VOL. 11, NO. 2, JANUARY 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

EXPERIMENTAL STUDY OF THERMAL EFFICIENCY ON PLATE-FIN SOLAR THERMAL COLLECTOR

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ABSTRACT

Plate-fin solar thermal collector with the dimension of plate 40 x 80 cm and 13 fins is constructed and its performance is investigated. Ambient air is forced to flow through the solar collector by using fans. The measurements of incident solar radiation, input air temperature, output air temperature, and velocity of air flow are conducted simultaneously. Data from measurements are used to calculate heat absorbed by air flow and the efficiency of solar collector system. The results show that the increasing of air temperature is 14.3 ^{o}C, averaged heat power absorbed is 102.1 W, and the thermal efficiency is 49%.

Keywords: renewable energy, solar thermal, plat-fin collector, thermal efficiency.

INTRODUCTION

Solar energy is one of the abundant renewable energy on earth with the total amount 5.46 x 10^{24} J annually. Not all of that energy reaches the ground of earth. However, small portion of total solar radiation is able to power the entire world [1]. Solar energy that comes to the earth consists of wide range of electromagnetic wavelength radiation including thermal radiation and visible light radiation [2]. Solar photovoltaic technology converts light energy into electricity while solar thermal technology absorbs thermal energy for specific needs.

Basic principle of solar thermal technology is first to absorb heat from solar radiation in one medium. Then, to use this heat energy, the medium is transported to the specific device. Solar thermal collector is needed to absorb solar thermal radiation as much as possible. Many types of solar thermal collector have been studied [3]. Generally, solar thermal collector is classified into two types, non-concentrating solar collector for low temperature needs and concentrating solar thermal collector for high temperature needs.

Solar thermal technology has been introduced since long time ago. Solar thermal energy is now applied for water heater, drier, power generation, air conditioning, etc [4,5]. Many studies have been conducted to develop and apply this technology include to support other advance technology. Xiaoguang gu *et al*. studied the application of solar thermal energy for methanol reforming [6]. Weichang *et al*. conducted the experimental study and theoretical analysis for finned absorber. Moreover, to support global solar thermal market, the standard and certification scheme for solar thermal collector, stores, and systems has been made by Stephen Fistcher [7].

Huge amount of energy is consumed in agricultural industry for drying process [8, 9, 10]. This process itself is performed by blowing the hot air into the object. Harnessing solar thermal energy is one of the methods to reduce the energy consumption in drying process. In this study, plate-fin solar thermal collector for air heater drying system is constructed and its performance is investigated.

EXPERIMENTAL SETUP

The constructed solar thermal collector system consisted of 40 x 80 cm aluminum plate and 13 fins attached on the plate. Each fin had dimension of 3.9 cm x 78 cm, shown in figure 1 (a). This solar thermal collector were then painted black and placed inside the insulated duct with transparent material (glass layer) on the top, figure 1(b). Fans were placed at one end of the duct and used to blow the ambient air into the solar collector parallel to the length of the fins. The experiment was conducted at 10.00 am to 2.30 pm on sunny day in Bandung, Indonesia.

(a)

(b)

Figure-1. (a) Plate-fins solar collector, (b) Solar collector inside insulated duct.

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The scheme of experimental setup is shown in Figure-2. The ambient (inlet) air temperature, output air temperature, incident solar radiation intensity, and velocity of air flow were measured simultaneously and logged every 180 second. Air mass flow rate is calculated by the following equation:

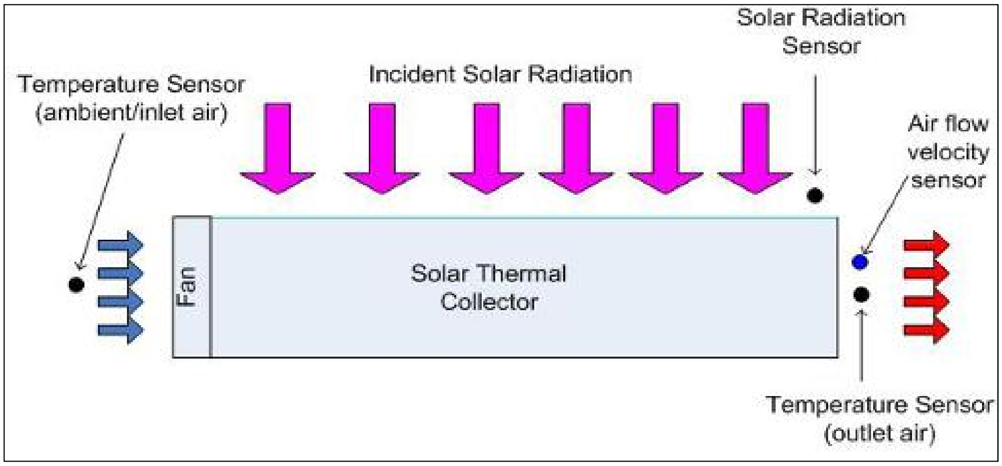

Figure-2. Experimental setup.

$$\dot{m} = \rho \cdot A_b \cdot v \tag{1}$$

where ρ is density of air, A_b is cross section surface area of the duct, and v is velocity of air flow. Once mass flow rate is obtained, the heat absorbed by airflow is determined by:

$$\dot{Q}_{air} = \dot{m} \cdot c \cdot (T_{out} - T_{amb}) \tag{2}$$

where c is heat specific of air, T_{out} is output air temperature, and T_{amb} is ambient air temperature. In the other hand, incident solar thermal power radiation is calculated by:

$$\dot{Q}_{rad} = I \cdot A_s \tag{3}$$

where I is intensity of incident solar radiation and A_s is total surface area of the solar collector.

To reduce the thermal mass effect since the solar radiation is not constant, the thermal efficiency is calculated by considering the total incident solar radiation energy and total heat absorbed energy during the experiment. The thermal efficiency is then calculated by:

$$\eta = \frac{\int \dot{Q}_{air} \cdot dt}{\int \dot{Q}_{rad} \cdot dt} \approx \frac{\sum \dot{Q}_{air} \cdot \Delta t}{\sum \dot{Q}_{rad} \cdot \Delta t} \tag{4}$$

where Δt is time interval in the measurement.

RESULT AND DISCUSSIONS

Incident solar radiation is first transmitted from glass layer to the solar thermal collector. Then, solar radiation is absorbed by plate-fin solar collector thus its temperature is increased. Since there is temperature difference, convection heat transfer occurs from solar thermal collector to the air flow. Therefore, after passing the solar thermal collector, the output air temperature is higher than ambient air temperature, shown in Figure-3. The average temperature difference is 14.3 ^{o}C.

Based on the measurement result, the velocity of air flow is 0.4 m/s. Then, the air mass flow rate calculated by equation 1 is obtained 0.07 kg/s. The incident solar radiation and heat absorbed by air flow are shown in Figure-4. It shows that heat absorbed is much lower than incident radiation. The total thermal efficiency calculated by equation 4 is 49%.

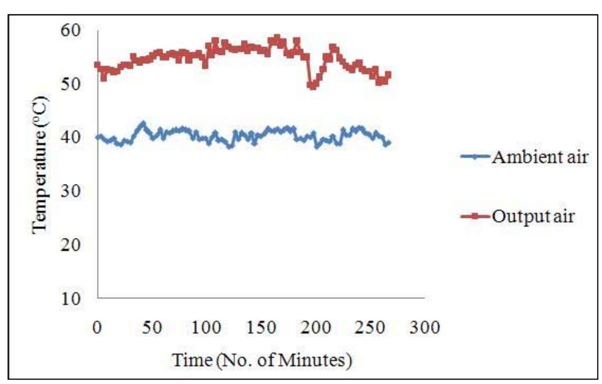

Figure-3. Ambient and output air temperature.

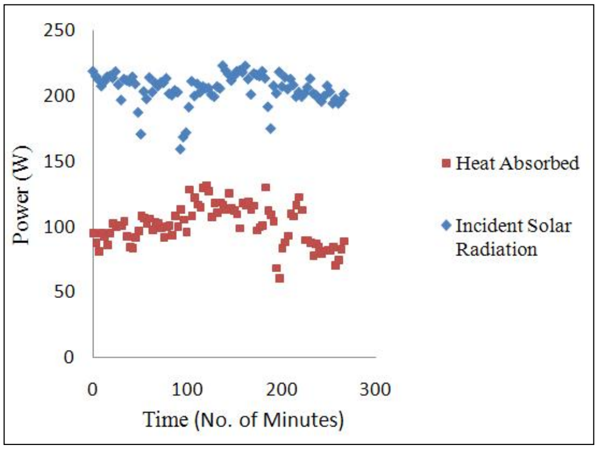

Figure-4. Heat absorbed and Incident solar radiation.

Not all of incident solar radiation is absorbed by solar thermal collector since the emissivity of black painted aluminum is still less than 1. It means that some of the thermal radiation is either reflected or transmitted by solar thermal collector. Heat loss also occurs at the glass layer since some portion of solar radiation is absorbed and reflected by glass layer instead of transmitted to solar thermal collector. Besides that, heat is spontaneously transferred from high temperature to low temperature [2]. Whenever the temperature inside the duct is higher than ambient, heat loss still occurs from inside suct to the surrounding through duct materials.

CONCLUSIONS

The experiment to investigate the thermal efficiency of plate-fin solar thermal collector is performed. The air mass flow rate is at 0.07 kg/s. The increasing of air temperature after passing the solar thermal collector is 14.3 ^{o}C. The analysis of thermal efficiency is calculated by considering the incident solar energy and heat energy absorbed by air flow. The thermal efficiency of this solar thermal collector is 49%. Heat losses occur through three ways: the emissivity of black painted aluminum (less than 1), heat absorbed and reflected by glass layer, and heat losses through the duct materials**.**

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