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Performance of Low-Cost Solar Water Heater

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Abstract

This study investigated the performance of a low-cost solar water heater (SWH). The SWH consists of a solar collector with a simple flat plate thermosiphon and water tank. The solar collector has, a glass cover, painted black on an aluminium absorber plate, water pipes and the sides insulated. During the testing process, the temperatures in the SWH were recorded at 1-second intervals by using Advantech Software DAQ Navi Data Logger, which is connected to a laptop via USB-4718, 8-Channel Thermocouple Input Module. The results that the efficiency of the solar collector ranged from 5% to 23%, with an average of 16% at water flow rate of 0.0019 kg/s. In addition, the time required by low-cost SWH to heat the water in a tank of 20 liters to reach its maximum temperature of 48.3°C is 8 hours 36 minutes.

Keywords: *Thermosyphon, Renewable energy, Solar collector, Solar Water Heater*

1. Introduction

Solar energy is an alternative and renewable energy resource, comes from the energy of the sun and serves as one of the most abundant permanent energy sources. Solar energy is free, clean, secure, and available on earth throughout the year. This form of clean energy is important to the world, especially during these times of high conventional fuel costs and environmental concerns arising from conventional fuel applications [1-3]. Furthermore, solar energy can be used in various applications such as thermal management using thermal collectors or electricity generation through photovoltaic (PV) cells. PV cell are semiconductor devices used to convert solar energy into electricity. The solar collector is a device used to convert solar energy into thermal energy. Solar energy to heat water has been in use for many years, and the design requirements of solar water heating equipment have been studied for more than 100 years.

Solar water heaters (SWHs) were not widely used, not due to lack of understanding, but because the other sources of energy were more economical. Interest in solar water heating in the past was limited to those having the understanding and enthusiasm necessary to build their equipment. Solar water heater (SWH) system is one of the absorber or collector of heat from solar radiation that serves to heat water, the main energy source of the solar collector is sunlight. Therefore, the result will depend on the weather conditions that are affected by solar thermal radiation reaching the earth. SWH is an alternative system that can be utilized to meet the needs of hot water. The geographical condition of the Indonesian on the equator causes the potential of Indonesia's solar energy to be quite high. The sun will continue to shine throughout the year, with an average radiation duration of 6-8 hours per day, as well as the average duration of exposure ideally 4-5 hours per day [4-11].

Technical advances in solar water heating have been very rapid in the last 40 years. The obvious benefits to the householders can no longer be overlooked, where the climate is ideally suited for the application of solar energy for water heating, particularly, in the present situation of acute energy shortage. Solar water heaters find wide applications in large establishments like hostels, hotels, hospitals, industries such as textiles, paper, and food processing, domestic uses, and in heating swimming pools. Solar water heaters offer several advantages such as (i) simple to construct and install, (ii) almost no maintenance and running cost, (iii) save time and energy, (iv) retrofittable to existing houses, (v) economically competitive with electric water heaters, (vi) required temperature easily achieved with simple equipment [12]. The purpose of this study is to determine the value of solar collector efficiency in absorbing heat and know the time required by solar water heater to reach its maximum temperature.

2. Material and Methods

The SWH test was conducted on March 4, 2018, while the design and manufacture of solar water heater is done in September - October 2017. The SWH was installed at the University of Muhammadiyah Riau Pekanbaru. The SWH consists of a solar collector with simple flat plate thermosiphon and water tank. The solar collector has, a glass cover, painted black on an aluminium absorber plate, water pipes and the sides insulated. The photograph of the low-cost SWH system as shown in Figure 1. The total length of the pipes is 11.1 m. The length and width of the collector are 1 and 0.6 m, respectively. The area of the collector is 0.6 m2.

The schematic of natural convection flow SWH as shown in Figure 2. The fluid in the tank flowing through the hose from the bottom of the tank to the bottom of the solar collector shown with mark A on the image. Then the fluid flows through the header and riser to the solar collector and returns to the water tank from the top of the collector through the hose to the top of the water tank shown with the mark B in Figure 2.

The testing of low-cost SWH was conducted on March 4, 2018, at the University of Muhammadiyah Riau Pekanbaru. The coordinates of the test location are Lat: 0o29'57,83 "N, Long: 101o24'55,71" E. The method used in testing the solar water heater that is by connecting the thermocouple sensor that has been installed on the device to the Laptop using USB-4718 then record the sensor reading data from 7:23 AM to 6:47 PM on the condition of the device functioning normally. A flowchart of the experimental of low-cost SWH is shown in Figure 3.

Figure 1. Photograph of low-cost SWH

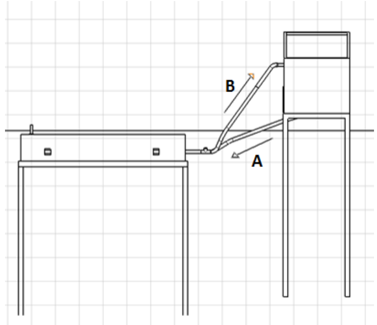

Figure 2. Schematic of natural convection flow SWH

To calculate the value of the excavated solar collector can use the Eq. (1) as follows [13, 14]:

$$\eta = \frac{\dot{m}\, c_p\, (T_{out} - T_{in})}{G_t\, A_a}\ 100\% \tag{1}$$

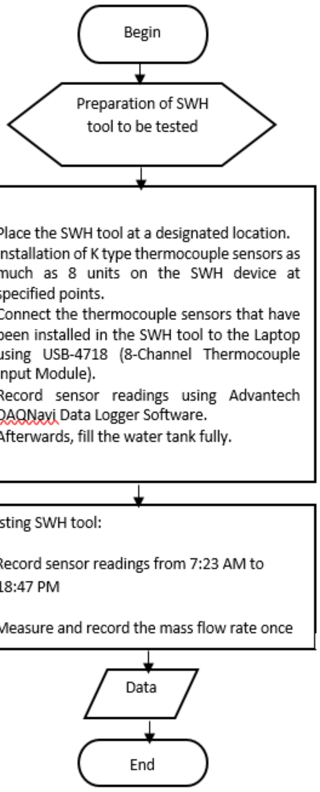

Figure 3. Flowchart of Experimental

3. Result and Discussion

Testing of the of low-cost SWH was carried out from 7:23 AM to 6:47 PM or approximately 11 hours 24 minutes, during sunny weather conditions, with the results of test data as shown in Figure 4. From Figure 4, can we analyze as: (i) Temperature of glass, film and plat (Tglass, Tfilm, TPla) are very close together and temperature of ambient (Tambient) is adjacent to output temperature of collector, (ii) Period hour 7:23 to

7:57 PM (Mark A) at the beginning of the test where the sunlight intensity is still low so that the value of the collector temperature deviation of outlet and inlet temperature (ΔT) becomes <0˚C, (iii) The period of 4:38 PM to 4:47 PM (Mark B) at the end of the test where the intensity of sunlight began to decline so that the value of ΔT becomes <0˚C, (iv).

the collector. The simple principle is to use the fluid properties that will decrease its density when exposed to heat. So the fluid becomes lighter and will rise to the top of the collector where the part will go to the tank. While the fluid is still in a cold state will lead to the bottom of the tank so it will flow into the solar collector.

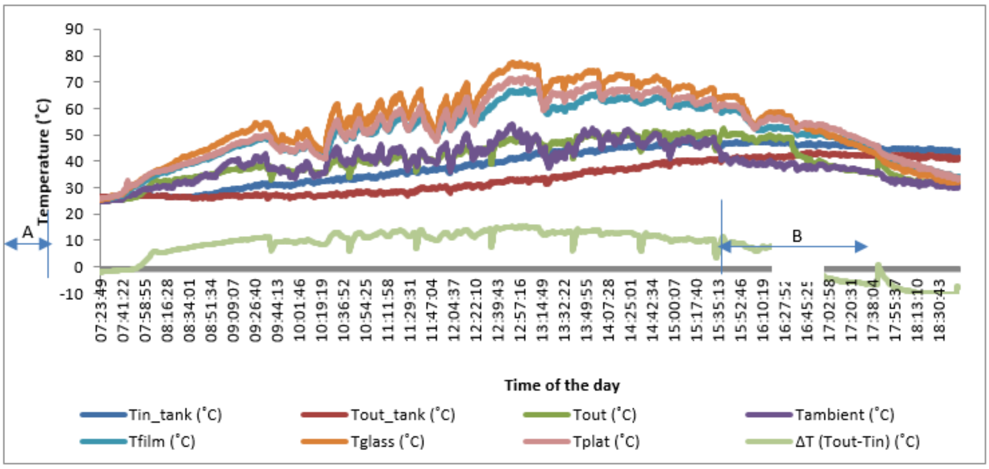

Figure 4. Variation temperatures versus time

When the device operates normally, the intensity of the stable sunlight from 7:57 AM to 4:38 PM is the average value of ΔT of 10˚C, (v) The water temperature in the tank gradually increases over time and reaches its maximum temperature of Tinlet water tank at 48.3°C at 4:00 PM or it takes about 8 hours 36 minutes to obtain the maximum water temperature in the tank from the beginning of the test, (vi) Outlet temperature of collector or water temperature coming out of the solar collector starts to decline at 16:33:49, but inlet temperature of water tank can still maintain its temperature is 42.2˚C, and (vii) From the two periods (mark A and B) it can be concluded that if the sun's low intensity of the SWH device can be a coolant which is not expected.

The efficiency of collector ranged from 5% to 23% with an average value of 16% at water flow rate of 0.0019 kg/s and average solar radiation of 606 W/m2. To compare the performance of the water tank before it was isolated and after it was isolated it can be analyzed using the water tank observation data as shown in Table 1. From Table 1, observation data temperature in water tank can be analyzed as: (i) Tin water tank without insulation has increased temperature faster than an isolated tank. However, Tin of water tank without insulation also experienced a faster temperature drops than the insulated tank, (ii) The fluid circulates with natural convection between the solar collector and the calculated tall tank above

Table 1.
Variation temperatures in water tank

Time	Tin_tank without insulation (˚C)	Tin_tank (˚C)	Tout_tank (˚C)	Tout (˚C)
2:30:00 PM	19.59	45.7	37.2	49.4
3:00:00 PM	39.76	46.9	40.0	50.1
3:30:00 PM	44.14	47.6	40.7	51.0
4:00:00 PM	44.41	47.0	41.3	48.5
4:30:00 PM	44.96	46.9	41.8	48.9
5:00:00 PM	43.14	46.6	43.0	39.6
5:30:00 PM	42.28	45.5	42.2	36.1

4. Conclusion

From the results of the test conducted for 11 hours 24 minutes, the time required by the low-cost SWH with simple flat plate to heat water in the tank 20 liters to reach its maximum temperature of 48.3˚C is 8 hours 36 minutes.

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NOMENCLATURE

B	dimensionless heat source length
CP	specific heat, J. kg^{-1}. K^{-1}
g	gravitational acceleration, $m.s^{-2}$
k	thermal conductivity, $W.m^{-1}$. K^{-1}
Nu	local Nusselt number along the heat source

Greek symbols

α	thermal diffusivity, m^2. s-^{1}
β	thermal expansion coefficient, K^{-1}
ϕ	solid volume fraction
Θ	dimensionless temperature
μ	dynamic viscosity, kg. $m^{-1}.s^{-1}$

Subscripts

p	nanoparticle
f	fluid (pure water)
nf	nanofluid