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ORIGINAL ARTICLE

Experimental study of heat transfer and thermal performance with longitudinal fins of solar air heater

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ABSTRACT

The thermal performance of a single pass solar air heater with five fins attached was investigated experimentally. Longitudinal fins were used inferior the absorber plate to increase the heat exchange and render the flow fluid in the channel uniform. The effect of mass flow rate of air on the outlet temperature, the heat transfer in the thickness of the solar collector, and the thermal efficiency were studied. Experiments were performed for two air mass flow rates of 0.012 and 0.016 kg s^{-1}. Moreover, the maximum efficiency values obtained for the 0.012 and 0.016 kg s^{-1} with and without fins were 40.02%, 51.50% and 34.92%, 43.94%, respectively. A comparison of the results of the mass flow rates by solar collector with and without fins shows a substantial enhancement in the thermal efficiency.

Introduction

Solar air heaters are effective devices to harness solar radiation for space heating and other purposes, and the efficiency of solar air collector can be improved by producing new designs of fins. Because of their simple construction and low cost, solar air collectors are extensively used in the world for heating purposes. In this study, a test of solar air collector was performed based on the heating of air by longitudinal fins (semi-cylindrical form) and the surface area for heat exchange. Our study seeks to increase the thermal efficiency of the solar collector, by using a single pass counter flow solar air collector with longitudinal fins. To this end, a semi-cylindrical form is one of the important and attractive design improvements that has been proposed to improve the thermal performance. This paper presents an experimental analysis of a single pass solar air collector with and without fins.

Comparison of the results reveals that the thermal efficiency of a single pass solar air collector increases with the increase of mass flow rate. Increasing the absorber area or fluid flow heat transfer area will increase the heat transfer to the

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Nomenclature

T_{ep}	temperature of exterior plate (°C)	V_f	air velocity (m/s^2)
T_{ab}	temperature of absorber plate (°C)	S	passage cross section (m^2)
T_{pl}	temperature of transparent cover (°C)	Q_u	useful heat collected for an air-type solar collector (W)
T_{bp}	temperature of bottom plate (°C)	Q	volume flow rate (m^3/s)
T_a	ambient temperature (°C)		
x_i	local direction longitudinal of points (m)		
y_i	local direction of thickness panel (m)	*Greek symbols*	
T_{in}	temperature inlet (°C)	η	collector efficiency (%)
T_{out}	outlet fluid temperature (°C)	I	global irradiance incident on solar air heater collector (W/m^2)
V_{wind}	wind velocity (m/s)		
h_w	convection heat transfer coefficient (W/m^2 K)	m	air mass flow rate (kg s^{-1})
C_p	specific heat of air (J/kg K)	ε	emissivity of absorber plate
A_c	area of absorber plate surface (m^2)	α_a	absorber plate absorption coefficient
i	position of the thermocouple connected of 1–4	τ	transparent cover transmittance
ΔT	temperature difference (°C)	α_g	absorptivity of the glass covers
t	time of the during day (h)		

flowing air; on the other hand, it will increase the pressure drop in the collector, thereby increasing the required power consumption to pump the air flow to cross the collector [1,2].

On the other hand, several configurations of absorber plates have been designed to improve the heat transfer coefficient. Artificial roughness obstacles and baffles in various shapes and arrangements were employed to increase the area of the absorber plate. As a result, the heat transfer coefficient between the absorber plate and the air pass is improved [3]. Reports are available on experimental investigation of the thermal performance of a single- and double-pass solar air heater with fins attached and a steel wire mesh as absorber plate [4]. The bed heights were 7 cm and 3 cm for the lower and upper channels, respectively. The result of a single or double solar air heater, when compared with conventional solar air heater, shows much more substantial enhancement in the thermal efficiency.

Few studies were carried out on numerical of the performance and entropy generation of the double-pass flat-plate solar air heater with longitudinal fins [5]. The predictions are done at air mass flow rate ranging between 0.02 and 0.1 kg s^{-1}. Fins serve as heat transfer augmentation features in solar air heaters; however, they increase pressure drop in flow channels. Results show that high efficiency of the optimized fin improves the heat absorption and dissipation potential of a solar air heater [6]. A double flow solar air heater with fins attached over and under the absorbing plate was designed. This resulted in a considerable improvement in collector efficiency of double flow solar air heaters with fins compared to single flowing, operating at the same flow rate [7]. An experimental investigation was carried out on the thermal performance of the offset rectangular plate fin absorber plates with various glazing [8]; in this work, the offset rectangular plate fins, which are used in heat exchangers, are experimentally studied. As the offset rectangular plate fins are mounted in staggered pattern and oriented parallel to the fluid flow, high thermal performances are obtained with low-pressure losses. [9]. A few experiments were carried out to study the performance of three types of solar air heater, namely flat-plate, finned, and V-corrugated solar air heaters. The V-corrugated collector was found to be most efficient, while the flat-plate collector was the least efficient. Another work used the cross-corrugated absorbing plate and bottom plate to enhance the turbulence and the heat transfer rate inside the air flow channel and tested its thermal performance [10,11]. The work title of the studies on a novel solar air collector of pin–fin integrated absorber was designed to increase the thermal efficiency [12]. In the performance analysis of varying flow rate on PZ7-11.25 pin–fin arrays collector, the correlation equation for the heat transfer coefficient is obtained, and the efficiency variation versus air flow rate is determined in this work. Another work compared results to those obtained with a solar air collector without fins using two types of absorbers: selective (in copper sun) and non-selective (black-painted aluminum) [13]. The report presents a solar water heater designed with a local vegetable material as insulating material. The study focuses on the comparative thermal performance of this collector and another collector, identical in design, fabrication, and operating under the same conditions, using glass wool as heat insulation [14]. Some studies reported the effect of the mass flow rate in range 0.0078–0.0166 kg s^{-1} on the solar collector with longitudinal fins [15,16]. The flat-plate solar air heater [17–21] is considered to be a simple device consisting of one (transparent) cover situated above an absorbing plate with the air flowing under absorber plate [20,21] Fig. 2. The conventional flat-plate solar air heater has been investigated for heat transfer efficiency improvement by introducing forced convection [22,23], extending heat transfer area [24,25] and increasing air turbulence [26,27].

Experimental

Thermal analysis and uncertainty

Heat transfer coefficients

The convective heat transfer coefficient h_w for air flowing over the outside surface of the glass cover depends primarily on the wind velocity V_{wind}. McAdams [28] obtained the experimental result as: