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Experimental investigation of thermal performance of a new solar air collector with porous surface

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Abstract

In this study, thermal performance of a new solar air collector with porous absorber plate was investigated. The porous surface was accomplished by laying out the copper meshing on the absorbing plate. Hence, it was aimed that the plate could absorb more heat and the thermal boundary layer of the flow would be disturbed. The experimental data was acquired for mass flow rates of 0.031 and 0.038 kg/s. The thermal efficiency was determined as 25 to 57 % while the thermal-hydraulic efficiency of the collector was calculated as 14 to 44 % depending on the experimental case. It was seen that temperature of the fluid at outlet of the collector, useful heat amount and pressure loss were increased as mass flow rate was increased. The results presented that the increasing the mass flow rate and establishing the surface of collector as porous would improve the thermal efficiency of the collector.

Keywords: solar air collector; porous absorber; thermal efficiency

1. Introduction

Solar energy is the most easily accessible and economically used one among the renewable energy sources. Due to carbon emission and expensive energy sources, the solar energy has been more attractive. The renewable energy sources have a significant role on the development of countries [1]. Although the initial investment cost of renewable

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energy sources is high, the solar collectors are comparably less expensive [2]. The solar air collector has a considerable place in solar energy systems since the utilized material is cheap and its amount is small for the construction as well [3]. The application of solar air collectors has a long a long history. They are widely used for space heating (comfort, greenhouse, barn, etc.) and drying industry such as vegetable, fruit, dyeing, etc. Furthermore, they are utilized in air-source heat pumps for increasing the heat transfer to the evaporator [4]. A solar air collector is simply composed of an insulated frame surrounding the absorber plate and a glass cover (glazing). It has two ducts for providing air inlet and heated air outlet.

It can basically be classified as non-porous absorber plate and porous absorber plate [5]. Additionally, it may be categorized as single-pass and double-pass depending on circulation condition of air in the collector. The researchers focused on enhancing thermal performance of solar air collectors by performing some constructional modifications including the use of an absorber with fins attached, matrix type absorber, corrugated absorber, with baffles, with packed bed, and different configurations in the previous studies [6–12]. Turkey has large solar energy potential because of its location with 36° and 42° North latitude in the Mediterranean region. The annual sunshine period of the country is 2624 hours. The intensity of main solar radiation is nearly 3.67 kWh/m^2/day [13]. In the present investigation, copper meshing was laid out on the absorber plate of an air solar collector with single-pass copper absorber plate in order to obtain higher thermal efficiency value. The efficiency was determined for two different cases of flow rate and the results are compared with the previous studies.

Nomenclature

A	area, m^2	*Greek letters*	
C_p	specific heat of air at constant pressure, kJ/kg K	ρ	density of fluid, kg/m^3
$\dot{m}$	mass flow rate, kg/s	α	absorbptivity, dimensionless
I	solar radiation, W/m^2	η	thermal efficiency, dimensionless
Q_u	useful heat rate, kW	$\eta_{t\text{-}h}$	thermo-hydraulic efficiency, dimensionless
P	power consumption of the fan, kW	*Subscripts*	
Δp	pressure drop through the collector, Pa	a	ambient
T	temperature, °C	c	collector
ΔT	temperature difference through the collector, °C	d	duct
V	velocity of air, m/s	i	inlet
		o	outlet

2. Experimental set-up and measurement procedure

The experimental study was carried out in the Faculty of Engineering, Dicle University at the city of Diyarbakır, Turkey. The tilt angle was taken 15° lower compared to the latitude of Diyarbakır which is 40.11°. The experimental test system is schematically demonstrated in Fig. 1. The solar air collector and measuring instruments can be seen in Fig. 2.

The experimental data was obtained using two different types of collectors with smooth surface absorber plate (Type-1) and porous surface absorber plate (Type-2). The dimensions of the collector are 900 x 1500 x 200 mm (width x length x height). The absorber plate is composed of copper material with a thickness of 0.30 mm. The case of collector is manufactured with aluminium composite material. The collector was insulated with glass-wool with 50 mm thick so that the heat losses from the bottom surface of absorber plate could be prevented.

A classic single-layer glass having a thickness of 5 mm was used as glazing for the collector. There were 3 labyrinth-shaped guiding plates inside the collector in order to lengthen the distance of flowing air. These guiding elements were composed of copper sheets with a thickness, height and length of 0.50 mm, 150 mm and 1250 mm, respectively. The inlet and outlet air ducts are circular having a diameter of 100 mm. The copper meshing wire having a width of 220 mm was laid out on the absorbing plate to obtain a porous surface. The thickness of copper wire was 0.24 mm while the dimensions of meshing were 3 x 3 mm.