained from the using of porous media which increase the heat transfer.

6. **Overlapped glass plate collector:** The overlapped glass plate air heater combines the advantages of low pressure drop and high efficiency for moderate temperature rises. The cost of the unit must, however, be carefully examined since the glass area requirements are four times the collection area, including the single cover glass. In case inlet air is at temperatures higher than the ambient, then double glass covers may be needed which increases the glass requirements five times as much as the absorber area.

Variation of the spacing between plates and number of plates slightly influences the collection efficiency. The cost of the heat collected decreases with the increasing collector length. However, due to difficulties of fabrication and handling of the collector units. Using clear glass as cover material improves collection efficiency, but the cost increase usually does not justify it. Using ordinary glass for intermediate staggered plates is in fact helpful due to increased absorption of the solar flux. If inexpensive configurated glass which has rough surfaces can be used, efficiency improvement is expected. Care must be exercised not to increase pressure drop excessively. The effect of semi-transparent glass to rough surfaced glass has not yet been fully investigated.

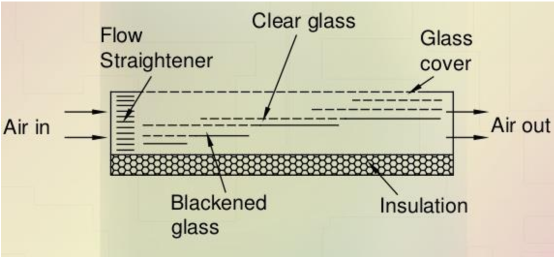

Fig.4: overlapped glass plate collector

7. **Packed bed air heater:** The performance of plate collector improves appreciably by packing its duct with blackened wire screen matrices and this improvement is a strong function of bed and operating parameters. Packed bed can be successfully used for the enhancement of heat transfer coefficient in solar air heaters. The air flows through the porous medium on which the solar radiation is directly incident. The radiation penetrates absorbing medium in depth and in turn gets absorbed. The high heat transfer area to volume ratio promotes heat transfer capability and the turbulence producing air flow path through the bed provide for a rapid increase of heat exchange. Use of packed bed for the improvement of performance of solar air heater has been proposed by several investigators. The materials used for packed bed includes wire mesh screen, matrices, pebble bed, chips of different materials etc.

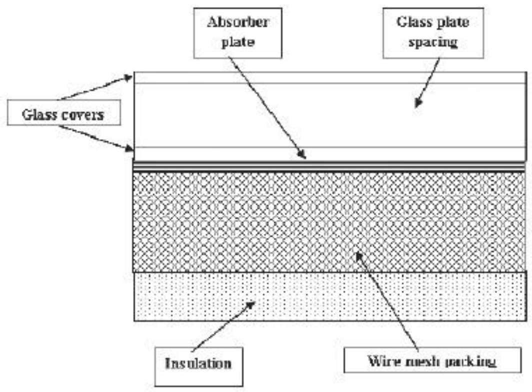

Fig.5: packed bed air heater

HORIZONTAL SPIRAL ROUGHENED SURFACE

Spiral is a curve on a plane that winds around a fixed center point at a continuously increasing or decreasing distance from the point. It is also defined as A three-dimensional curve that turns around an axis at a constant or continuously varying distance while moving parallel to the axis; a helix.

In order to increase the roughness of the absorber plate, spiral made of metals can be used to attach on the plate which will create the turbulence to the entering air increasing the convective heat transfer from the plate to air.

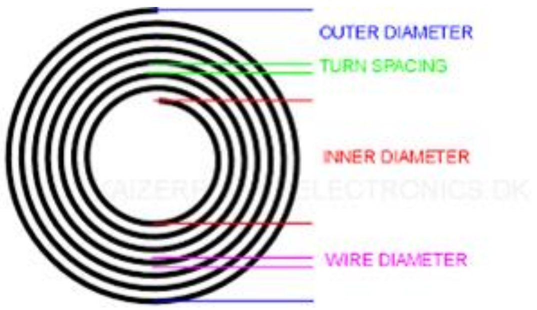

Fig.6: spiral coil

Isosceles Right Triangle Rib: R.Ranjan,M.k.Paswan and N.Prasad worked on isosceles right triangle rib roughness and has found the average nusselt number tends to increase as Reynolds number increases in all cases. The average friction factor has been found to be 3.45 times over the smooth duct. The average friction factor tends to decrease as the Reynolds number increases. Increment in Thermal performance obtained for Maximum thermo-hydraulic performance is obtained for relative roughness pitch of 5 and relative roughness height 0.045

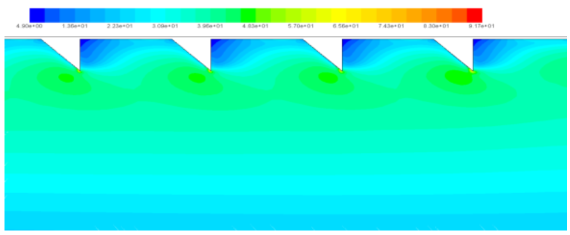

Fig 7.Geometry of Isosceles Right Triangle rib

MATHEMATICAL MODELLING: The collector under consideration consists of a glass cover and absorber plate with a well insulated parallel bottom plate, forming a rectangular duct profile through which the air to be heated flows. The corrugation of the absorber plate is trapezoidal in shape and the air is made to flow along the corrugation. The theoretical solutions of the thermal performance of the SAH system involve the formulation of the energy balance equations that describe the heat transfer mechanisms at each component of the solar air collector. The heat distribution through the air heater is as shown in Fig.7. The energy balance equations obtained are as follows:

The energy balance in the glass cover is:

$S_1+(h_1+h_{r21})(T_{ap}-T_c)=(h_w+h_{rs})(T_c-T_a)$……………………(1)

Energy balance on the absorbing plate is:

$S_2=(h_1+h_{r21})(T_{ap}-T_c)+h_{r23}(T_{ap}-T_{bp})+h_3(T_{ap}-T_f)$…..(2)

Energy balance for the fluid:

$h_3(T_{ap}-T_f)=q_u+h_4(T_f-T_{bp})$…………………….. 3)

Energy balance on the bottom plate:

$h_{r23}(T_{ap}-T_{bp})+h_4(T_f-T_{bp})=U_b(T_{bp}-T_a)$………… (4)

The solar radiation absorbed by the absorbing plate per unit area which is equal to the difference between the incident solar radiation and the optical loss, is calculated by:

$S_1 = \alpha I$

The convection heat transfer coefficient between the glass cover and the absorbing plate is:

$h_1 = Nu_{ap\text{-}c}\frac{k}{H}$

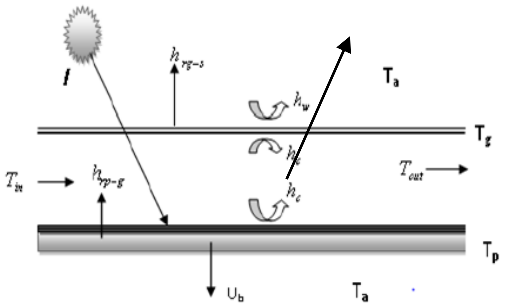

Fig.7: solar air heater indicating the variables used.

The optical yield (ηo) and the energy lose coefficient (UC) are the parameters that characterize the behaviour of the solar collector. Note that η represents the fraction of the solar radiation absorbed by the plate and depends mainly on transmittance of the transparent covers and on the absorbance of the plate.

The energy loss coefficient includes the losses by the upper cover, the laterals, and the bottom of the collector. The upper cover losses prevail over the others, depending to a large extent on the temperature and emissivity of the absorbent bed, and besides, on the convective effect of the wind on the upper cover. The thermal efficiency of the solar collectors (η) is defined as the ratio between the energy gain and the solar radiation incident on the collector plates is given by

$$\eta = m * c_p *(T_{out} - T_{in})/ I * A$$

PARAMETERS USED: The mathematical modeling was done at the same operating condition to identify the thermal efficiency of each collector. The mathematical modeling was done for the operating conditions listed below in Table.1.

Parameter	Value	Unit	Parameter	Value	Unit
I	600	W/m^2	ε_{ap}	0.94	--
Θ	30	Degrees	ε_{bp}	0.90	--
W	1	M	ε_c	0.94	--
L	2	M	α_{ap}	0.06	--
H_g	0.05	M	α_c	0.95	--
H_c	0.025	M	τ_c	0.84	--
M	0.035	Kg/m^{2}s	V_w	1	m/s
T_a	300	Kelvins	σ	5.67E-^{08}	W/m^{2}K^4
T_{fi}	300	Kelvins	g	9.81	m/s^2
K_i	0.025	W/mK	U_f	1	m/s

The efficiency and output temperature of the collector for flat plate collector and spiral roughened is found to be increased by 20.5% and temperature rise by 15^{o}C. With the introduction of the horizontal spiral roughened absorber, the heat transfer coefficient increases which increase the heat transfer and hence the temperature difference increases and also the efficiency.

CONCLUSIONS

This paper on the review of solar air heater using horizontal spiral roughened absorber plate is aimed to provide the information about the solar air heater, its performance and spiral roughened surface. It has been reviewed from the previous researches that the conventional solar air heater performance is poor because of the poor heat transfer between the absorber plate and the air flowing over the plate. This is because of the formation of laminar sub layer above the absorber plate. The performance of the heater can be improved by establishing turbulence in the laminar sub layer region. This turbulence can be provided by the spiral roughness elements. The shape, size and orientation of the spiral elements play critical role in the effectiveness of the heat transfer.

NOMENCLATURES

I solar insolation rate incident n the glass cover (W/m^2)

τ_c Transmissivity of solar radiation of the glass cover

α_{ap} absorptivity of the solar radiation of the absorbing plate

S solar radiation absorbed by the glass cover and the absorber plate (W/m^2)

Q_u energy gain (W/m^2)

H_c gap between v-groove absorber and glass cover (m)

H_g height of v-groove(m)

T_s sky temperature (k)

T_c mean temperatures on the glass cover (k)

T_{ap} mean temperature on the absorbing plate (k)

T_f mean air temperature (k)

T_{bp} mean temperature on the bottom plate (k)

T_a ambient air temperature (k)

T_{fi} inlet temperature (k)

T_{fo} outlet temperature (k)

Q_u heat transferred to the air (W/m^2)

C_p specific heat of air (J/kgk)

M_f air mass flow rate per unit area of the collector (kg/s)

h_1 Thermal losses to the glass cover by natural convection(W/m^2 K)

h_{r21} Thermal losses to the glass cover by thermal radiation(W/m^2 K)

h_{r23} Thermal losses to glass cover by bottom plate by thermal radiation (W/m^2 K)

h_4 Convection heat transfer coefficient of fluid on the bottom plate(W/m^2 K)

h_w Convection heat transfer coefficient from glass cover due to wind(W/m^2 K)

h_{rs} Radiation heat transfer coefficient from the glass cover to sky(W/m^2 K)

U_b Conduction heat transfer coefficient across the insulation(W/m^2 K)

h_3 Convection heat transfer coefficients for the fluid(W/m^2 K)

SUBSCRIPTS:

a ambient
av average
b back, beam, bottom
c cold, cover
d destroyed, diffuse
e equivalent, side
E exergy
f air stream
h hot
i insulation
in inlet
l leakage, overall.

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