

Study on exergy efficiency of active desalination coupled solar collector

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Abstract. In this work, a double slope desalination active with basin size area 1,932 m² wide with 1 m² glass surface with two pieces with 3 mm glass thickness and 15° glass slope angle. The water level from the bottom of 20 mm and with solar collectors size area 1m² wide 500mm² was tested for 8 days in August 2018 starting at 8:00 to 18:00. The exergy value from the calculation of the highest exergy value on the first day of testing at 12.00 is 225.238 kWh, the highest exergy value at the test of the second day at 17.00 WIB is 52.332 kWh, the highest exergy value at 13.00 WIB is 13.680 kWh, exergy value the highest on the fourth day of testing at 11.00 WIB at 6,734 kWh, the highest exergy value on the fifth day test at 12.00 WIB at 22.218 kWh, the highest exergy value on testing the sixth day at 15.00 WIB at 8.728 kWh, the highest exergy value on testing the seventh day at 17.00 WIB amounting to 8.33 kWh, and the highest exergy value at the test of the eighth day at 15.00 WIB amounting to 6.712 kWh.

1. Introduction

On earth water is a natural resource that is very important for life. Water can be obtained from land, springs, rivers, lakes and sea water. One of the renewable energy sources is the sun. Indonesia's solar energy potential is quite abundant. The abundant solar energy from solar radiation can provide results by utilizing that energy for thermal technology and solar or photovoltaic cell technology. Water that is on land and in the sea must evaporate due to the sun's heat. Evaporation is gathered into clouds, after clouds have condensed and cooling will form water points and rain occurs. Part of the water falling into the earth seeps into the ground into ground water and spring water, some flows through a channel called river water, some of it collects in lakes / swamps and some returns to the sea. For humans, water is one of the main needs. This is because humans do not only need water for their body needs (drinking) but also humans need water for washing, cooking, bathing, and so on. However, humans are often faced with difficult situations where freshwater sources are very limited and on the other hand there is an increase in demand Rainwater which is a source of water that has been prepared in rainwater tanks (PAHs) is often not sufficient in the dry season. Solar thermal technology is widely used for example to dry agricultural and fishery products, and many more, one of which is the process of purifying seawater into fresh water or often referred to as the desalination process. Desalination is one of the many processes available for water purification, and sunlight is one of several forms of heat energy that can be used to give strength to the process. Sunlight has the advantage of using thermal energy from the sun /

solar, one of which is seen from the absence of fuel so that it can be said as a renewable and sustainable energy source. But to collect solar thermal energy, more space is needed. This is a good practical alternative, to offer life to areas where there is a lack of clean water. So far, several studies have focused on the study of the performance of these devices from a thermodynamic standpoint. In fact, energy analysis (based on the first thermodynamic law) does not show how energy is transformed and the location of energy degradation. Using exergy analysis, based on the first and second thermodynamics laws, it is possible to inform the true potential of various types of energy. Because thermodynamic irreversibility exist through any process, the exergy efficiency of a process is often low; this shows a different decrease in energy quality [1]. Exergy analysis is widely used in the design, simulation and evaluation of thermal performance and thermo-chemical systems [2]. Muangnoi et al. [1] investigating the performance of cooling towers based on a second legal analysis. In their study, that water slightly cooled by counter-current air flow. The result is confirmed that the degradation of high energy quality at the bottom and decreases at the top. They also mentioned that exergy analysis together with the analysis of the second law of thermodynamics = can be used as a guide to find out the optimal potential point to improve the performance of cooling towers.

Sun Refining is the simplest, most cost-effective, and environmentally friendly technology for water purification. It is estimated that in the future, desalination will be strongly supported and increasingly more popular. Even countries with large oil producers such as Saudi Arabia are increasing their use of solar energy to ignite their distillation systems to develop sustainable desalination systems Desalination is one of the many processes available for water purification, and sunlight is one of several forms of energy heat which can be used to move the process. Sunlight has the advantage of zero fuel costs but it requires more space for its collection [3].

The energy and exergy performance of solar stills has been investigated by many researchers. Using energy and exergy calculations to determine optimal operating conditions for solar desalination uses the benefits of reverse osmosis and nano-filtration technology. They show promising results for the use of integrated reverse osmosis and nano screening processes [4]. Using pinch technology to determine the humidification process for maximum saturation temperature and recycling of water temperature. They also considered the dehumidification process to calculate the water temperature in a heat exchanger. They revealed that solar collectors have the least amount of exergy efficiency; The humidification-dehumidification desalination process has a lower exergy efficiency, and rejected water has a large exergy loss. Also, they show that the rate of energy recovery and exergy of the desalination process are lower ... [5]Analysis and evaluation of the exergy performance of various renewable energy sources investigated by Hepbasli utilizes mass, energy, and entropy to balance equations, exergy efficiency, and irreversibility relative to the comparison of various renewable energy resources. Hepbasli presents an exergy flow diagram, which is a very precise and useful representation of exergy flow and losses for some renewable energy sources [6] ..Exergy analysis in the form of a pyramid sun. They investigated the effects of fan depth and basin on exergy efficiency during summer and winter for solar power with a small fan (active system) and the sun is still passive (fanless). They revealed that during the summer the passive system had lower exergy efficiency than the active system whereas in winter there was no significant difference between the exergy efficiency of the two solar desalination systems. Their results also show that exergy efficiency is lower when the depth of water in the basin is higher [7]. There are also researchers developing mathematical models

to discuss experimental and theoretical energy and exergy analysis for solar desalination systems. They revealed that increasing the length of the humidification tower caused a decrease in the overall exergy of efficiency [8]. Numerical and experimental methods were also developed at the laboratory scale of natural vacuum desalination units and also solar energy simulations using electric heaters in the evaporator [9]

2. Research Objectives

Previous researchers examined the exergy value of an active desalination system using a working fluid nanofluid (embryonic fluid and heat energy carrier) with 2 systems: A. Active double slope desalination with collector plate and B. Double slope active desalination with helical shaped heat exchanger and the study This study was carried out in New Delhi, India. This desalination water also flowed into a solar collector to obtain additional heating and analyzed exergy in Indonesia.

3. System Description

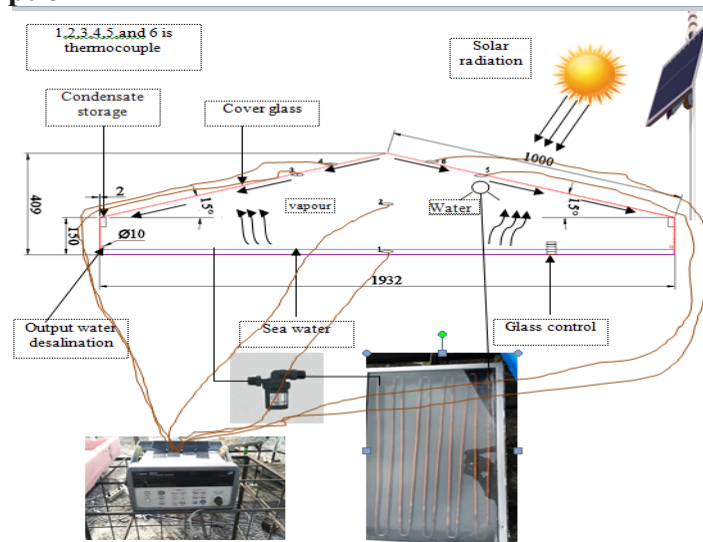


Figure 1. The active double desalination process with the addition of a solar collector.

Figure 2. An active desalination system scheme with the addition of a solar collector.

The seawater in the basin is circulated towards the solar collector, where there is a "sized copper pipe along 6 copper pipe passages to obtain additional heat to accelerate heating using a DC pump.

Analysis on Exergy

Exergy analysis is carried out using the first and second thermodynamic laws and is defined as the maximum number of jobs a system or mass or energy can produce when it comes to equilibrium with the reference environment [10]. Energy analysis has systematic weaknesses compared to exergy analysis[11].

- The direction of the process is not considered in energy analysis.
- Energy quality is not taken into account in energy analysis.
- Energy analysis fails to interpret some thermodynamic phenomena. For example, enthalpy changes are zero in the isothermal air of compression while exergy is greater than zero.
- Energy analysis does not show internal irreversibility.

Energy efficiency and exergy of a system have different behaviors depending on climate and operating conditions. Basically, exergy analysis compared to energy analysis gives us a better insight into how the physical process works [13]. Escalation of irreversibility causes entropy to increase when system exergy decreases. Therefore, it is necessary to determine and reduce irreversibility (ii) for all parts of the equipment

a. Inner glass cover

$$\alpha' g I(t) A_g + h_1 (T_w - T_{gi}) A_g = \frac{k_g}{L_g} (T_{gi} - T_{g0}) A_g \quad (1)$$

Where $\alpha'g$ is the glass absorptivity, $I(t)$ solar intensity (W / m^2), A_g = glass cover area (m^2), h_1 ($+ h_{ew} + h_{cw} + h_{rw}$) total internal heat transfer coefficient from water to glass ($W / m^2 \text{ } ^\circ C$); h_{ew} , h_{cw} , h_{rw} , respectively, are the evaporative, convective, and radiation heat transfer coefficients of the water surface ($W / m^2 \text{ } ^\circ C$), basin water temperature ($^\circ C$), T_{gi} the temperature of the inner surface of the glass cover ($^\circ C$), T_{g0} the surface temperature of the glass cover ($^\circ C$), K_g thermal conductivity of the glass cover ($W / m \text{ } ^\circ C$), and L_g is the thickness of the glass cover (m).

b. Outer glass cover

$$\frac{k_g}{L_g} (T_{gi} - T_{g0}) A_g = h_2 (T_{g0} - T_a) A_g \quad (2)$$

Where T_a is the ambient temperature ($^\circ C$), h_2 ($1/4 h_{cg} + h_{rg}$) the total external heat transfer coefficient from the glass surface to ambient ($W / m^2 \text{ } ^\circ C$); h_{rg} and h_{cg} is the radiation and convective heat transfer coefficient, respectively, from the glass surface to ambient ($W / m^2 \text{ } ^\circ C$).

c. Mass of Water

$$\alpha' w I(t) A_b + h_3 (T_b - T_w) A_b + Q_{uth}, N = M_w C_w \frac{dT_w}{dt} + h_1 (T_w - T_{gi}) A_b \quad (3)$$

Where $\alpha'w$ is water absorbency, A_b basin area of the sun is still (m^2), T_b basin temperature, h_3 ($1/4 h_w$) natural convective heat transfer coefficient from basin to water ($W / m^2 \text{ } ^\circ C$). C_w water specific heat, ($J / kg \text{ } ^\circ C$), and M_w is the basin water mass in the sun still (kg).

d. Basin liner

$$\alpha' b I(t) A_b = h_3 (T_b - T_w) A_b = h_b (T_b - T_a) (A_b - A_s) \quad (4)$$

$$\frac{dT_w}{dt} + a T_w = f(t) \quad (5)$$

$$\text{dimana } a = \frac{U + N(A_c + A_m) U I, N}{M_w C_w}$$

$$f(t) = \frac{[\alpha_{eff} I(t) + N(A_c + A_m)(\alpha \tau)_{eff} N I_c(t) + U + N(A_c + A_m) U I, N]}{M_w C_w}$$

The basin water temperature can be searched by the equation below:

$$T_w = \frac{f(t)}{a} [1 - e^{-a \Delta t}] + T_{uee} e^{-a \Delta t} \quad (6)$$

e. Thermal exergy efficiency of the active system

$$\eta_{exergy} = \frac{(h_{ef.E} [(T_f - T_{gi.E}) - (T_a + 273) \ln \frac{(T_f + 273)}{(T_{gi.E} + 273)}] + h_{ef.W} [(T_f - T_{gi.W}) - (T_a + 273) \ln \frac{(T_f + 273)}{(T_{gi.W} + 273)}]) A_b}{(0,933) [A_b I(t) + N A_c I_c(t)]} \times 100 \quad (7)$$

4. Results and discussion

4.1. Results and Discussion of Exergy

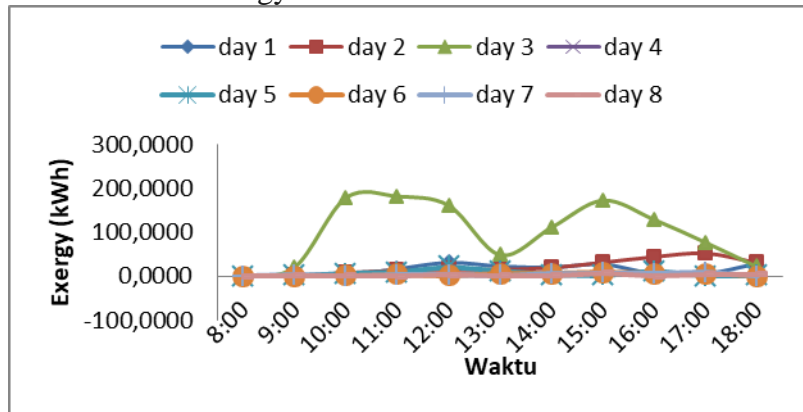


Figure 3. Exergy loss for the first to eight day.

Based on the test results, calculations can be made to obtain exergy data, where the highest exergy value at the first day of testing at 12.00 is 225.238 kWh, the highest exergy value at the test of the second day at 17.00 WIB is 52.332 kWh, the highest exergy value is at 13.00 WIB amounting to 13,680 kWh, the highest exergy value on the fourth day of testing at 11.00 WIB amounting to 6,734 kWh. Based on the test results, calculations can be made to obtain exergy data, where the highest exergy value on the fifth day test at 12.00 WIB is 22.218 kWh, the highest exergy value on the sixth day test at 15.00 WIB is 8.728 kWh, the highest exergy

value is at 17.00 WIB amounting to 8.33 kWh, and the highest exergy value at the test of the eighth day at 15.00 WIB amounting to 6.712 kWh.

4.2. Results and Discussion of Exergy Efficiency

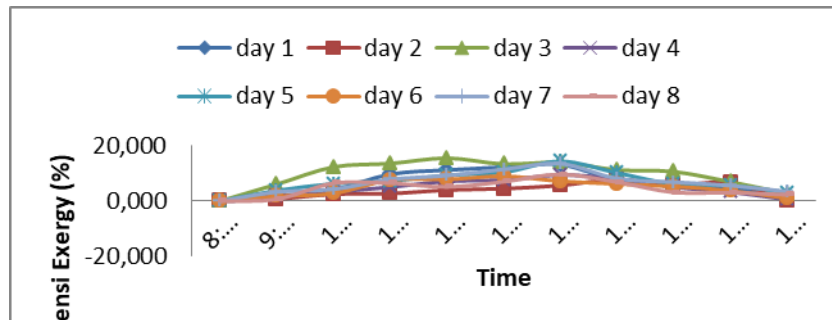


Figure 4. Efficiency of Exergy the first day to eight

Based on the test results, calculations can be made to obtain exergy efficiency data, where the highest exergy efficiency value at the first day testing at 14.00 is 13.235%, the highest exergy efficiency test at the second day at 3:00 p.m. is 7.854%, the highest exergy efficiency value is on day testing third at 12.00 WIB at 15.588%, the highest exergy efficiency value at the testing of the fourth day at 14.00 WIB at 9.435%. Based on the results of testing, calculations can be made to obtain exergy efficiency data, where the highest exergy efficiency value at the fifth day test at 15.00 WIB is 10.320%, the highest exergy efficiency test at the sixth day at 13.00 WIB is 9.013%, the highest exergy efficiency is on day testing seventh at 14.00 WIB at 13,561%, and the highest exergy efficiency value at the test of the eighth day at 14.00 WIB amounting to 9,672%.

5. Conclusion

In this study, the exergy analysis and efficiency of exergy are the following conclusions:

- maximum loss of exergy is 182,219 obtained on the third day of testing at 11:00.
Also, the minimum exergy is 6,712 obtained on the eighth day of testing at 3:00 p.m.
- The maximum exergy efficiency is 15.58% obtained on the third day of testing at 12.00.
Also, the minimum exergy efficiency is 7.85% obtained on the second day of testing at 3:00 p.m.

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