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The effect of using transverse fins on a double pass flow solar air heater using wire mesh as an absorber

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Abstract

The thermal performance of a double pass solar air heater with 2, 4, and 6 fins attached was investigated experimentally. Wire mesh layers were used between the fins instead of an absorber plate. The effects of mass flow rate of air on the outlet temperature and thermal efficiency were studied. The indicated results show that the efficiency increases with increasing the mass flow rate for the range of the flow rate used in this work between 0.0121–0.042 kg/s. Moreover, the maximum efficiency was obtained by using 6 fins at the same mass flow rate. The maximum efficiency obtained for the 2, 4, 6 fins of SAH were 75.0%, 82.1% and 85.9% respectively for the mass flow rate of 0.042 kg/s. In addition, the maximum average temperature difference between the inlet and the outlet, ΔT, for the SAH with 6 fins was the highest for the same mass flow rates compared to 2 and 4 fins SAHs. The maximum average and instantaneous peak of ΔT obtained were 43.1 °C and 62.1 °C respectively for the 6 fins SAH when the mass flow rate was 0.0121 kg/s. Comparison of the results of a counter flow packed bed collector with those of a conventional collector shows a substantial enhancement in the thermal efficiency.
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Keywords: Counter flow solar air heater (SAH); Wire mesh; Fins; Thermal efficiency

1. Introduction

Solar air heaters (SAHs) are cheap and extensively used as solar energy collection devices employed to deliver heated air at low to moderate temperatures for space heating, drying agricultural products such as fruits, seeds and vegetables, and in some industrial applications (Akpinar et al., 2004).

Conventional solar air heaters mainly consist of panels, insulated hot air ducts and air blowers in active systems. The panel consists of an absorber plate and a transparent cover. Different factors affect the air heater efficiency such as collector dimensions, type and shape of absorber plate, glass cover, inlet temperature, wind speed and etc.

Major heat losses from flat-plate solar collectors are found to be through the top cover; heat losses from the bottom and the sides of the collector are low as they are adequately insulated. In order to minimize the heat losses and improve the efficiency, double glazing was recommended (Prasad et al., 2009). Some others suggested to insert the absorber plate into the middle of the solar air heater channel, so that the air will pass above the absorber plate then directed to pass below it (Sopian et al., 1999, 2009) or vice versa (Ho et al., 2005; Lertsatitthanakorn et al., 2008) or to flow above and below the absorber plate at the same time (Yeh et al., 2002; Ozgen et al., 2009) which is known as a double pass solar air heater. (Mohamad, 1997) introduced the counter flow to minimize the heat losses from the top cover of the collector, in his analysis; the air is first passed between the upper and lower glasses. Then, air is redirected to flow through the lower channel filled with porous media.

On the other hand several configurations of absorber plates have been designed to improve the heat transfer coefficient. Artificial roughness obstacles and baffles in

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different 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 will be improved (Romdhane, 2007). (Esen, 2008) investigated experimentally, the introduction of the obstacles in the air channel fixed on the absorber plate; he reported that the obstacles are playing an important role for the improvement of the collector efficiency. Furthermore, Esen et al. (2009a,b) theoretically modeled SAHs by using least square support vector machines and artificial neural network wavelet approaches. An experimental study has been carried out by Varun et al. (2009) to investigate the efficiency of the SAH duct provided with transverse and inclined ribs as artificial roughness elements on the absorber. Mittal et al. (2006) reported that there is a considerable enhancement in the effective efficiency of SAHs having roughened duct provided with different types of roughness elements. Youcef-Ali (2005) indicated that the offset rectangular plate fins increased the thermal heat transfer between the absorber plate and the working fluid. Ozgen et al. (2009) investigated experimentally the effect on efficiency by inserting an absorbing plate made of aluminum cans into the double-pass channel in a flat-plate SAH. They argued that this configuration substantially improved the collector efficiency by increasing the fluid velocity and enhancing the heat transfer coefficient between the absorber plate and air. Romdhane (2007) compared SAHs with and without baffles and found that baffles favored the heat transfer in SAH. The studies on various types of baffles placed in air passage showed that the introduction of suitable baffles in SAHs have increased both efficiency and outlet temperatures. Akpinar and Kocyigit (2010) experimentally investigated a flat plate SAH having several obstacles and indicated that the efficiency of the collector with obstacles was significantly better than that without obstacles. Alvarez et al. (2010) reported after their experimental work the serpentine geometry showed a better performance compared to the parallel one. The study by Gupta and Kaushik (2009) of various types of artificial roughness showed that roughness geometries in the absorber plate of SAH duct and their characteristics increased the efficiency in comparison to smooth surface.

Utilization of packed porous materials like wire screens, cross rod matrices aluminum-foil matrices, etc., in the duct of a SAH have been proposed by researchers for the enhancement of thermal performance. Porous media increases the turbulence of the flowing air so the heat transfer coefficient between packing elements and air increases. Another advantage of using porous medium is that it tends to increase the surface per unit volume ratio (Mittal and Varshney, 2006). Kolb et al. (1999) suggested a new design bed using two layers of wire mesh with the flat plate in order to overcome the physical problems of conventional flat-plate disadvantages. Kolb et al. (1999) experimentally investigated their design and argued that the thermal performance improved with higher heat transfer rates to the airflow and has less friction losses compared to flat-plate air collectors of conventional SAHs. The considered air mass flow rates were between 0.01 kg/s and 0.0367 kg/s, the obtained efficiencies were between 58% and 81% respectively, while the maximum pressure drop was 19 Pa. El-Sebaii et al. (2007) used two different configurations, limestone and gravel as packed bed materials, and obtained 65% thermal efficiency at 0.05 kg/s mass flow rate, where the pressure drop was 400 Pa. Parasad et al. (2009) presented an experimental investigation which had been carried out on a packed bed SAH using wire mesh as packing material for air flow rates ranging from 0.0159 to 0.0347 kg/s m^2. They reported that the efficiency of the packed bed SAH with porosity of 0.599 increased from 53.3% to 68.5% compared to the conventional SAH. Moreover, they mentioned that the efficiency increased by decreasing the porosity. Paisarn (2005) studied numerically the heat transfer characteristics and performance of the double-pass flat plate solar air heater with and without porous media. He reported that the efficiency was varied from 38% to 59% for the bed without porous media, and it was varied from 42% to 70% with porous media for mass flow rates between 0.03 and 0.07 kg/s respectively.

This work investigates experimentally the counter flow pass SAH with porous media and fins in the channel acting as an absorber plate. The porous media consists of steel wire mesh layers placed 1 cm apart. Porous media is employed such that it has high porosity and low pressure drop. The aim of using the porous media is to increase the heat transfer surface area. In order to increase the airflow path length, transverse fins were fixed within the channel to give a snake path. Increasing the path length increases the air velocity for the same mass flow rate. Also, the aim of this work is to investigate the effect of the number of the transverse fins on the thermal performance and the outlet temperature of the counter flow SAH packed with porous media (wire mesh). Tests were conducted under actual conditions.

2. Experimental set-up and equipments

The schematic of an experimental set-up is shown in Fig. 1. The set-up was designed and constructed in order to obtain data for the investigation. The set-up consists of a wooden bed 150 cm long and 100 cm wide. The frame of the collector was made of 2 cm thick plywood painted internally with black and externally insulated with 2 cm thick styrofoam. Normal window glass of 0.4 cm thickness was used as glazing while the distance between the upper glass and the second glass is fixed to be 3 cm. The distance between the second glass and the bottom of the collector was fixed to be 7 cm. In order to find the effect of the fins on the efficiency and the outlet temperature 2, 4, and 6 steel fins were installed in the collector and investigated separately. The length, height and thickness of each fin were 50 cm, 7 cm and 0.1 cm respectively (Fig. 1). The fins were painted with black color and positioned transversely along the bed such that three, five and seven equally spaced sections were created. In this way, air flows in a snake path