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Factors Affecting to Double Wave Absorber Solar Water Heater Performance

Mustafa
Department of Mechanical, Faculty of Engineering, University of Merdeka Madiun,
Madiun, Indonesia

Abstract: The specific objective of this study is to find or develop new models that can improve the efficiency of solar water heater. The research conducted using the experimental method to compare the water temperature result of double-plate solar water heater and double-wave solar water heater. We investigate the cover glass number intake flow rate and initial heating the intake working fluid that can improve the efficiency of both models. The results are: the best efficiency of the solar water heater uses triple-layer glass cover, if it compared to the double layers and single layer cover glass number; the efficiency of solar water heaters increases linearly to the intake water flow rate; initial heating the intake working fluid step by step causes the efficiency of solar water heater close to zero. Generally, the performance of double-wave absorber solar water heater is better than double-plate absorber solar water heater.

Key words: Absorber plate, intake flow rate, initial heating, solar water heater, efficiency increases, fluid

INTRODUCTION

Solar energy is one of the best alternative in the connection with the human desire to improve energy sources. Gradually, we continue to improve the efficiency.

In this study, we use solar energy for water heater that produces hot water. The advantage of this energy is environmentally friendly, free and provided unlimited (Arismunandar, 1995; Duffie and Beckman, 1980). Many research had been done to collect solar energy for human life. It is explained as the following.

According to previous research, the heat absorption efficiency in double-plate solar water heater is higher than the of the conventional (Mustafa, 2008; Ismail, 2008; Farid and Ismail, 2010) and on double plate solar water heater decline more sharply than conventional solar heater (Ismail, 2008). In many tests of the intake flow rate on the heat absorption efficiency solar heater double plate is higher than the conventional. The output temperature of solar water heater using double plate when in the afternoon is decline slower than the conventional. Ismail (2008) also examines that the solar water heater efficiencies with absorber double plate using concrete cast in a simple model is higher than single absorber plate. The cast concrete absorber plate wave form generating efficiency of solar water heater is higher than the flat absorber plate (Ismail, 2008).

According to Farid and Ismail (2006) and Anggaraini (2001), the efficiency of triple-layer cover glass solar water heater with a thickness of 5 mm produces is higher than that using double or single layer. Ismail (2008) uses a thickness of 3 mm glass solar water heater that has an efficiency higher than that using a 5 mm glass thickness and spacing of glass with the best absorber plate is 20 mm. According to Mustafa (2008), the efficiency of the best solar water heater is the triple-layers cover glass if it compared to the double layers and single layer cover glass.

The greater the intake flow rate of wate and the efficiency of solar water heater has a positive correlation. the initial heating on intake water causes the both water exit temperature and the absorber plate is relatively the same, so the efficiency of solar water heater close to zero (Ismail, 2005, 2007).

No one of the previous research had studied double-wave solar water water heater. We hope that, the wave plate gives better efficiensi significantly because it has a lager area to capture the direct sunlight. This is the reason why I choose this main topic as my research. The result is an attempt to increase the efficiency has written in this study.

Solar water heater: The solar water heater systems component consists of 3 main parts (Arismunandar, 1995; Bhide *et al*., 1982):

- Solar collector who receive and transfer the sun's radiant energy into thermal energy in the working fluid
- The working fluid channels system or diverter pipe. This part connects the collector to the storage
- Fluid storage tank as a storage container of hot water

Based on the desired temperature the heat collector can be clasified into three main parts (Kreith and Kreider, 1980; Sambada, 2004; Rahardjo and Ekadewi, 2012):

- Centering collector using a low concentration that has the temperature between 80°-150°C
- Flat plate collectors for temperatures lower than 80°C

Plate collector efficiency: Solar water heaters generally consist of a thermal conductive material leaflets called absorber plates that connect to the pipes carrying the heat transfer fluid that usually water. The solar radiation that converted into heat on the absorber plate is transmitted through pipes that the bottom and all sides is isolated (Rahardjo and Ekadewi, 2012; Kristanto and San, 2001; Subarkah, 2001).

Collector panel efficiency is the ratio between the heat rate (QU) that is transferred to the fluid divided by the solar radiation cover plate. The efficiency can be shown in equation of Duffie and Beckman (1980) as the following:

$$\eta = \frac{Q_u}{A_c G_t} \tag{1}$$

The η_s is the efficiency of the absorber plate while the heat is absorbed by the absorber plate at specified intervals:

$$\eta_i = F_R(\tau\alpha) - F_R U_L \frac{(T_i - T_a)}{G_t} \tag{2}$$

$$\eta_i = \frac{\dot{m} C_P (T_{out} - T_{in})}{G_t \times A_C} \tag{3}$$

Where:

Q_u = The absorbed energy by the collector (W/m^2)
A_c = collector area (m^2)
F_R = The factor of collector heat loss
U_L = Overall heat loss ($W/m^2 \times °C$)
G_t = Totaly solar radiation intensity (W/m^2)
T_{in} = The intake water temperature (°C)
T_{out} = The output water temperature (°C)
τ = Glass cover transmissivity value
α = Absorber plate absorptivity value

Many studies of solar water heater and absorber plates has been carried out by researchers. Some of previous researchers are used as a basis to support the implementation of this study.

Bhide *et al.* (1982) introduces a simple method for comparing the thermal performance of flat plate collectors which is coated with a layer of a known value of absorption and reflection of sunlight. This is a simple way to get the correct values and for the selection of a particular collector surface.

Bhide *et al.* (1982) has introduced a simple method for comparing the flat plate collectors thermal performance which is coated with a layer of a known value of absorption and reflection of sunlight.

Subarkah (2001) has conducted the research on the plate absorber for sea water distillation. Some of test material in this study obtained material coated with copper matte black paint types have good heat absorption coefficient which the value is 0.82.

The parameters that affect the performance of the collector of which are the thickness of the absorber plate and the distance between the collector pipes called the fin efficiency of the collector (Kristanto and San, 2001). The results showed the thickness of the absorber plate has a positive correlation and the negative correlation for the both distance between the collector pipes.

The study that determines the effect of the range from plate to glass that states received great summer (Anggaraini, 2001). The glass that used for the research is clear glass and frosted glass with a thickness of 3 and 5 mm, respectively. The result that has the highest temperature is achieved when the glass plate used type of clear glass 3 mm with distance to the both glass plates 20 mm.

Water circulation using the water solar heating termosifon occured naturally due to differences in density of the water in the tank and it in the collector, the water so it does not require a pump (Sambada, 2004).

The collector using two pieces of cover glass obtained better efficiency than using one glass only. The both temperature difference between the water intake of the collector and the output of the collector with 2 layers of glass cover can be higher about 17°C if compared with a glass cover collector (Rahardjo and Ekadewi, 2012).

The water flow rate on the solar heater has the negative correlation to the resulting warm water. The solar water heaters in type flat plate collectors with collector that has a tilt angle 0° produces the most optimum water temperature, the average temperature is 59.375°C and so, a maximum temperature is 71°C (Ismail, 2005, 2007).

The solar water heater of three-layer glass cover with a thickness of 5 mm has a higher efficiency than it using two or one layer (Farid and Ismail, 2006).

The efficiency in the solar heater using double plate heat absorption is higher than the conventional solar heaters (Mustafa, 2008). Otherwise, the heat absorption efficiency of the (Ti-Ta)/Gt in double plate solar heater decline greater than conventional solar heaters.

The water flow rate in the simple solar heater using a single absorber plate has a negative correlation to the solar heater performance (Ismail, 2007).

The study about the both double and single absorber plate use absorbent concrete cast on a simple solar water heater explain that the efficiency using double absorber plate is higher than the single absorber plate (Ismail, 2008).

The flow rate variation test showed that the efficiency of heat absorption in the solar heater with double plates is higher than the heat absorption efficiency of conventional solar heaters. The output temperature of solar water heater with double plates while in the afternoon have a smaller decline than the temperature of the water output of conventional solar heater.

The absorber plate of concrete waveform generating the solar water heater efficiency value higher than the flat absorber plate (Farid and Ismail, 2010).

MATERIALS AND METHODS

The research conducted using the experimental method that compare the water temperature result of double-plate solar water heater and double-wave solar water heater. We change three factor, i.e., the cover glass number intake flow rate and initial heating the intake working fluid to improve the efficiency of both models. At the stage of observation, we take the data using computer software AID and then processing the data, construct the graphs, analyze and then infer the conclusions (Fig. 1-3). Which the research equipment are the following:

- Flat absorber plate with a thickness of 3 mm, aluminum and painted black dof
- Wave absorber plate with a thickness of 3 mm, aluminum and painted black dof
- Plate heat storage of PVC, thick 10 mm
- Glass cover 5 mm thick one side
- The distance between the absorber plate and the storage is 20 mm
- Isolator from 3 cm thick styrofoam materials
- The angle the glass North-facing inclination 15°C
- Water channel using PVC pipe 25.4 mm
- Pump using aquarium pumps

Observations were made starting at 10.00 a.m. until 14.00 p.m. (peak time) under direct sunlight with the duration of the data recording is done every 10 min. The testing laboratory locatated in solar and alternative energy of Engineering, Department of Mechanical Engineering, Faculty of Universitas Brawijaya, Malang, Indonesia.

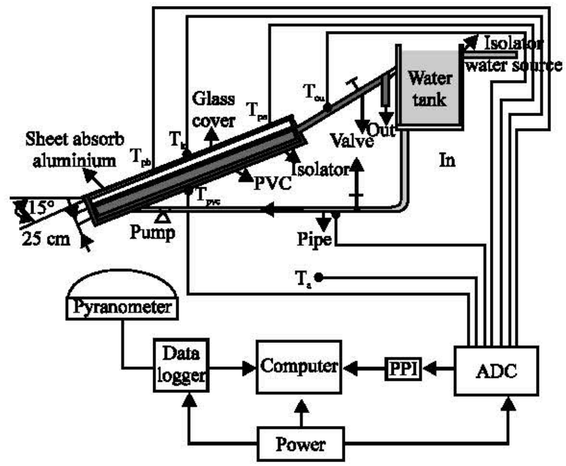

Fig. 1: Scheme of experimental tools solar water heater (side view)

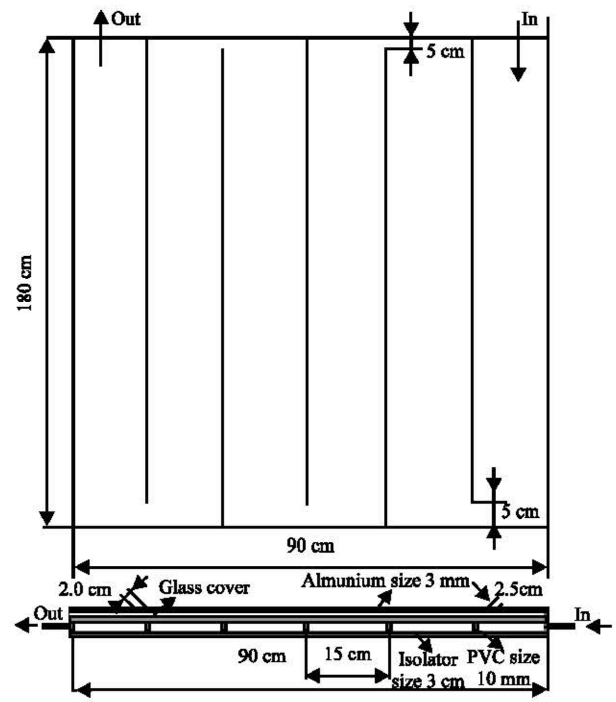

Fig. 2: Scheme of experimental tools of flat absorber plate zig-zag grooves (top and side view)

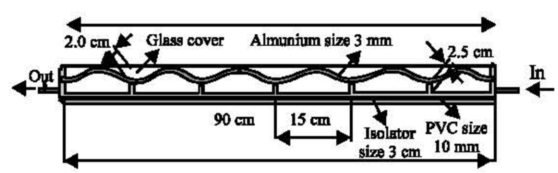

Fig. 3: Schematic experimental tools absorber plate waves and zig-zag grooves (side view)

RESULTS AND DISCUSSION

The surface area: The following is the theoritical approximation for each 15 cm wavefunction of the side of collector:

$$f(x) = 2.25\times\cos\left(\frac{2\pi}{15}\right)x$$

For the precision result of collector wafe surface, we use the numerical integration. The result is 19,350 cm^2. It has the extra surface area 3,150 cm^2 or 19.5% wider if we compare to the flat surface area.

Temperature and totaly solar radiation intensity average: The total solar radiation intensity on average have the same pattern with average temperature (i.e., temperature of glass cover, absorber plate temperature, water inlet temperature and water temperature output). Thus, the amount of energy that absorbed by the solar water heater will be in accordance to the solar radiation energy as the energy source. The environmental temperature does not have the same as the pattern like the solar radiation, it because there are many other factors that affect the temperature. Those factor are the wind speed and air humidity.

We assume that the sunrise at 06.00 a.m. and the sunset at 18.00 p.m. The sunlight at 10.00 am has a slope 60° to the solar collector plane and the sun moves through to an angle 120° at 14.00 p.m. It means $60°\leq\theta\leq120°$. Totaly solar radiation intensity on the flat plate collector from 10.00 a.m. up to 14.00 p.m. is as the following:

$$Tot\_G_t\_Flat = \int_{\pi|3}^{2\pi|3} G_t\times\sin(\theta)d\theta = G_t$$

For an approximation of each wave shape, we use the isosceles triangle. Each triangular pedestal is 7.5 cm and the height is 4.5 cm. The sunlight at 10.00 am will be perpendicular to the first hypotenuse of the triangle and it will have an angle 30° to the second hypotenuse. The sunlight moves through to 150° the first hypotenuse of the triangle and perpendicular to the second hypotenuse.

Totaly solar radiation intensity on the wave plate collector from 10.00 a.m. up to 14.00 p.m. for the first hypotenuse and the second one is as the following:

$$Tot\_G_t(1) = \int_{\pi|2}^{5\pi|6} G_t\times\sin(\theta)d\theta$$

And:

$$Tot\_G_t(2) = \int_{\pi|6}^{\pi|2} G_t\times\sin(\theta)d\theta$$

$$Tot\_G_t\_wave = Tot\_G_t(t)+Tot\_G_t(2)$$

$$Tot\_G_t\_wave = \sqrt{3}\times Tot\_G_t\_Flat$$

Totaly solar radiation intensity on the wave plate collector from 10.00 a.m. up to 14.00 p.m. is close to totaly solar radiation intensity on the flat plate collector from 10.00 a.m. up to 14.00 p.m. that multiplied by $\sqrt{3}$.

Efficiency testing of heat absorption of solar radiation uses the variation form of the plate surface solar radiation absorber: The results of these calculations can be made graphic relationship to the efficiency of solar water heater (Ti-Ta)/Gt as Fig. 4 at the following.

It can be seen in Fig. 4, the efficiency of solar water heater using double plates absorber plate surface waveforms can present a higher solar water heater efficiency. The decrease in efficiency becomes smaller if it compared to the efficiency of solar water heater with flat plate surface absorbent form. These conditions are caused by the different surface area, so the heat energy that absorbed from the solar radiation plate surface waveforms is greater. Thus, the wave-shaped surface of the absorber plate can improve the efficiency of solar water heater.

The flow rate testing using a model of the wave absorber plate: Solar radiation recorded by the data logger via. pyranometer during testing quite varied, so did the temperature of the glass cover, absorber plate temperature ambient temperature, water temperature and the temperature of incoming water out. Data obtained from 10:00 a.m. until 14:00 is presented in Fig. 5. It looks the intensity of total solar radiation on average have the same pattern with average temperature (temperature of glass cover, absorber plate temperature ambient temperature, water inlet temperature and the water temperature output). Thus, the amount of energy absorbed by the solar water heater will be in accordance to the solar radiation energy as the energy source. The decline of the average temperature is more visible in the test flow rate 0.03 L/sec if it compared with the rate of water flow beneath.

Efficiency of solar water heater on the water flow rate testing using a double plate solar water heater with three glass cover: From Fig. 6, it can be seen that the efficiency of double-plate solar water heater with a flow

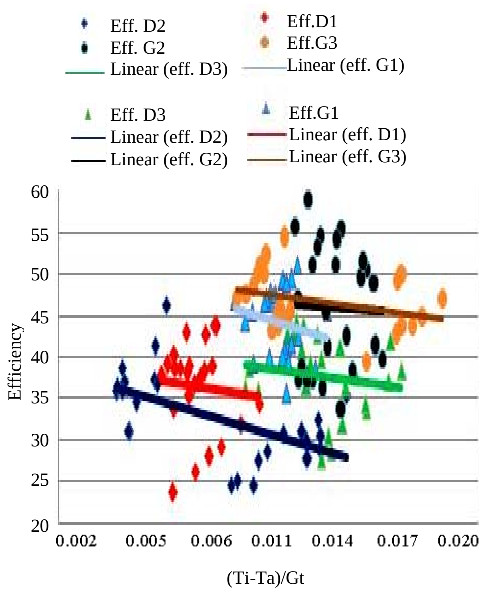

Fig. 4: The flow rate testing using a model of the wave absorber plate

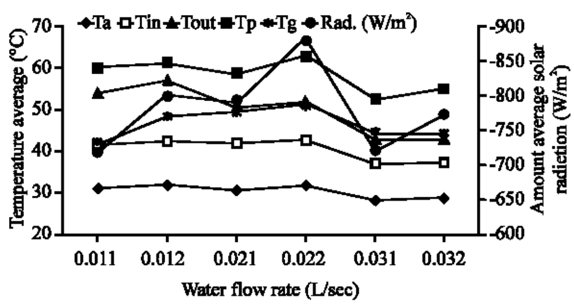

Fig. 5: Temperature and intensity of solar radiation on average total flow rate testing using a solar water heater double plate wave model; 0.011 = Testing using the flow rate 0.01 (L/sec plate first day; 0.012 = Testing using the flow rate 0.01 (L/sec) the second day; 0.021 = Testing using the flow rate 0.02 (L/sec) first day; 0.022 = Testing using the flow rate 0.02 (L/sec) second day; 0.031 = Testing using the flow rate 0.03 (L/sec) first day; 0.032 = Testing using the flow rate 0.03 (L/sec) second day

rate 0.03 L/sec using a wave-shaped absorber plate surface can produce solar water heater with highe efficiency and it has a greather slope of decline in efficiency if it compared to the efficiency of solar water heater with a water flow rate of 0.01 and 0.02 L/sec. These conditions caused the flow rate it self where the flow rate in the calculation process put as a multiplier, so the

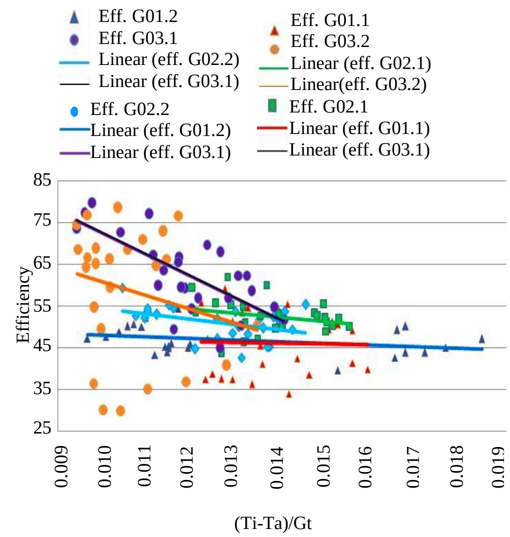

Fig. 6: Testing of the relationship of the efficiency of solar water heater (Ti-Ta)/Gt to the flow rate using a solar water heater double plate wave model

efficiency of solar water heater becomes high. Otherwise, the decline in the efficiency of the solar water heater (Ti-Ta)/Gt becomes great.

Temperature and solar radiation intensity total average testing using first warming water intake: This test uses preheating 30-60°C with a solar water heater equipment using wave-shaped absorber plate surface with different flow rates (0.01, 0.02 and 12.03 L/sec).

The data pre-heating test results presents that the average temperature and total solar radiation intensity on average at the beginning of the heating test as Fig. 7.

The pre-heating that given at the beginning of the heating water in the reservoir will imply in the rising in water temperature intake to the solar water heater system. It influences to rate of the temperature of the absorber plate greather decline, especially with the rate inreasing of intake water the flow.

Efficiency of the solar water heater preheats intake water testing (in the reservoir) using a solar water heater double plate-shaped wave: From Fig. 8, it can be seen that the efficiency of double-plate solar water heater preheats intake water on 30°C has a higher efficiency compared to preheat 40° and 60°C and it all happens for all flow rates. Thus, the intake water temperature greatly affect the efficiency of solar water heater. If the water intake temperature becomes greater then the efficiency of the solar water heater approaching zero because the intake water temperature and output relatively same.

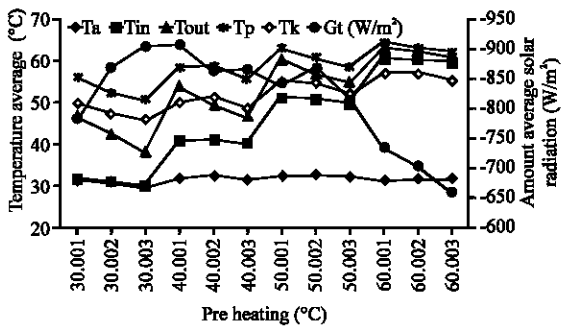

Fig. 7: Temperature and intensity of solar radiation on total average preheating testing using dual plate solar water heater wave model; 30.001 = Testing preheating 30°C with flow rate 0.01 (L/sec); 30.002 = Testing preheating 30°C with a flow rate 0.02 (L/sec); 30.003 = Testing preheating 30°C with a flow rate 0.03 (L/sec); 40.001 = Testing preheating 40°C with a flow rate 0.01 (L/sec); 40.002 = Testing preheating 40°C with a flow rate 0.02 (L/sec); 40.003 = Testing preheating 40°C with a flow rate n 0.03 (L/sec); 50.001 = Testing preheating 50°C with a flow rate 0.01 (L/sec); 50.002 = Testing preheating 50°C with a flow rate 0.02 (L/sec); 50.003 = Testing preheating 50°C with a flow rate 0.03 (L/sec); 60.001 = Testing preheating 60°C with a flow rate 0.01 (L/sec); 60.002 = Testing preheating 60°C with a flow rate 0.02 (L/sec); 60.003 = Testing preheating 60°C with a flow rate 0.03 (L/sec)

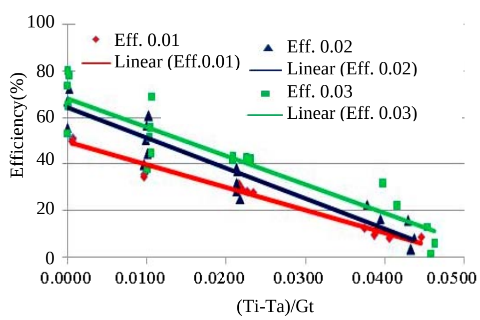

Fig. 8: The relationship of the efficiency of solar water heater to (Ti-Ta)/Gt with pre-heating test using solar water heater double plate wave model

CONCLUSION

From the results of the study can be summarized as the following: the efficiency of the solar water heater uses triple-layer glass cover is better if it compared to the double layers and single layer cover glass number only; the greater the water flow rate imply to the efficiency of solar water heater increases; the heating first on intake water causes the output water temperature and the temperature of the absorber plate is relatively the same, so the efficiency of solar water heater close to zero. The efficiency with three factor variances of the solar water heater absorber plate surface is better using the wave-shaped surface if it compared to the flat absorber plate.

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