Actual Performance Evaluation of a Solar-Biomass Hybrid Cooling System

Boonrit Prasartkaew[1,*], Thosapon Katejanekarn[2]

[1]Combustion and Solar Energy Research Laboratory (CASE Lab.), Department of Mechanical Engineering, Faculty of Engineering, Rajamangala University of Technology Thunyaburi, Klong 6, Thunyaburi, Patumthani 12110, THAILAND

[2]Building Energy Systems Laboratory, Department of Mechanical Engineering, Faculty of Engineering and Industrial Technology Silpakorn University, 6 Ratchmankanai Rd., Muang, Nakhon Pathom 73000, THAILAND

*Corresponding Author: boonrit.p@en.rmutt.ac.th, Tel. 662-549-3547, Fax. 662-549-3432

Abstract

This paper presents the performance evaluation of an actual solar-biomass hybrid cooling system using the collected experimental data. The experimental result of the fabricated 7-kW nominal cooling capacity was used for energy balance analysis. The study results demonstrate that the COP of the overall system during the operation on solar energy was lower than the operation on biomass energy. When the system was operated using solar energy, as its vary large surface loss and fluid loss during long distance of the water circulation loop, the total energy loss is high at about 75% of input energy. While the system energy loss, when it energized by the biomass gasifier, was only about 59% of biomass input energy, as its smaller surface and distance of water pipe.

Keywords*:* Solar energy; Absorption cooling; Biomass; Hybrid system.

1. Introduction

Currently, almost all energy needed for human activities has been served by the utilization of fossil fuels via combustion processes [1]. As the perceived rapid advances in technology to improved comfortable living (e.g.: industrial production, air-conditioning, and transportation, etc.) and abundant use of energy, cause two major serious problems to any life on the earth. One is fast depletion of fossil fuel resources (or energy crisis problem); the other is environmental pollution, especially global warming problem. To simultaneously mitigate these big problems, renewable energy utilizations should be encouraged [2]. As it is the biggest energy resource and original of earth warming, solar energy, the biggest energy resource, should be more utilized. There is a major barrier, however, solar energy can be utilized only daytime and it is intermittent. This barrier can be carried out by hybrid with another renewable energy. Biomass energy, as a renewable energy, pays an important role; due to it is a CO_2 neutral and which can be forever cropped. This research proposed a renewable energy based air conditioning system which driven by the solar-biomass thermal hybrid system. This current paper demonstrates the energy balance analysis of an actual 7-kW solar-biomass hybrid cooling system using the collected experimental data to determine its coefficient of performance.

2. System description

The proposed solar-biomass hybrid cooling system comprises of three main parts, as shown in Fig. 1. The first part is a solar water heating (SWH) system, which consists of a field of flat plate solar collectors, a hot water storage tank and a circulating pump. The second part (in the middle) is an auxiliary heater (AUH) which consists of an automatic up-draft gasifier and a gas-fired sensible-heat boiler, called a biomass gasifier-boiler (BGB). The part on the right hand side is an absorption chiller (ABC) which consists of an absorption chiller equipped with a fan coil unit, a cooling tower and three aqua-pumps: hot, chilled and cooling water pumps. Mathematical model used for the component sizing.

3. Energy balance analysis

The energy balance of overall system and components was conducted to show the amount and ways of input, output and especially losses of energies which relate to the efficiencies. Actually, this energy balance results can be used for the improvement of system efficiency by directly reducing this identified major losses. To analyze the energy balance of each system component and overall system, the summation of energy during steady state periods were determined using the first law of Thermodynamics.

There are three types of steady state period, depend on an energizing source: solar (called 'solar steady state period'), biomass (called 'biomass steady state period') and both energy (called 'solar-biomass steady state period') periods. To demonstrate the energy balance and system performance analysis, a selected experimental day was used. The performance will be described using both steady state and one day data. It should be noted that all graphs (except weather data graph) will be plotted using 5-minute data but their lines will be marked every fifteen minutes for easier reading.

4. Study results

The energy balance analysis was conducted for evaluating the overall system performance analysis.

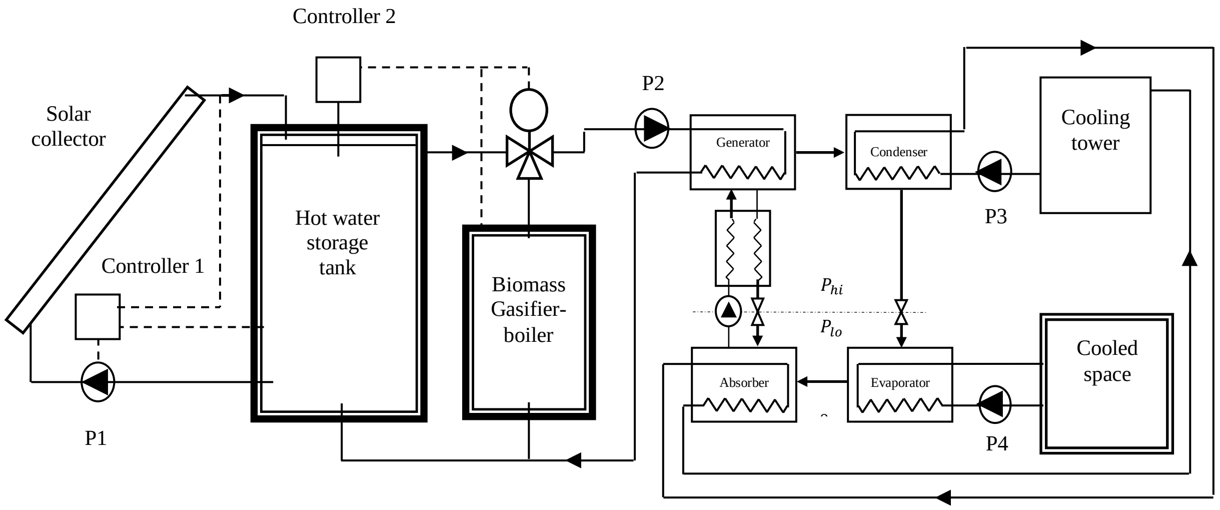


Fig. 1 Schematic diagram of the solar-biomass hybrid

The energy balance of the complete solar-biomass hybrid cooling system was analyzed as shown in Fig. 2. The energy balance of the proposed system was determined using Eq. (1), where the values of input and output (heat) of each component were substituted in this calculation.

$$Q_{sol} + Q_{BM} + Q_{ev} = Q_r + Q_l \qquad (1)$$

where,

Q_{sol} is input solar energy [MJ]

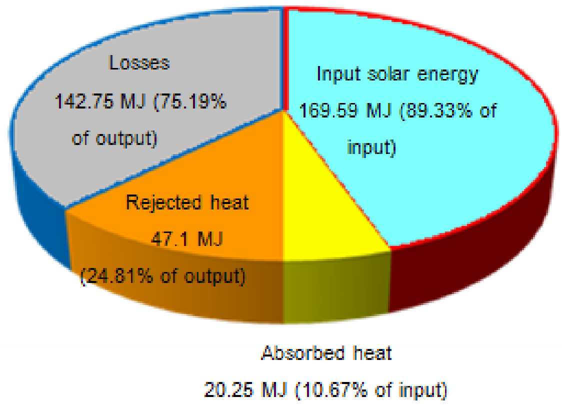
Q_{BM} is input biomass energy [MJ]

Q_{ev} is input/absorbed heat at evaporator [MJ]

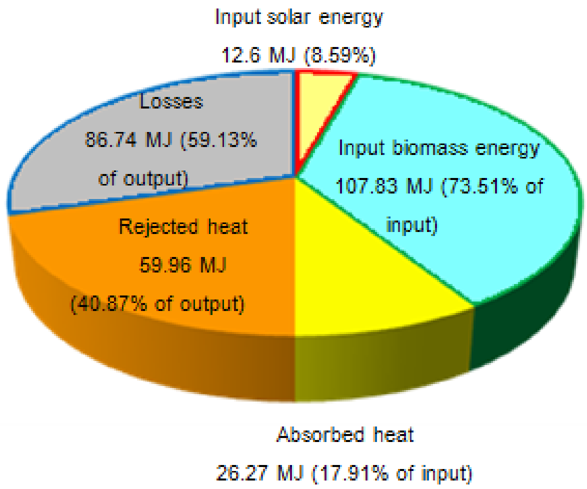
Q_r is output/rejected heat at cooling tower [MJ]

Q_l is overall heat loss [MJ]

Figure 3(a) and (b) show the energy balances of the proposed system during solar and biomass steady state periods, respectively. The total amounts of input energy of these periods were



(a)



(b)

Fig. 3 (a) Energy balance during solar and (c) energy balance during biomass steady state periods

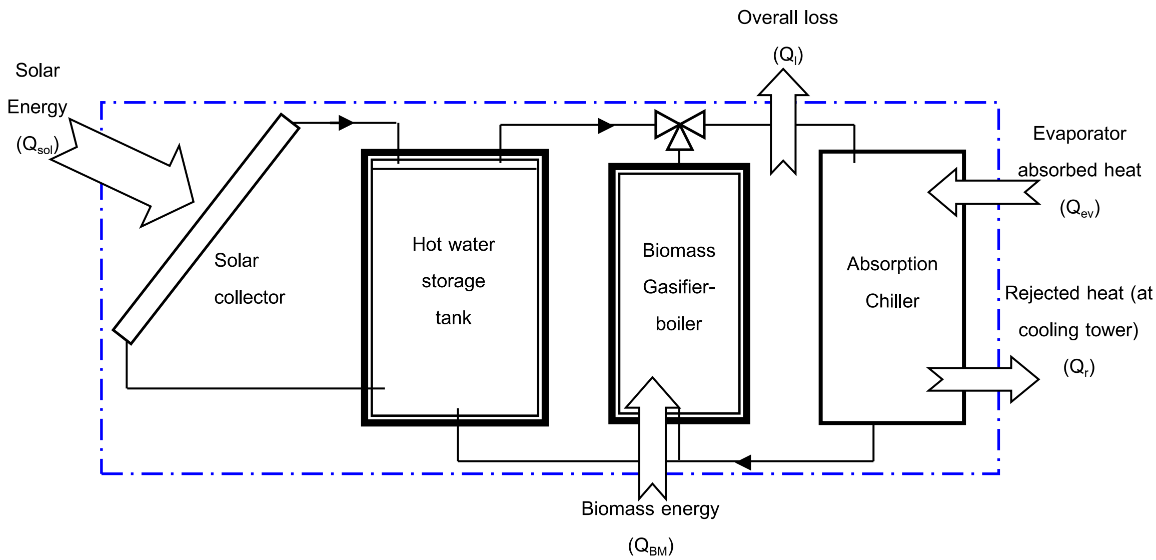


Fig. 2 Energy balance of the complete solar-biomass

about 89 and 82% (solar + biomass) of input energy, respectively. In addition, 12.6 MJ of solar energy was supplied in the system while the system was run on biomass energy source but this amount of solar energy was not supplied to chiller. So, it can be said that this amount of solar is a portion of losses and can be ignored as it has no effect on the system performance. Similar to the energy analysis of the chiller, the energy absorbed (for cooling the room) of each period was 10.67 and 17.91% of input energy, respectively. The results also show that the COPsys during the operation on solar energy was lower than the operation on biomass energy two times, with the values of 0.12 and 0.24, respectively.

Figure 4 shows the Coefficient of performance of chiller (COP) and overall system and (COP_{sys}) during experimental day. Since the chilled water was produced at around 10:10 (about 1.40 hr from the beginning), both COP and COP_{sys} values were higher than zero at this time. During steady state conditions, the COP and COP_{sys} varied in the range 0.45 to 0.64 and 0.15 to 0.33, respectively. The average value of COP is 0.53.

5. Conclusion

The performance of a solar-biomass hybrid cooling system was actually evaluated using the setup experimental system. The tests were conducted during 8:00 to 18:00. The experimental data of system performance in a partly cloudy day are illustrated as an example day performance.

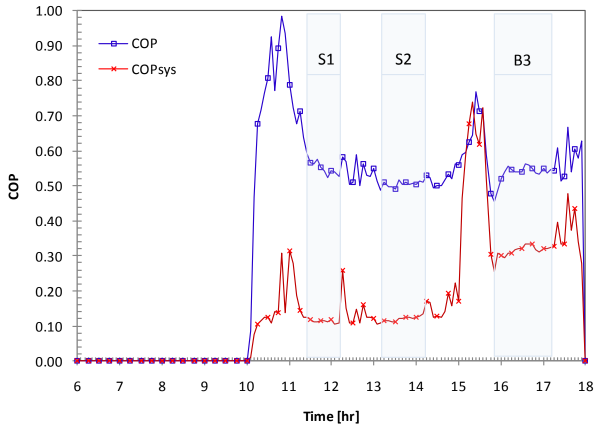


Fig. 4 Coefficient of performance of chiller and overall system

The total amounts of input energy of solar and biomass energizing periods were about 89 and 82% (solar + biomass) of input energy, respectively. The energy absorbed (for cooling the room) of each period was 10.67 and 17.91% of input energy, respectively. The experimental data demonstrate that system was operated at about 75% of nominal capacity an average COP about 0.6 was achieved.

6. Acknowledgement

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7. References

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