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A review on different techniques used for performance enhancement of double pass solar air heaters

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ABSTRACT

The performance of a conventional solar air heater (SAH) can be effectively improved by reducing the losses from the collector surface by providing the proper insulation and increasing the convective coefficient between heat collecting surface and working fluid by enhancing the heat transfer area which can be increased by double pass design. Various experimental and theoretical investigations have been considered to enhance the performance of double pass solar air heaters (DPSAHs) provided with performance enhancement techniques i.e. using packed bed materials (PBMs), extended surfaces and corrugated/grooved absorbing surfaces. These studies include the cost analysis, thermohydraulic characteristics and design of DPSAH. The objective of present study is to review the various investigations conducted on performance enhancement of double pass system. Based on the review, it is found that the most of the investigations were performed on double pass system having PBM and integrated with extended surfaces. Few studies were conducted on corrugated or grooved absorbing surface and very few studies have been presented on double pass systems having artificial roughness. Further, in order to compare the thermal performance of different designs of DPSAHs, an attempt has been made to generate the performance results using correlations developed by various investigators.

Contents

1. Introduction

Among all the non-conventional energy resources, solar energy is found to be most promising energy source because of its abundance, inexhaustibility and pollution free nature. Solar energy falling on the earth surface in the form of solar radiation can be utilized in two different ways. One is the solar thermal applications and

Abbreviations: SAH(s), solar air heater(s); SPSAH(s), single pass solar air heater(s); DPSAH(s), double pass solar air heater(s); MFR, mass flow rate of air; PBM, packed bed material.

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Nomenclature

D	Equivalent Diameter or Hydraulic Diameter, m
$\dot{m}$	Mass air flow rate per unit cross section, kg/s
L	Length of the duct, m
Re	Reynolds number
I	Solar radiation, W/m^2
h	Heat transfer coefficient, W/m^2 K
U	Overall heat transfer coefficient, W/m^2 K
h_{fgc}	Convection coefficient between the glass and fluid, W/m^2 K
h_{fap}	Convection coefficient between absorber plate and fluid, W/m^2 K
h_{fb}	Convection coefficient between bottom plate and fluid, W/m^2 K
h_{rapgc}	Radiation coefficient between absorber plate and glass, W/m^2 K
h_{ragc}	Radiation coefficient between the glass and ambient, W/m^2 K
Gz	Gratz number
W	Width of the duct, m
H	Height of the duct, m
AR	Aspect ratio
Q_u	Useful heat gain, W
e/D	Relative roughness height
α	Angle of attack
P/e	Relative roughness pitch
e	Rib height, m
P	Pitch, m
R	Recycle ratio
d_1	Depth of upper channel, m
d_2	Depth of lower channel, m
k_p	Thermal conductivity of packing material, W/m K
η	Thermal efficiency
q_u	Useful heat flux, W/m^2
T	Temperature, K
Φ	Porosity of packing material
G	Gap between glass covers, m
N_f	Number of fins
s	Distance between two fins, m
A	Area of the collector, m^2
Δ	Ratio of channel thickness
ε	Emissivity of the plate
r	Air flow ratio
D_R	Channel depth ratio
v	Velocity of air, m/s

Subscripts

∞	Ambient, air
l	Lower channel
u	Upper channel
f	Fluid, fin
p	Absorber plate
c	Convection
g	Glass cover
b	Base plate
r	Radiation
i	Inlet
t	Total

other is the direct conversion into electricity using solar photo voltaic (SPV) system. In solar thermal applications, solar energy can be converted into thermal energy by using solar collectors which can be classified as flat plate collectors and focusing type collectors. The flat plate solar collectors are used for low and moderate temperature applications and are further classified as SAHs and solar liquid heaters.

SAHs are specific types of heat exchanger devices that provide energy in the form of heat for the purpose of space Heating [1], drying agricultural products (paddy drying, fruit drying, timber drying, cash crop drying etc.) and some industrial applications [2,3] or other locations normally requiring the use of conventional energy sources to maintain a constant temperature. Thermal efficiency of the conventional SAH is found to be poor due to low convective coefficient between heat collecting surface and working fluid. So it becomes essential to increase the convection coefficient in order to increase the thermal performance of the system. It has been found in literatures that the convective coefficient can be increased by various methods which includes: (i) use of the extended surfaces i.e. fins or turbulators (ii) use of the PBMs i.e. a volume of porous media and (iii) breaking of the laminar sublayer in turbulent boundary layer region, by using wires ribs, corrugated surfaces and protrusions to make absorbing surface artificially roughened [4]. Various investigators performed experimental and theoretical investigations to increase thermal performance of the DPSAH using different techniques i.e. extended surfaces using fins, PBMs and corrugated absorber but so far very few studies have been reported with DPSAHs provided with artificial roughness. The purpose of the present study is to review different heat transfer enhancement techniques used in DPSAHs. In this study, various designs of SAHs have been considered and technical information is obtained which has been used to determine the best performing design under economic and thermohydraulic consideration.

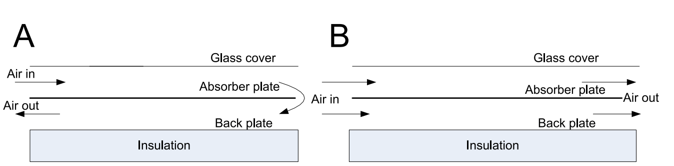

Fig. 1. (a) Counter flow DPSAH with single glass cover (b) Parallel flow DPSAH.

2. Material and methodology

A simple SAH consist of a glass cover, an absorber plate, a back plate and insulations provided on the sides of the duct to reduce the conduction losses to the environment. DPSAHs can be categorized on the basis of direction of the fluid flow i.e. counter or return flow DPSAH and parallel flow DPSAH. In counter flow type, air flows above and below the absorber plate in opposite direction

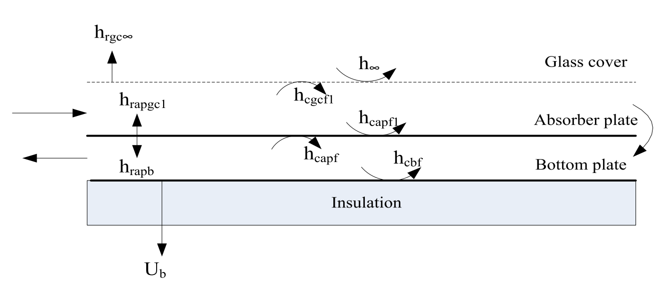

Fig. 2. Counter flow DPSAH with single glass cover [10].