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Investigation of device performance for recycling double-pass V-corrugated solar air collectors

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Abstract

A new design of recycling double-pass solar air collectors is proposed which incorporates a V-corrugated absorber to the conventional flat-plate device for increasing thermal efficiency. With the air flowing over and under the V-corrugated absorbing plate, the turbulence intensity as well as the convective heat-transfer coefficient are enhanced. The theoretical predictions and experimental results are presented graphically and show that both higher air mass flow rate and recycle ratio can lead to improvement of the collector performance as compared to that of the flat-plate solar air collectors.

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Keywords: Performance improvement; V-corrugated absorber; double-pass operations; recycling; solar air collector.

1. Introduction

The applications of the recycle-effect concept to heat transfer devices and chemical reactors has been confirmed by several investigators [1,2] in increasing the convective heat-transfer coefficients due to the flow turbulence enhancement and heat-transfer area enlargement [3-5].

A new design of solar air collector with welding of a V-corrugated absorber into double-pass designs under recycling operation was proposed and studied, as shown in Fig. 1. The experimental setup was fabricated with the V-shape corrugated absorber onto the flat-plate solar air collector and to validate the theoretical predictions calculated by the mathematical modeling. The higher device performance improvement of recycling double-pass V-corrugated collector was obtained as compared to that of the flat-plate solar air collector under the same working dimensions.

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By theoretical and experimental investigations, the purposes of the present work are: (a) to obtain theoretical predictions and experimental results of the recycling double-pass V-corrugated solar air collector; (b) to study the effects of the recycle ratio and air mass flow rate on the heat-transfer efficiency improvement and the power consumption increment in considering the economic feasibility.

Nomenclature

A_c	surface area of the collector = $L \times W$ (m^2)
c_p	specific heat of air at constant pressure (J/(kg K))
D_e	equivalent diameter (m)
E	deviation of the experimental measurements from theoretical predictions
f_F	Fanning friction factor
I_0	incident solar radiation (W/m^2)
I_P	power consumption increment, defined in Eq. (15)
I_V	collector efficiency improvement index, defined in Eq. (8)
L	channel length (m)
ℓ_{wf}	friction loss of double-pass device (J/kg)
$\dot{m}$	total air mass flow rate (kg/h)
P_S	power consumption of downward-type single-pass device (W)
P_V	power consumption of double-pass V-corrugated device (W)
Q_u	useful energy gained by air (W)
R	recycle ratio
Re	Reynolds number
T_{in}	inlet air temperature (K)
$T_{a,0}$	the mixing temperature of the subchannel a at x=0 (K)
$T_{a,L}$	the temperature of the subchannel a at x=L (K)
$T_{b,0}$	the temperature of the subchannel b at x=0 (K)
$T_{b,L}$	the temperature of the subchannel b at x=L (K)
$T_a(z)$	axial fluid temperature distribution in the lower subchannel (K)
$T_b(z)$	axial fluid temperature distribution in the upper subchannel (K)
T_{c1}	temperature of glass cover 1 (K)
T_p	temperature of absorbing plate (K)
$T_{p,m}$	mean temperature of absorbing plate (K)
T_R	temperature of bottom plate (K)
T_s	ambient temperature (K)
U_L	overall loss coefficient (W/m^2 K)
$\bar{v}$	mean air velocity (m/s)
W	width of both upper and lower subchannels (m)
z	axial coordinate (m)

Greek Letters

α_p	absorptivity of the absorbing plate
η_D	collector efficiency of the flat-plate type double-pass device
η_S	collector efficiency of the downward type single-pass device
η_V	collector efficiency of V-corrugated solar air heater, defined in Eq. (6)
τ_g	transmittance of glass cover
ξ	dimensionless channel length