Investigation on Performance of Solar Collector in the Adsorption Process with Variation of Angle of Surface Plate

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Abstract: Sunlight radiation energy is currently being used as an alternative energy source in order to replace energy that is derived from petroleum fuel. Therefore the sun's energy that never runs out can be utilized. This research aims to determine the heat used by the collector for the desorption process and the angle variations of the collector effect for collector efficiency using activated charcoal adsorbent. Accordingly that, one of them can be used for the water cooling process using a solar collector device on a solar heat adsorption cycle cooling machine. This research was conducted by varying the angle of the collector's refrigeration with an adsorption cycle using solar energy. The test results show that the average useful heat of the collector (Qu) obtained by the 0° collector angle is 183.3 Watt, for 15° collector angle is 173.3 Watt, and for 30° collector angle is 158,2 Watt. The average efficiency of the collector (η) obtained by the 0° collector angle is 48,22%, 15° collector angle is 45,322% and for 30° collector angle is 41,573%.

1 INTRODUCTION

Indonesia has substantial solar energy resources, with an average solar radiation intensity of roughly 4.8 kWh/m^2 per day due to its equatorial location between 6°N and 11°N and 9°E and 141°E. The total annual solar radiation received by all regions of Indonesia is around 2500 hours, with an average of 14.5 MJ/m^2/day. Thus, unlimited solar energy may be used to power the Indonesian people. Solar radiation energy is currently used as an alternative energy source to replace petroleum-based energy. One application of radiation energy is water cooling via a solar collector device on a solar heat adsorption cycle cooling system.

Many researchers performing research to investigate the performance of solar collectors. The analysis was undertaken for a small public office building in Bialystok (Poland), where solar collectors were regarded as the primary source of renewable energy for the domestic hot water (DHW) system, with the idea that the existing oil boiler would serve as a backup (Krawczyk, Żukowski, & Rodero, 2020). The article discusses the viability of employing a non concentrating direct absorption solar collector (DAC) and compares its performance to that of a conventional flat-plate collector (Tyagi, Phelan, & Prasher, 2009). Experiments are conducted to determine the influence of a CuO–water nanofluid as the working fluid on a flat-plate solar collector (Moghadam, Farzane-Gord, Sajadi, & Hoseyn-Zadeh, 2014). Experiments were conducted to determine the efficiency of a novel design and production process for flat plate solar collectors. Solar collector design adjustments are always a viable option for improving thermal efficiency significantly (Verma, Sharma, Gupta, Soni, & Upadhyay, 2020). a novel technique for optimizing the performance of solar thermal collectors The solar reflector is used in conjunction with the solar collector to boost the collector's reflectivity (Bhowmik & Amin, 2017). research and optimization of the thermal performance of an evacuated CPC (Compound Parabolic Concentrator) solar collector equipped with a

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cylindrical absorber (Kim, Han, & Seo, 2008). Artificial neural networks (ANNs), least squares support vector machines (LSSVMs), and neuro-fuzzy are utilized to advance prediction models for photovoltaic-thermal solar collector (PV/T) thermal performance (Ahmadi et al., 2020). a numerical simulation of forced convective heat transfer using a two-dimensional heat function formulation through a direct absorption solar collector (DASC) packed with water-copper nanofluid (Nasrin, Parvin, & Alim, 2015). Experiments have been done to ascertain the collector's dual function. It is demonstrated that the collector's thermal efficiency reached 50% when used for water heating and fluctuated between 41% and 55% when used for air heating, depending on the ambient temperature and flow velocity (Ma et al., 2011). Dispersing nanometer-sized particles into the base fluid is offered as an efficient way for improving the working fluid's heat transfer capabilities (Amin, Roghayeh, Fatemeh, & Fatollah, 2015).

As far as we know, no researcher carried out the efficiency of the solar collector by varying the angle of the surface to horizontal.

This research aims to ascertain the amount of heat absorbed by the collector during the desorption process and the angle variations in the collector's effect on collector efficiency. The angle of the solar collector's surface was varied with the values 0^o, 15^o and 30^o. The research was carried out by drying the adsorber in the sun. The desorption process lasts ± 9 hours from 08.00 WIB - 17.00 WIB.

2 MATERIALS AND METHOD

2.1 Dimension of Solar Collector

Figure 1 shows the three-dimensional model of the solar collector. The dimension of the solar collector is 500 mm x 500 mm x 80 mm.

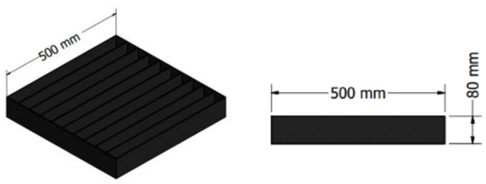


Figure 1: Three Dimensional Model of Solar Collector.

Figure 2 shows the inside part of the solar collector. This part consists of glass, active charcoal, sponge, Rockwool, plywood and styrofoam. Solar collectors are a type of heat exchanger that generates heat energy by employing solar radiation as the primary energy source. When sunlight strikes the solar collector's adsorber, some of the light is reflected back into the environment. At the same time, the majority is absorbed and converted to heat energy, which is then transported to the solar collector's circulating fluid for use in a variety of applications.

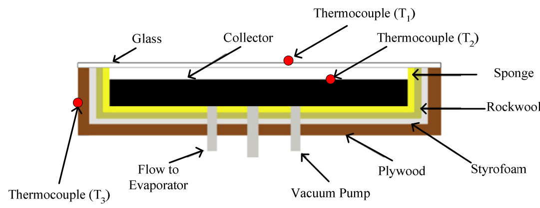
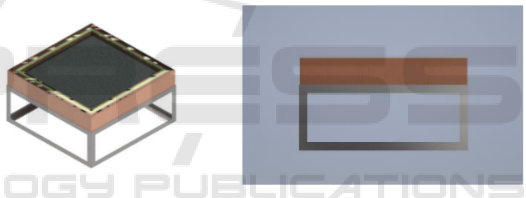


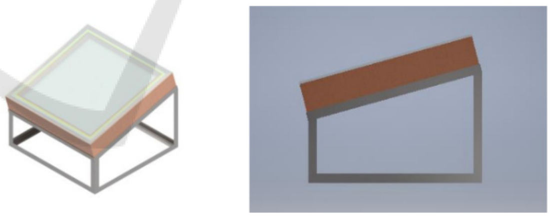
Figure 2: Inside Part of Solar Collector.

On solar collectors, three thermocouples are used to determine the temperature of the glass surface, the adsorbent plate surface, and the ambient temperature, respectively. Before installing the thermocouple, it should be checked at every point to make sure there is no error in connection.

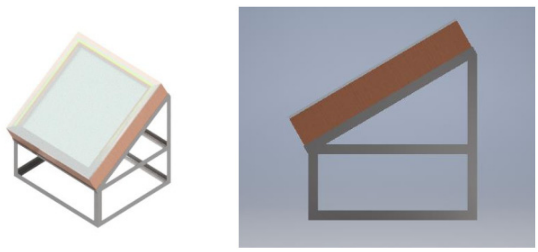
2.2 Material Properties



(a) Solar Collector with angle 0^o



(b) Solar Collector with angle 15^o



(c) Solar Collector with angle 30^o

Figure 3: Angle Variation of Solar Collector.

Figure 3 shows the angle variation of the solar collector. The solar collector's angle is modified utilizing three different angles, namely 0, 15 and 30. Angle adjustments are included to demonstrate the angle's effect on the intensity of sunlight striking the collector. The intensity of the sunlight can be calculated using the equation :

$$G_{bT} = G_{bn} \times cos\theta_T \quad (1)$$

where :
G_{bT} : solar intensity on an inclined plane (W/m^2)
G_{bn} : solar radiation intensity at an angle of entrance normal to the horizontal surface (W/m^2)
θ_T : the angle between the direction of the sun's rays and the direction perpendicular to the inclined surface.

Calculation of heat absorbed at the collector can be calculated using the formula :

$$S = (\tau\alpha)_{ave} \times Q_{it} \times A_c \quad (2)$$

where :
S : heat absorbed (J)
$(\tau\alpha)$: the average absorptive transmissivity of glass
Q_{it} : intensity of solar radiation (J/m^2)
A_c : collector cross-sectional area (m^2)

Then, the heat loss coefficient lost to the collector can be calculated using the formula:

$$QL = Q_T \times Q_B \times Q_E \quad (3)$$

where :
Q_T : total heat loss at the top of the collector (W)
Q_B : total heat loss at the bottom of the collector (W)
Q_E : total heat loss on the sides of the collector (W)
Q_L : total heat loss on each side of the collector (W)

The actual efficiency of the solar collector during the test can be calculated in the empty state and contains activated carbon. Empty collector efficiency can be calculated using the following formula:

$$\eta = \frac{Q_u}{I_{bn} \times A_c} \quad (4)$$

where :
η : collector efficiency (%)
Q_u : heat absorbed by collector (W)
I_{bn} : intensity of sunlight through the collector (W/m^2)
A_c : area of collector's surface (m^2)

3 RESULT AND DISCUSSION

3.1 Calculation of Solar Radiation Intensity

Table 1 shows the result calculation of solar radiation intensity from 08:00 to 17:00. The maximum intensity of solar radiation occurs around 12 o'clock with the solar collector tilted at a 0-degree angle to the horizon.

Table 1: The result calculation of solar radiation intensity.

Time (WITA)	Angle 0°	Angle 15°	Angle 30°
08:00	259.94	319.63	353.74
08.30	361.56	358.71	349.16
09.00	413.22	416.16	426.35
09.30	448.29	451.53	475.96
10.00	505.46	506.41	517.54
10.30	483.69	488.89	493.63
11.00	614.52	638.60	632.74
11.30	625.73	633.84	651.98
12.00	703.34	698.76	691.79
12.30	697.89	672.02	689.83
13.00	649.63	663.38	647.75
13.30	641.09	621.48	638.69
14.00	568.48	551.86	584.76
14.30	494.56	514.00	507.05
15.00	384.92	370.63	400.06
15.30	299.75	290.80	313.36
16.00	263.74	243.18	253.85
16.30	103.23	111.37	124.14
17.00	54.41	60.65	58.44

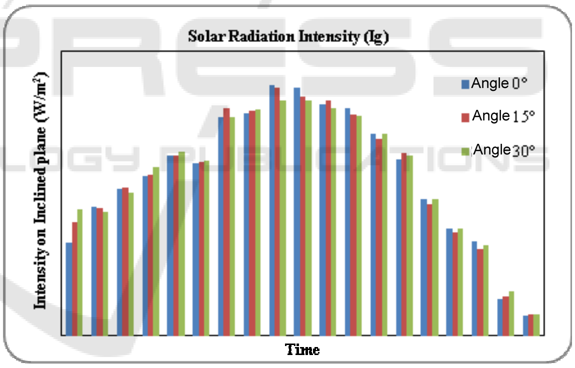


Figure 4: Solar Radiation Intensity on an Inclined Plane.

Figure 4 shows the radiation intensity on an inclined plane. It can be seen that the intensity of solar radiation is almost the same and changes over time. Overall, the highest global radiation intensity (Ig) lies in the 0° collector angle test at 12.00, which is 703.34 W/m^2. Meanwhile, the lowest global radiation intensity (Ig) is in the 0° collector angle test at 17.00, which is 54.41 W/m^2. The average global radiation intensity (Ig) from 08.00 – 17.00 WITA obtained by collector angle 0° is 451.24 W/m^2, collector angle 15° 453.259 W/m^2, and collector angle 30° is 463.73 W/m^2 on each test day.

3.2 Calculation of the Heat Absorbed by the Collector

Table 2: The results of the calculation of the heat absorbed by the collector.

Time (WITA)	Angle 0°	Angle 15°	Angle 30°
08:00	130,02	159,87	176,93
08.30	190,46	188,95	183,93
09.00	223,74	225,33	217,43
09.30	246,48	248,26	260,41
10.00	280,4	280,93	287,1
10.30	269,75	272,66	275,3
11.00	343,81	357,29	344,42
11.30	350,7	355,25	357,2
12.00	430,23	427,43	405,06
12.30	391,14	376,64	370,19
13.00	363,46	371,15	357,61
13.30	357,54	346,60	344,04
14.00	315,36	306,14	315,9
14.30	271,92	282,6	278,78
15.00	208,41	200,67	208,78
15.30	157,9	153,18	159,48
16.00	131,92	121,64	126,97
16.30	46,56	50,23	55,99
17.00	19,63	21,89	21,09

The relationship between the heat absorbed by the collector and time can be seen from Figure 5 below:

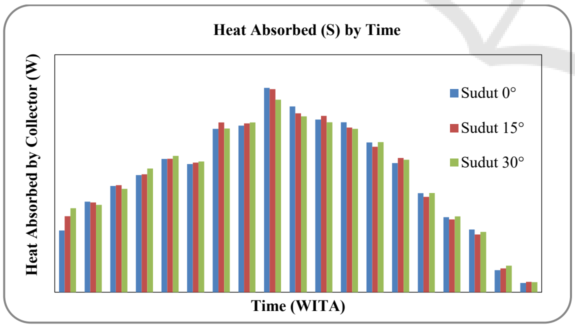


Figure 5: Heat absorbed by Collector.

It can be seen that the heat absorbed by the collector (S) is almost the same and changes over time according to the angle of each collector. Similar to the intensity of solar radiation (G_{bT}), the heat absorbed by the collector (S) can also be affected by erratic weather factors, wind speed and the angle of incidence of light on the collector surface (θ_1). Overall, the highest heat absorbed by the collector (S) lies in the 0° collector angle test at 12.00 which is 430,23 Watt. Meanwhile, the lowest heat absorbed by the collector (S) lies in the 0° collector angle test at 17.00, which is 19,63 Watt. The average heat absorbed by the collector (S) obtained by the 0° angle collector is 248,916 Watt, the 15° collector angle is 249,826 Watt, and the 30° angle collector is 249,821 Watt on each test day.

3.3 Calculation of the Collector Efficiency

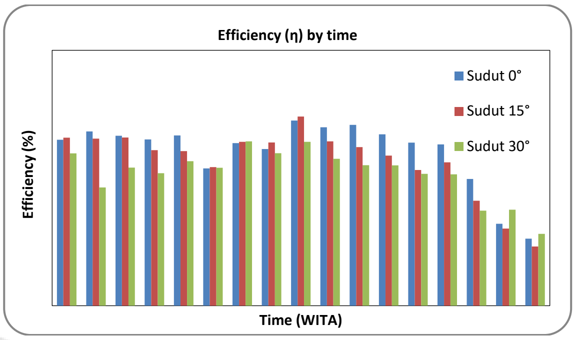


Figure 6: Efficiency of Solar Collector.

It can be seen that the efficiency (η) tends to be almost the same. In general, collector efficiency is the ratio between useful heat and the intensity of solar radiation entering the absorber. The useful heat from the collector is the heat flux absorbed by the absorber minus the rate of heat loss to the environment. The amount of useful calorific value does not necessarily cause the value of useful efficiency to be large. The useful calorific value is obtained from the difference between the heat absorbed by the collector and the heat loss lost to the collector. The greater the heat absorbed by the collector, the greater the heat loss lost to the collector to the environment.

Similar to the discussion of the useful heat graph (Qu), in this measurement at 16.30 the calculation of efficiency (η) began to get a negative value. This happens as described because at the time of the test the heat loss lost to the collector (Ql) is greater than the heat absorbed by the collector (S). The peak of heat absorbed by the collector occurred at 12.00, after which the heat absorbed began to decline. While the heat loss lost from the collector decreases according to the measurement of the heat temperature that has been obtained. Therefore, to get the average efficiency (η) that is effective, it is taken from 08.00 to 16.00 . Overall the highest efficiency (η) lies in testing the 0° angle collector obtaining a value of 48,22 %, the 15° angle at 45,32 % and the 30° angle collector getting a value of 41,57 %.

3.4 Discussion

The researcher suggests that this can be accomplished by adding an angle regulator to the collector that allows it to be adjusted in response to the angle of incidence of the sun and variations in other adsorbent materials, as well as by selecting a good insulating material to minimize heat loss to the collector.

4 CONCLUSIONS

From the results of tests and analyzes that have been carried out, conclusions can be drawn from this research, namely as follows:

1). The highest useful heat in the collector (Qu) lies in testing the collector at an angle of 0° at 12.00 which is 272.064 Watt. Meanwhile, the lowest useful heat in the collector (Qu) lies in the collector test at an angle of 0° at 17.00, which is -42.18 Watt. The average proper heat at the collector (Qu) obtained by the 0° angle collector is 139.878 Watt, the 15° collector angle is 118.624 Watt, and the 30° angle collector is 113.611 Watt on each test day.

2). Collector efficiency (η) from 08.00–16.00 WITA. The 0° angle collector gets a value of 42.617%, the 15° angle is 36.377% and the 30° angle collector gets a value of 33.708%.

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