INVESTIGATION PERFORMANCE OF SOLAR WATER HEATER SYSTEM USING PARAFFIN WAX

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ABSTRACT

Solar power system has been applied to heat water for night time home activity in rural areas. The system will provides hot water availability out the day. The system consist of a solar water heater and a heat storage unit filled by Phase Change Material (PCM). The solar water heater used for supplying hot water during the day. Storage unit stores the heat in PCM during the day and convert to be hot water during the night. Type of solar water is thermosyphone. The main component of solar water heater is a solar collector box, insulating material, circulation tubes and absorber plate. The heat storage that filled paraffin wax integrated with solar collcector unit for absorbing solar heat. Paraffin wax that comercially available in the market used for heat storage material. The experimental investigation conducted in open field located at Faculty of Engineering, Syiah Kuala University. The water temperature, absorber plate temperature and solar intensity was measured and recorded every 10 minute. The experiment test started from 8.00 am up to 23.00 pm. The results show that temperature of hot water at 17.00 pm is 45 °C. Temperature optimum of solar water heating system that could be achieved up to 20.00 pm is 40 - 45 °C. The maximum temperature of hot water produced by collector solar water heater which is equipped parffin wax is 70 °C. The maximum efficiency of a collector solar water heater is 36.6 %. Based on experimental results, by adding of paraffin wax in the solar collector could able to increase efficiency of solar water heating systems.

Keywords: solar water heater, thermal energy storage, phase change material.

INTRODUCTION

Solar energy is widely applied to support home activity in rural area as thermal energy resources, such as for cooking, distilating sea water, and heating water. Utilization solar power to heat water can be done by collecting solar energy and use it to heat water. According to the World Energy Council (2007), the usefulness solar water heating systems has reached to 105 Giga Watt Thermal (GWTh) or 1.3 % of global energy utilized.

According to the Energy Saving Trust (2005), utilization of solar water heaters could be able to reduce electrical energy cost. In addition, it has positive contributing to reduce environment impact. By reducing carbon dioxide emissions about 0.4 - 0.75 tons per year. Solar energy used for heating water requires some devices incluiding solar collector box, heat energy absorber and water tubes. The mechanism of solar energy heating proces is started by solar radiation tauch on solar cllector surface which is nade from clear glass, then forwarded and absorbed by absorber. Energy heat from absorber is used to heat water flowing in the pipes. Hot water is stored in a storage tank for later utilization. To keep the water temperature constant at night or during cloudy weather, water storage tanks are equipped with an electric heater. The use of an electric heater leads to additional operational costs of solar water heaters.

Some research has been done to improve design and performance of solar water heating systems. The results concluded that the way to increase the systems performance can be done by maximizing the collection of solar radiation energy and minimizing the heat loss in the hot water storage tank [2, 3].

Previous research has been done to maximize the heat storage in the hot water storage tank by using phase change material (PCM) as a heat storage material. PCM is made in small chunks and put in the hot water storage tank. During the day, heat which is received by water from solar radiation will be absorbed by PCM. It cause PCM change its phase from solid to liquid. When the intensity of solar radiation decreases, water temperature will decrease. Since, the PCM will release heat back into water. As a result, water temperature can be kept constant.

Talmatsky [2] studied numerical analyses in solar water heating systems. The analysis was conducted for Tel Aviv city weather conditions. I stated that adding PCM in a hot water storage tank of solar water heating system does not show a beneficial impact for applications in commercial systems. Because, heat energy stored by PCM is much smaller than energy required to keep water temperature at night.

Kousksou [3] has done numerical analysis to prove Talmatsky statement [2]. His analysis was performed with the same conditions as Talmasky's research. The result shows that PCM in solar water heating systems was not only depend on melting temperature of the PCM, nut also need to consider the layout of the heat storage material.

In fact, there is an opportunity to do research on utilization of heat storage material in solar water heating systems. Researchers present the idea to use phase change material in a tank [4-8]. This research will design and fabricate with thermosyphon type of solar water heating system. A flat plate solar collectors which are equipped with heat storage material.

VOL. 9, NO. 10, OCTOBER 2014 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

EXPERIMENTAL METHOD

Solar water heater system consist of a solar water heater and a heat storage unit filled by Phase Change Material (PCM). In order to design solar water heater, recording data of solar radiation intensity every month in a year. The experimental investigation conducted in open field located at Faculty of Engineering, Syiah Kuala University. Result show that solar radiation intensity in November month was 466 W/m^2. It is smaller intensity found within a year. Wind speed 4 m/s^2. This data was used to design dimension of solar collector. Temperatur output was design in 50 °C, temperature input 28 °C, and hot water capacity 115 liters

Figure-1 shows thermosyphon type water heating system. The specifications of each component: a solar collector box made of 0.9 mm aluminum, strengthened box frame also made of aluminum. Isolator is glass wall material with thickness 25 mm. For box cover made of clear glass with dimension 1600 mm x 1000 mm x 3 mm. An absorber plate from aluminum plate that black paint coating. It dimension is 1600 mm x 1000 mm x 0.4 mm. Head collector tubes made of copper pipe ½ inch diameter. A collector absorber tube also made of copper with diameter ¼ inch. Storage tank is integrated with collector box made of 0.5 mm thick of aluminium. It dimension is 450 mm x 900 mm coated with insulating glass wall. On top surface of storage tank covered by aluminum plate 0.2 mm thick.

Table-1. Properties of paraffin wax thermo-physical.

Descriptions	Value
Melting temperature	46.7 ^{0}C
Thermal conductivity (solid)	0.1383 W/m.^{0}C
Thermal conductivity (liquid)	0.1383 W/m.^{0}C
Specific heat (solid)	2890 J/kg.K
Specific heat (liquid)	2890 J/kg.K
Density (solid)	947 kg/m3
Density (liquid)	750 kg/m3
Latent heat	209 kJ/kg

In order to get maximum thermal energy and high of efficiency, a solar collectors equipped by clear glass and black paint coated absorber. To investigate performance of solar water heating system, all data analyzed and shown in graph form as follow as:

- Comparing solar radiation intensity (I_t) and Heat Energy (Q_u) without using coated paint on absorber plate.
- Identifiying correlation among of solar radiation intensty (I_t), absorber plate temperature (T_p), input fluid temperature (Tf_{in}), output fluid temperature (Tf_{out}), and time observation (Hours).
- Identifiying correlation of solar radiation intensty (I_t), Heat Loss (UL) and time observation (Hours).
- Identifiying correlation of efficiency (η) and time observation (Hours).

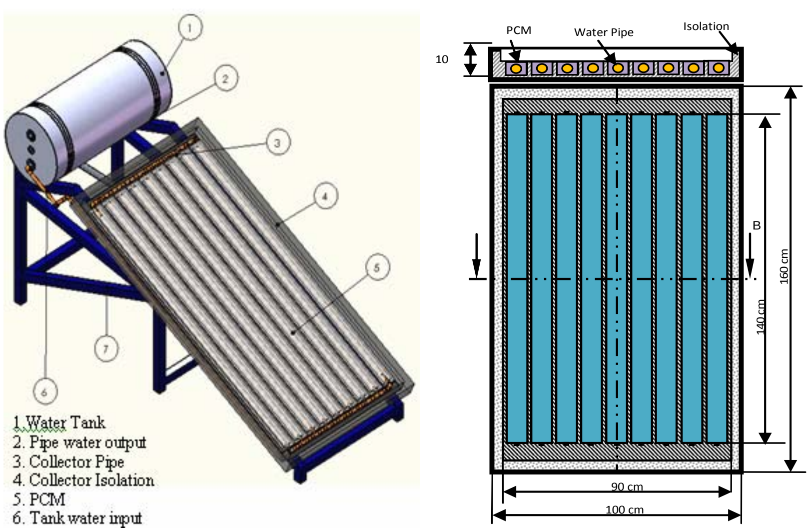


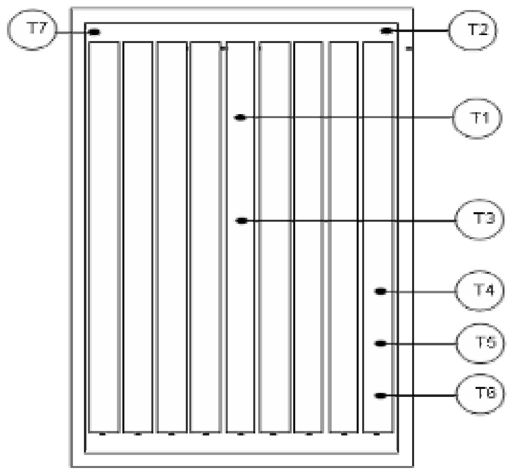
Figure-1. Solar water heating system.

Paraffin wax commercially available in market used as heat storage material. Data paraffin wax properties is given in Table-1.

Data measurement of water temperature, absorber plate temperature and solar intensity was measured and recorded every 10 minute. It started from 8.00 am up to 23.00 pm. Position of temperature measurement device are placed in T1 up to T7, as shown in Figure-2.

RESULTS AND DISCUSSIONS

Based on investigation results, at time observation 17.00 pm, temperature of output water of solar water heating systems is remained constant at 45 °C. While, the ambient temperature in glass cover at surface of collector box decreased below 50 °C. It shown that heat transfer where paraffin wax absorbed heat and released to water, as presented in Figure-3.



T1 = temperature of paraffin on the collector position
T2 = temperature of the incoming water
T3 = temperature of the paraffin in the middle of the collector
T4 = temperature of the space on the side of the absorber plate and glass
T5 = temperature of the wax on the underside of the collector
T6 = temperature of the glass
T7 = temperature of the water out

Figure-2. Position of temperature measuring instruments

From this experimental result found that heating process and amount of heat absorbed by solar water heating system depends on solar radiation intensity. The higher solar radiation received by absorber plate leads to higher water temperature. In contrast, decreasing solar radiation intensity and lossing heat of solar collector to environment, leads to reduce out water temperature. Figure-4 presented, a performance test of solar water heating system run for 24 hours.

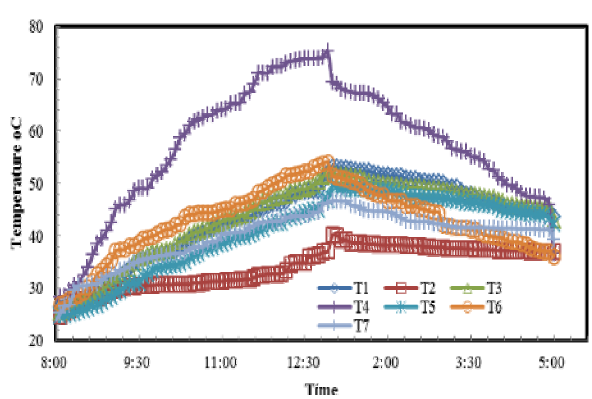


Figure-3. Temperature of output water above day time.

Temperature of solar collector at 21.00 pm tend to decrese up to 30 °C. If comparing at 17.00, its temperature was 45 °C. This condition would not be suitable used for bathing purpose at night. Moreover, the water temperature at night attain to 20 - 25 °C. During the day started at 9:00 am, solar collector temperatur had reached 31 - 32 °C. It also addressed that system could able to increase temperature of water rapidly. Generally, this system has been able to work with expected performance. However, for commercial purpose, it needs further analysis of water storage tank insulation and solar collector frame insulation system.

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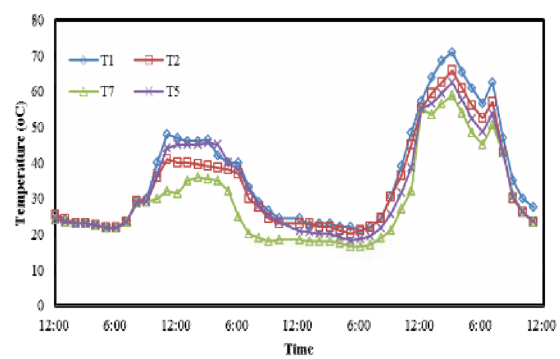

Figure-4. Experimental data recorded for 2 days.

The amount of energy applied that can be absorbed by solar collector was determined based on observational data per day. Observation time started at 9.00 am. It found that based on calculation for energy applied wast 441 W. At 10.00 am, energy applied increase to 572.94 W. Then, rate of energy applied remain stable approximately 563.67 W up to 13.00 pm. The highest energy applied is 627.21 W that occurred at 12:51 pm. The lowest energy applied is 150.35 W that occured at 15.00 pm.

The outcome of this study is improving solar water heating system performance by adding paraffin wax as heat storage material. To measure solar water heater performance could be done by calculating its system efficiency. The efficiency system in operational condition are inaccurate because fluid properties constantly change proportional to time change.

Based on overall heat loss calculation whereas coefficient at steady state. It can describe based the graphic result of experiment that the highest efficiency is 49 % occured at 12.00 am and the smallest 3.02 % occur at 8.00 pm. The average efficiency is 30.64 %. The result of efficiency of operating conditions shown in Figure-5.

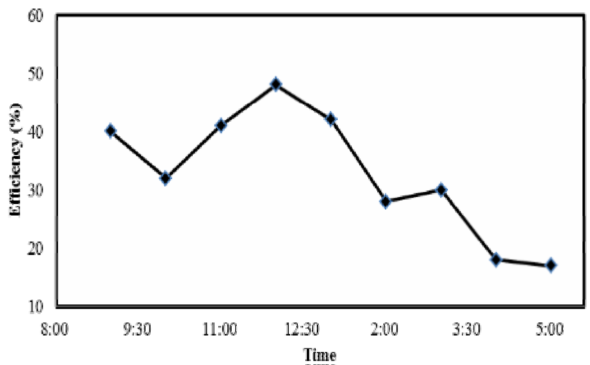

Figure-5. Efficiency of solar water heating systems.

From this research, it can be stated that the higher energy of solar radiation is received by absorber plate. It significantly contribute to increase water temperature. Amount of water and length time water were heated in the system also affect to required energy. The greater period of water present in the system, the greater energy required to raise water temperature. Since, it will affect to increase extensive collectors needed. It will also increase the cost of manufacturing solar water heating systems.

Based on this investiation results, reducing solar radiation energy is important in long period of time to avoid significant losses. Apprpriate slope of laying position of solar collector system could able to attain good performance. At first time instalation of solar collector heating and running the system, temperature of glass cover directly affects to temperature of water out.

The results also showed that use of heat storage material in solar collector could able to improve performance of system. This can be seen in the afternoon, water temperature can be maintained at out temperature range 40 - 50 °C, whereas solar radiation had begun to decline. The amount of energy absorbed by paraffin wax as heat storage material is highly dependent on the temperature of the absorber plate.

From experimental result when the system ran for 48 hours, water temperature can be maintained only at 20:00 pm. It can be concluded that solar water heating system proposed can be used optimally at 9.00 am up to 20.00 pm with exit water temperature arange around 40 - 45 °C.

CONCLUSIONS

The main objective of this research is improving performance of solar water heating systems by applying heat storage material. To achieve this objective, designing, manufacturing and testing of the system with the climatic conditions of the city of Banda Aceh Indonesia were carried out. Some conclusion from experimental result concluding as follow as:

1. The thermosyphon solar collector water heating that equipped by paraffin wax as heat storage material has a maximum efficiency 36.6 %.
2. The maximum temperature of hot water produced by collector solar water heater which is equipped heat storage material is 70 °C.
3. Hot water temperature can be maintained up to 20.00 pm at night. It means solar water heating system can be used optimally started at 9.00 am until 20.00 pm with output water temperature 40 - 45 °C.
4. Thermal collector efficiency depends on solar radiation intensity, input and output temperature, and fluid flow rate.

However, further research can be done to study the phase change material usage gains can be made by selecting the heat storage material with a melting temperature below 47 ° C, and modify the placement of PCM in the collector.

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