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(Research Article)

The influence of the incoming air velocity with the fan on the inlet side of an air-water generator on the freshwater mass

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Abstract

The air-water generator is a promising device to provide freshwater in the future. However, the machine still produces less freshwater; hence, a study of the effect of air velocity with a fan installed at the entrance of a simple air-water generator on the freshwater mass was conducted under environmental conditions. The air velocities varied were 4 m/s, 5 m/s, and 6 m/s. The air-water generator was made from a refrigeration machine system using R134a refrigerant as the working fluid. The compressor specification was 1 PK rotary type. The results show that the highest average freshwater mass obtained is 1241 g for 7 hours, the highest COP was 4.72, and the highest total heat transfer rate is 208.21 J/s.

Keywords: Air water generator; Air velocity; Freshwater mass; Total heat transfer rate

1. Introduction

Water is one of the essential components for the development and growth of living organisms. Indonesia is a country located on the equator with only two climates, the rainy season and the dry season. When the dry season arrives, several regions in Indonesia experience drought or a clean water crisis. Therefore, the areas affected by this situation struggle to find a water source for daily needs as reported by Gaol [1].

Mirmanto et al. [2-4] stated that there were various models of water generators, such as harvesting water from the air using nets, harvesting water from the air using windmills, and harvesting water from the air using cooling machines. However, the easiest, simplest, and most versatile method that can be used anywhere is harvesting water from the air using a cooling machine.

The air-water generator machine using a cooling system has been extensively researched by scholars such as Dalai et al. [5], Atmoko [6], Winata [7], Prasetya [8], Faroni [9], and Ahmad et al. [10]. However, the conducted studies have not yet been able to yield water optimally; e.g. 2 kg for one hour. Winata [7] studied the effect of evaporator numbers on freshwater mass. He stated that the machine produced freshwater mass as much as 0.5043 kg of water over 7 hours, while the research by Prasetya [8], Faroni [9], and Azari [11] achieved outputs of only 0.4384 kg, 0.369 kg, and 0.44 kg respectively. These findings were comparatively lower than those of Winata [7]. Therefore, further research on a water-generating machine is still crucial to enhance its water production capacity.

Several factors that influence the quantity of freshwater mass produced include the incoming air relative humidity (RH), incoming air temperature, evaporator construction, evaporator surface area, evaporator pipe diameter, and incoming air velocity as reported by Mirmnto et al. [2-4]. Therefore, this study examines an evaporator with a pipe diameter of

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1.7 mm because Faroni [9] stated that a smaller evaporator pipe diameter yields a greater freshwater mass. This study utilized an evaporator with the smallest pipe size, consisting of parallel pipes with a diameter of 1.7 mm, totalling 138 pipes, each with a length of 40 cm. This evaporator had been investigated previously by Pengestu [12], however, Pangestu used free convection system resulting in low freshwater production.

2. Material and methods

The method employed in this research was an experimental method with the schematic diagram of the apparatus shown in Figure 1. This type of research method could be used to test a new treatment or design by comparing one or more test groups with treatment and without treatment. This research utilized two types of variables:

- Dependent variables, which could not be determined or controlled, were obtained during data collection and incorporated into the analysis of research findings. The dependent variables in this study included: air temperature leaving the evaporator, condensation freshwater mass, refrigerant temperatures T_1 to T_4, refrigerant pressures P_2, P_3, and P_4, while P_1 was kept constant at approximately 15 psi, and relative humidity (RH) of air leaving the evaporator. The position of the thermocouple and pressure location can be seen in Figure 2.
- Independent variables, which could be controlled or determined, or changed according to the research objectives. The independent variable in this study was the incoming air velocity, namely (4 m/s, 5 m/s, and 6 m/s).

The tools and materials were prepared beforehand. The equipment and materials used in this study comprised a thermal aluminium foil, anemometer, barometer, data logger, filter, high-pressure gauge, hygrometer, fan, compressor, condenser, low-pressure gauge, capillary tube, potentiometer, fan power meter, compressor power meter, stopwatch, thermocouple, digital scale, vacuum pump, water container, wooden blocks, plywood, and R-134a refrigerant.

This study aims to determine the freshwater mass, COP and total heat transfer rate. Therefore, some equations are used to estimate the COP and total heat transfer rates, while the freshwater mass is just weighed using a digital balancer model Joil 5 kg with a resolution of ± 1 g. All temperatures were recorded using thermocouples K-type connected to data logger Applent AT 4532. All pressures were measured using manifold pressure gauges in psi. The ambient pressure, temperature and RH were detected using a digital hygro-barometer model Sunroad FR500.

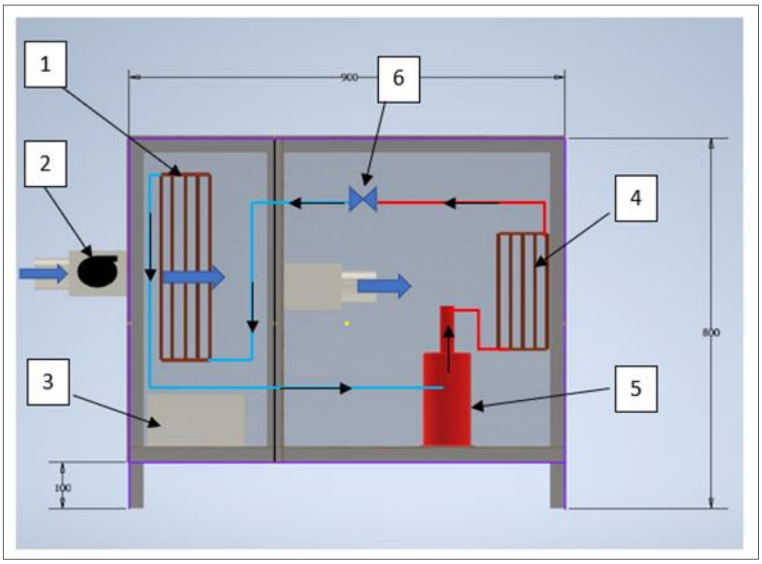

Figure 1 Schematic diagram of the apparatus: 1. Evaporator, 2. Fan, 3. Bucket, 4. Condenser, 5. Compressor, 6. Capillary tube

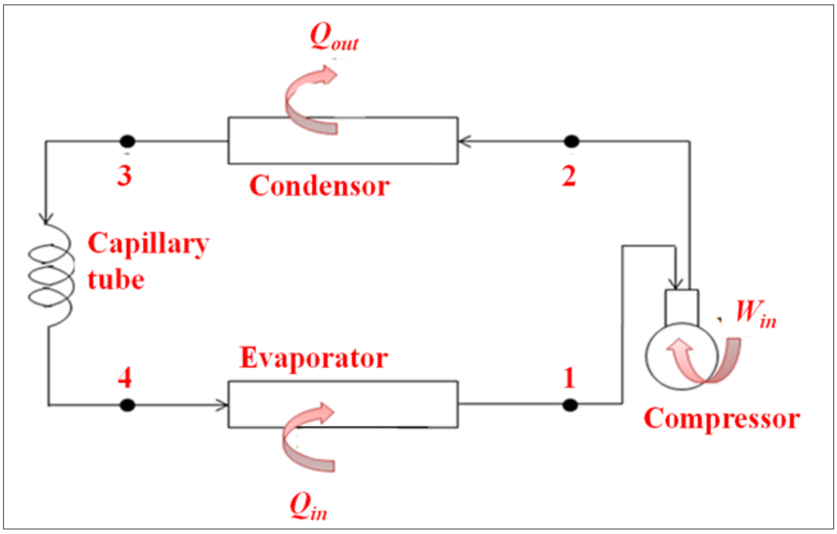

Figure 2 Positions of thermocouples and pressures in the system

COP is an indicator of refrigeration machine which equals the energy absorbed by the refrigerant in the evaporator divided by the compressor work, and expressed as:

$$COP = \frac{Q_{in}}{W_{in}} \quad \text{...............(1)}$$

Q_{in} is the energy absorbed by the refrigerant (J/kg), Win indicates the compressor work (J/kg). To obtain Q_{in} and W_{in}, equations in Cengel and Boles [13] can be applied.

The total heat transfer rate can be predicted using equation (2). The equation can be found in Mirmanto et al. [2-4] and expressed as:

$$\dot{Q}_t = \dot{Q}_{da} + \dot{Q}_v + \dot{Q}_d \quad \text{.........(2)}$$

$\dot{Q}_t$ is the total heat transfer rate from the air to the evaporator walls (W), while $\dot{Q}_{da}$, $\dot{Q}_v$, and $\dot{Q}_d$ are the heat transfer rate from dry air (W), from vapour (W), from dew (W). They can be seen in Miranto et al. [2-4].

3. Results and discussion

This study aims to determine the performance of the air-water generator machine, namely the freshwater mass, the flow rate of heat transfer to the condensing unit and COP. Therefore several stages need to be analyzed both on the refrigerant side and the air side. The results are presented in the form of graphs; freshwater mass, COP and total heat transfer rate.

Figure 3 shows the freshwater mass obtained in the experiments. The air velocity of 4 m/s resulted in freshwater of 525 g (for 7 hours). Increasing air velocity levels freshwater production. However, there is a different phenomenon for the air velocity of 5 m/s to 6 m/s. At the air velocity of 6 m/s, the freshwater production is less than that of 5 m/s. Based on the error analysis, the different freshwater masses resulted in the air velocity of 5 m/s and 6 m/s is not significant. The difference is still in the error range because the error legs still overlap each other. This meant that at 6 m/s, the water vapour might not have time to condense due to the fast flow.

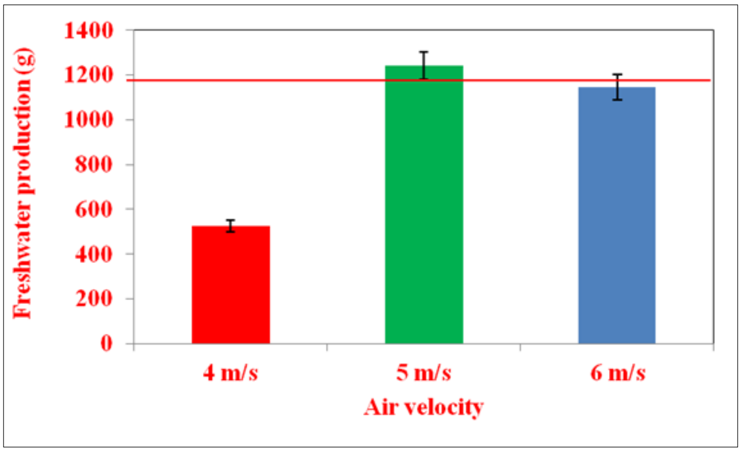

Figure 3 Relationship of freshwater production with air velocity

Refrigerant enthalpy is used in the calculation of the vapour compression cycle, where the enthalpy includes: enthalpy when leaving the condenser unit (h_1), enthalpy when leaving the compressor (h_2), enthalpy when leaving the condenser (h_3), enthalpy when entering the condensing unit (h_4). h_1 and h_2 can be found in the table for superheated refrigerant 134a vapour, while h_3 and h_4 have the same enthalpy, which can be found in the table for liquid refrigerant 134a saturated temperature. The data that are used to find the enthalpy in the thermodynamic table include refrigerant pressure leaving the condenser unit (P_1), refrigerant pressure leaving the compressor (P_2), refrigerant pressure leaving the condenser (P_3), temperature leaving the condenser unit (T_1), compressor outlet temperature (T_2) and condenser outlet temperature (T_3).

COP is the ratio of the heat load (absorbed by the refrigerant) per unit mass of refrigerant in the condensing unit to the compressor work per unit mass of refrigerant. Figure 4 shows the experimental COP of the machine. The actual COP at all air velocities is lower than COPrev. This means that the experiments are on track. However, based on the error bar, the effect of air velocities is not significant because the error legs are touching each other for both COP actual and COPrev. This occurs due to the same setting of the machine. Although the airflow is fast when the setting of the machine is the same, the COP is not different. The refrigerant inside the machine is nothing to do with the fluid flowing outside the machine. The refrigerant is inside the machine while the air flow is outside the machine. The condition of the outside of the machine can change but as long as the setting of the machine is the same for all air velocities then the inside of the machine does not change, consequently, the COP does not obey the increase in the air velocities.

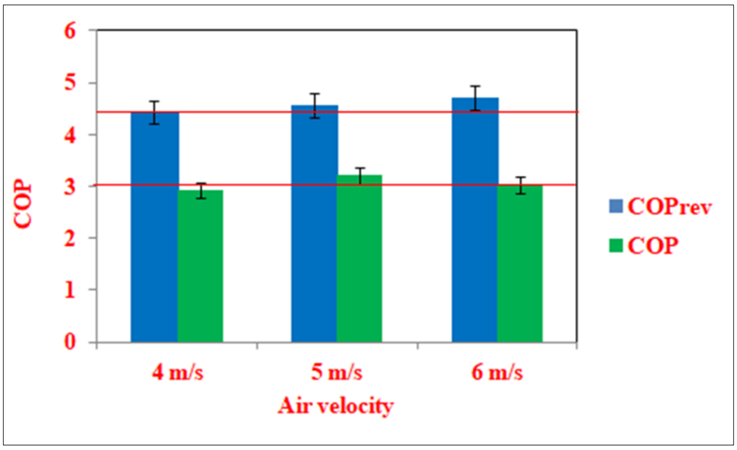

Figure 4 Relationship COP and COPrev with air velocities

The total heat flow rate absorbed by the condensing unit from the air of 3 variations can be found by adding up $\dot{Q}_{da}$, $\dot{Q}_v$, and $\dot{Q}_d$. Figure 5 shows that the highest total air $\dot{Q}_t$ value occurs at a variation of air speed of 5 m/s with a total air $\dot{Q}_t$ value of 199.14 J/s.

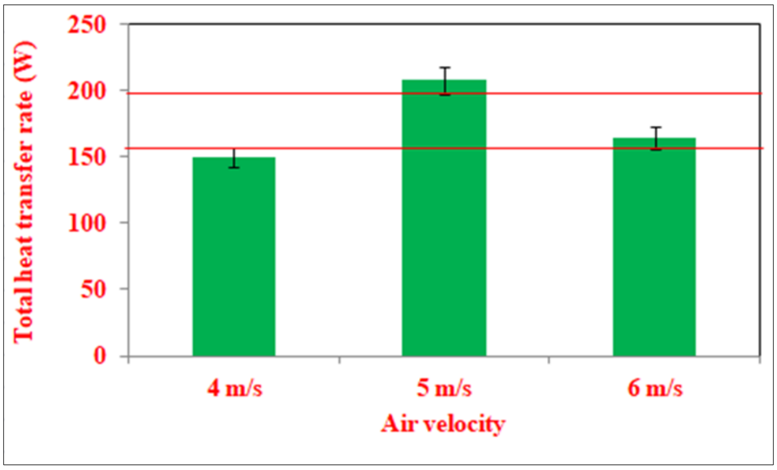

Figure 5 Relationship total heat transfer rate $\dot{Q}_t$ with air velocities

For the higher air velocity (6 m/s), the freshwater production and the total heat transfer rate are lower than that of 5 m/s. This can happen probably due to the fast air flowing. The fast air flowing may have no time to contact the evaporator wall, consequently, at the air velocity of 6 m/s, the freshwater production and total heat transfer rate are lower.

4. Conclusion

Based on the results of research and analysis regarding the influence of the inlet air velocity with the fan on the inlet side on the resulting freshwater mass as follows:

- The results of the study showed that the highest freshwater mass occurred at a variation of the inlet air velocity of 5 m/s with an average mass of freshwater of 1.241 kg/7 hours.
- There is no effect of the air velocity on the COP and COPrev.
- The total heat flow rate absorbed by the condenser unit with the highest value occurs at the variation of the inlet air velocity of 5 m/s with the total heat transfer rate $\dot{Q}_t$ of 208.21 J/s.
- The study needs further investigation at higher air velocities.

Compliance with ethical standards

Acknowledgement

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Disclosure of conflict of interest

No conflict of interest is to be disclosed.

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