Improvement of thermal performance of the finned tube flat plate solar water heater

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Abstract. The collector is the main component of the solar thermal system. The collector collects the heat of the sun's energy, and then transfer this heat into a fluid. This paper studies the effect of an absorber tube with a tube finned of a solar flat plate water heater. The investigation of this system is carried using an experimental study. A plat absorber of 1.6 m x 1.1 m size was employed. Here, fins are used as an extended surface inside an absorber tube. Radiation, ambient temperature, mass flow, temperature water inlet, temperature water outlet was collected during the experiment. The performance of the water heater was discussed. The experimental performance of the system solar water heater was focused on measured collector’s outlet hot water temperature and solar irradiance power available during sunny hours. Thermal efficiency is found to be higher for utilized of tube fin.

1. Introduction

Nowadays each part of the world strives to find renewable energy resources for survival. Besides that, the high cost of energy and global warming became a hot issue for discussion in recent times. Exploration of solar energy one of the solutions for some problems with energy resources, application of solar energy began to spread globally to direct towards reducing dependence on fossil fuels. The application and uses of solar energy have varied, among solar energy for solar water heater, solar thermal energy (PV), solar energy for drying system, solar energy for refrigeration, etc [1]. Including Indonesia, the location and climate of Indonesia were supported makes it one of the most promising areas for exploration of solar energy. The daily solar irradiation in Indonesia varies from 3.2 kWh/m$^2$ to 6.2 kWh/m$^2$, in a year it can be 1300 kWh/m$^2$ to 2200 kWh/m$^2$ [2].

The utilization of solar energy was widely applied in people's lives. Like solar energy for water heater, which is widely used in many buildings. Today solar water heater has been showing a significant impact on development technology in many countries. This matter making an investigation about solar water heater continue development. Many researchers studied the performance of the solar water heater. Himsar Ambarita [3] studied the development of a solar water heater that is suitable for Indonesia. In this paper, design, and test several types of solar water heaters which is suitable for Indonesia's climate. Sitepu et al. [4] design a prototype of a solar water heater using refrigerant R134a as transfer fluid. Nirmala [5]...
investigated the performance of single glass and double glassed flat plate solar water heater. From the research has been found that the double glass is performing satisfactorily than a single glass. Sujit et al. [6] designed and compared the conventional flat plate solar collector and spiral-shaped solar collector. From the research spiral solar collector enhancement in thermal efficiency achieves is 21.94% compared to conventional flat plate solar collector. Man Fan et al. [7] tested the solar water heater with a new V-corrugated absorber. The design of a V-corrugated absorber can improve the collector optical and thermal efficiency.

Recently, the optimization of the solar water heater was continued to study. Therefore in this research, the collector to be tested to improve the efficiency of water heaters is the addition of fins on the surface of tube pipes in the flow of water, where the fins on the pipe are useful to accelerate the rate of heat transfer to the water. All the parameters will be collecting as long as the experiment, like the radiation, ambient temperature, water inlet, and outlet, all of the side collectors. This research will increase the performance of a solar water heater in the future.

2. Solution Method

2.1. Thermal analysis of the solar air heater

The main concern of the thermal performance of a solar water heater is the heat transfer process within it. The energy gained by the collector can be calculated by using the relation:

\[
Q_a = \alpha \tau I A_c - U_L A_c (T_c - T_a)
\]

Where \(A_c\) is a solar collector area (m\(^2\)), \(I\) the incident insolation (W/m\(^2\)), \(U_L\) the overall heat loss by the collector (W/K), \(\alpha\) the solar absorptance, \(\tau\) transmittance of the absorber plate, \(T_c\) the collector temperature (K), and \(T_a\) the ambient air temperature (K).

The heat gained, is given by:

\[
Q_g = \dot{m} a C_{pa} (T_c - T_a)
\]

Where \(\dot{m}\) is the mass flow rate of air through the dryer per unit time (kg/s) and \(C_{pa}\) the specific heat capacity (kJ/kg K)

![Figure 1. Solar water heater using fin tube](image)
The coefficient of heat transfer between the air and the heated plate is given by:

$$h = \frac{Q_g}{\{A_c \left( T_{mp} - T_{bm} \right)\}}$$

(3)

Where $A_c = LB$ is the collector area of heat transfer, $T_{mp}$ and $T_{bm}$ are weighted mean value of plate temperature and bulk mean air temperature. \(\left( \frac{T_o - T_a}{2} \right)\)

The Nusselt number and Reynold number to provide required information on heat transfer quality are given as:

$$NU = \frac{hD}{k}$$

(4)

And

$$Re = \frac{GD}{\gamma}$$

(5)

Where $D = 4BH \div \{ 2(W+H) \}$ is the hydraulic diameter, $G = ml(BH)$ which is the mass velocity of the air through the duct.

The friction factor ($f$) can be obtained from the measured value of pressure drop $\delta p$ across the length of the duct:

$$f = \frac{2(\delta p)pD}{4LG^2}$$

(6)

The collector heat removal factor ($F_R$):

$$F_R = \frac{m_a C_{pa} \left( T_c - T_a \right)}{A_c \left[ \alpha \tau_1 - U_L \left( T_c - T_a \right) \right]} = \frac{Q_g}{Q_u}$$

(7)

The collector efficiency ($\eta$) is expressed:

$$\eta = \frac{m_a C_{pa} \left( T_c - T_a \right)}{IA_c}$$

(8)

2.2. Experimental set-up

The operation and detail of the main components of the system are explained. The experiment was constructed as shown in figure 2. The experimental performance of the system solar water heater was focused on measured collector’s outlet hot water temperature and solar irradiance power available during sunny hours. The solar collector having dimensions $1.6 \text{ m} \times 1.1 \text{ m}$. In this research, a solar water heater collector was tested with a capacity of 120 liters of water. The design of the collector there is, tube pipe with finned, absorber, transparent cover (glass), and insulation on the collector. The finned tube pipe manufactured using a copper sheet of 1 mm thickness with a spacing of finned 12 cm. the total finned used was 234 pieces, installed along the tube pipe. The total length of the tube pipe was 2397 cm. The mass flow rate of the system 0.041 kg/s. In the experiment, solar radiation was collected and recorded with an interval record every five minutes. The temperature of the solar collector was measured by An Agilent data logger, and a HOBO-micro station was used to record the solar radiation.
Figure 2. Experimental setup of water heater process

3. Result and Discussion
In this part, the obtained experimental results are showed and discussed in detail. The experiment was done on August 22 at Medan, Indonesia with geographic coordinate 3°34’ North and 98°40’ East, and the experiment started at 08.00 pm to 16.00 am. Figure 3 shows the variation of the solar radiation and temperature of the ambient of the solar water heater. It is clear from the figure that the two temperatures and solar radiation increased with time while from the afternoon toward evening.

Figure 3. Variation of solar radiation and temperature ambient
In figure 3 is shown the radiation and temperature of the solar water heater have recorded as long the experiment. The total radiation was collected 182138.4 Watt/m² with an average of 378 Watt/m². The higher radiation during the experiment at 13.20 WIB with 680.6 Watt.

3.1. Collector efficiency
In this section, figure 4 shows the efficiency of a solar water heater collector during the experiment. It showed that the highest collector efficiency occurred at 10:54 pm obtained by 86.28%. The material of the system decides the efficiency of the solar water heater.

![Figure 4. Collector efficiency](image)

3.2. Tank Temperature
In figure 5 shows that the temperature at the flat plate absorber and water versus time during the sunshine hours available (08.00 am-4.00 pm).

![Figure 5. The absorber plate and the water temperature versus time](image)

In figure 5 is shown a graph of temperature and plate absorber versus time during the experiment. The higher temperature of the plate absorber was 73.14 °C at 13.15 WIB and the water temperature was...
49.84 °C at 13.30 WIB. High and low temperatures are affected by irradiance through into collector. This research showed that the use of finned tube solar water heater can be a solution to improve the temperature outlet of the solar water heater.

4. Conclusion
The following conclusions were obtained from this study. The tube pipe with finned solar water heater showed that the temperature would increase parallel with the enhancement of global solar irradiation during sunshine hours available. The efficiency of the tube finned flat plate water heater was obtained at 86.28%. This research showed that the use of finned tube solar water heater can be a solution to improve the temperature outlet of the solar water heater.

References
[1] Dina, Sari Farah., Farel Napitupulu dan Himsar Ambarita. Seminar Nasional Teknologi Industri Hijau, Semarang 2013.
[2] Sibagariang Y P, Sihombing H V, Setyawan E Y, Kishinami K, Ambarita H 2020 AIP Conference Proceeding 2221 070002.
[3] Ambarita H 2018 IOP Conf. Series: Material Science and Engineering 420 012013.
[4] Sitepu T, Sembiring J, and Ambarita H 2018 IOP Conf. Series: Material Science and Engineering 309 012007.
[5] Nirmala P.N 2020 Material Today: Proceedings.
[6] Verma S K, Sharma K, Gupta N K, Soni P, Upadhyay N 2020 Energy 194 116853.
[7] Fan M, You S, Gao X, Zhang H, Li B, Zheng W, Sun L, and Zhou T 2019 Energy Conversion and Management 184 235-248.