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The Effect of Incoming Air Speed on the Water Mass Produced in the Air-Water Harvester Machine with a Power of 1 PK

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Abstract
In the dry season, several regions in Indonesia experienced drought and clean water crises. One of the efforts to obtain clean water is to present a tool called an air-water harvester using a steam compression system. This study aims to determine the effect of incoming air velocity on the air mass produced and heat transfer rate in an air-water harvester machine with a power of 1 PK. Three centrifugal fans were used to push the air coming into the machine and the air velocities applied were 2 m/s, 3 m/s, 4 m/s. The results show that the highest water mass of 6,644 kg was obtained at the air velocity of 4 m/s and the highest total heat transfer rate absorbed by the evaporator was 1757.88 W. At these conditions increasing the air velocity levels the water mass and heat transfer rate.

Keywords: *Air-water harvester, air velocity, air mass, heat transfer rate*

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I. INTRODUCTION

Water in human life has a very important role and must be fulfilled in daily life. In the dry season, some parts of Indonesia experience drought and clean water crisis. For example, in the Bima, Dompu, and NTT regions, there is always drought and a clean water crisis. Various efforts are being made to meet the current need for clean water. One of the efforts to obtain clean water is to present a tool called an airwater harvester using a steam compression system.

There are many models of water harvesters such as harvesting water from the air using nets, harvesting water from the air using windmills and harvesting water from the air using a cooling machine. The easiest and simplest and can be used anywhere is to harvest water from the air using a cooling machine as long as there is electricity in the location, several studies that have researched the method of harvesting water from the air using a cooling machine are Prasetyo [1], Setiawan [2], Suriatman [3], Ramadhan [4], Firdaus [5], Sutrisno [6], Handaru [7], and Mirmanto et al. [8-12].

Prasetyo [1] conducted an experimental research on airborne water capture machines used in open system types. By using AC1.5 PK components, and plus one fan which is used to compress the air with a power of 72.6watts. The refrigerant used is R22. Prasetyo [1] produces water as much as 4280ml/h at a variation of 250 rpm fan rotation or air speed of 2.64m/s.

Setiawan [2] has conducted research on the effect of outlet fan rotation on the characteristics of aquades producing machines with steam compression cycles. Variations of the research using the rotation speed of the outlet fan 0 rpm produced water of 1,858 liters/h, 981rpm produced water of 1,985 liters/hour, 1226 rpm produced water of 1,950 liters/hour, and 1664 produced water of 2,017 liters/hour.

Suriatman [3] conducted a study on the performance of a water harvester with a small pipe condenser unit at various incoming air speeds experimentally with the R134 compressor or rotary type 1PK. The results showed the highest average air mass of 0.728 kg/7 hours.

Ramadhan [4] examines the performance of water harvester machines in various fan positions. The fluid used is refrigerant R134 and a compressor with a power of 1 PK. This study varied the position of the fan of the condenser unit, namely the position of the fan pushing the air, the position of the fan sucking in the air, and the position of the fan pushing and sucking the air. The results of the study showed that the highest average water mass obtained was 0.977 kg/7 hours.

Firdaus [5] has conducted a study on "Demonstration of water-harvester machines with shell-spiral condenser units at various incoming air speeds". The varied air velocity is 3 m/s, 4 m/s and 5 m/s with a pressure of 15psi. The refrigerant used is R134a, the compressor used is 1/2 PK rotary type. The results showed that the highest water mass was obtained at a variation of air speed of 5 m/s of 0.622 kg for 7 hours and the heat energy absorbed by the evaporator of the highest refrigerant mass (Qin) was found at a variation of 4 m/s as large as 165.2kj/kg. The total heat absorbed by the condenser unit from the highest air is found at a variation of 5 m/s of 161.71 W and the efficiency of the highest condenser unit is found at a variation of air speed of 5 m/s of 6.46 %.

Ahsani [6] has conducted experiments with the refrigranR134a working fluid, the compressors used are 1 PK compressors of the rotary type and evaporators used in the form of a coil-shaped with 2 evaporators. Evaporatorcoil, which is only one of them, has been researched by other students. The diameter of the copper pipe used to make the evaporator is 6.35 mm and the diameter of the coil is 80 mm and the number of coils26 per evaporator and the inlet air velocity used in this study is 4 m/s, 5 m/s, and 6 m/s. The total water mass and heat transfer absorbed by the evaporator.

The results showed that the highest water mass was obtained at the variation air velocity of 5 m/s as much as 1.457 kg and the highest total heat absorbed by the evaporator from the air can be found in the 5m/s variation of 250.91 J/s. Handaru [7] conducted research on the effect of the position of the evaporator coil on the performance of the forced convection water harvester water machine. This research was conducted experimentally with R134a refrigerant working fluid. The compressor used is a 1 PK rotary compressor. This research varies the position of the evaporator The results showed that the highest average water mass obtained was 0.653kg/7h using the vertical position variation. the total heat flow rate absorbed by the evaporator from the highest land occurred in the vertical position variation which amounted to 124.16J/s.

The amount of water produced depends on several factors, namely air temperature, RH, the shape of the evaporator, the number of evaporators, the diameter of the evaporator pipes, and the air velocity entering the condensing unit or fan rotation. Most of the above studies used evaporators designed by the researchers themselves except Prasetyo [1] who used a 1.5 PK AC machine. Therefore, the proposed research uses the original 1PK AC machine and the velocity of the entry air is varied. Of course, this velocity variation was intended to see the effect of entry velocity on the mass of water produced and is expected to produce more water mass than previous studies. The air velocities varied here were 2 m/s, 3 m/s, and 4 m/s. Studies of Mirmanto etal. [8-12] still mentioned unclear things of the effect of air velocity on the fresh water mass and heat transfer rate. Therefore, this study investigated the effect of air velocities on the freshwater production and heat transfer rate of an air-water harvester machine (AWHM) using a fabricated evaporator.

II. MATERIALS AND METHOD

The method used in this research is the experimental method. The machine used was an air-water harvester that used several components of an air conditioning or cooling machine. However, the evaporator component in this machine was used as a unit that condenses the water vapor in the air. Inside the evaporator, the refrigerant did not condense, but evaporated due to heat from the air flowing over it. The refrigerant evaporated inside the evaporator by absorbing heat from the surrounding air material. The walls of the evaporator cooled down and became below the water's dew point. Therefore, the water vapour in the air that touches these walls condensed. Since the focus of this study was on freshwater production and heat transfer rate on the outer wall of the evaporator, then the temperatures and pressures of the refrigerant were not recorded. On the inside evaporator the refrigerant evaporated while on the outside evaporator the water vapor condensed.

In this research there were two types of variables. The dependent variable is a variable that cannot be determined or cannot be regulated, and its value is obtained at the time of taking the data and is included in the analysis of the research results. Included in the dependent variables in this study were total heat transfer rate, mass of water resulting from condensation, while the independent variables or free variables were the air velocities of the air entering the evaporator with the velocities of 2 m/s, 3 m/s, 4 m/s. How to obtain the data some steps were conducted: (i) turn on the data logger by clicking start so that all temperatures were recorded automatically, (ii) recording RHin, RHout, Tling, RHling, Pling, freshwater mass, air velocity before the engine running, (iii) set the air velocity at a certain value, such as 2 m/s, (iv) start the AWHM, (v) recording RHin, RHout, Tling, RHling, Pling, freshwater mass, and air velocity at every hour, (vi) turning off the AWHM after 7 hours, (vii) perform procedures 1-6 for the next air velocity variation.

All temperatures were recorded using a data logger APPLENT AT45-32 channels with temperature sensors of K-type thermocouples with an uncertainty of ±0.5°C. The mass of the freshwater produced was measured using a digital balancer and the RH was measured using a digital hygrometer, and the power of the machine was indicated by power meter. Meanwhile, the air velocity was measured using a digital anemometer model Anemometer Data Logger Benetech GT8907 Wind Meter Flow Air Tester 8907.

To analyze the data some equations were used. The mass flow rate of the freshwater or dew can be predicted using eq. (1).

$$\dot{m}_d = \frac{m_d}{t} \quad (1)$$

$\dot{m}_d$ is the freshwater mass flow rate (kg/s), m_d is the mass of freshwater (kg) and t is the total time of the experiments. The total air mass flow rate can be calculated using eq. (2).

$$\dot{m}_t = \rho AV \quad (2)$$

$\dot{m}_t$ is the total air mass flow rate (kg/s), ρ represents the density of air (kg/m^3) obtained from atmospheric pressure air table based on the temperature. A is the area of the entrance for the air coming into the machine (m²) and V is the velocity of the air coming into the machine (m/s) measured using a digital anemometer mentioned above. To be able to calculate the heat transfer from dry air and from water vapor, it is necessary to know the flow rate of dry air and water vapor. The dry air flow rate can be calculated by equation (3).

$$\dot{m}_{da} = \frac{\dot{m}_t}{w+1} \quad (3)$$

$\dot{m}_{da}$ is the dry air mass flow rate (kg/s), w is the share of water vapor in air (kg/kg$_{da}$), and w is obtained from the online psychrometric chart [13], based on the temperature and RH of the air at the entrance. The mass flow rate of vapor can be calculated based on the equation (4).

$$\dot{m}_v = w\dot{m}_{da} \quad (4)$$

$\dot{m}_v$ is the water vapour mass flow rate (kg/s).

The heat transfer rate from the air to the evaporator wall can be divided into three things, namely heat transfer from dew, heat transfer from dry air and heat transfer from water vapor. The heat transfer rate from dew can be expressed by equation (5).

$$\dot{Q}_d = \dot{m}_d h_{fg} \quad (5)$$

$\dot{Q}_d$ is the heat transfer rate of freshwater or dew (W) and then the heat transfer rate of dry air is predicted using eq. (6).

$$\dot{Q}_{da} = \dot{m}_{da}(h_i - h_o) \quad (6)$$

$\dot{Q}_{da}$ is the heat transfer rate from the air to the evaporator walls (W), h_i and h_o indicate the enthalpy of the air at the entrance and exit (J/kg$_{da}$). h_i and h_o obtained from [17] with input of temperature and RH. Then the heat transfer rate from water vapor to the evaporator wall is expressed by the equation (7).

$$\dot{Q}_v = \dot{m}_v c_{pv}(T_i - T_o) \quad (7)$$

$\dot{Q}_v$ is the heat transfer rate from the vapour to the evaporator walls (W). T_i and T_o is the air temperatures at the entrance and exit (°C). The total heat transfer rate is then can be expressed as

$$\dot{Q}_t = \dot{Q}_d + \dot{Q}_{da} + \dot{Q}_v \quad (8)$$

$\dot{Q}_t$ is the total heat transfer rate from the air to the evaporator walls (W).

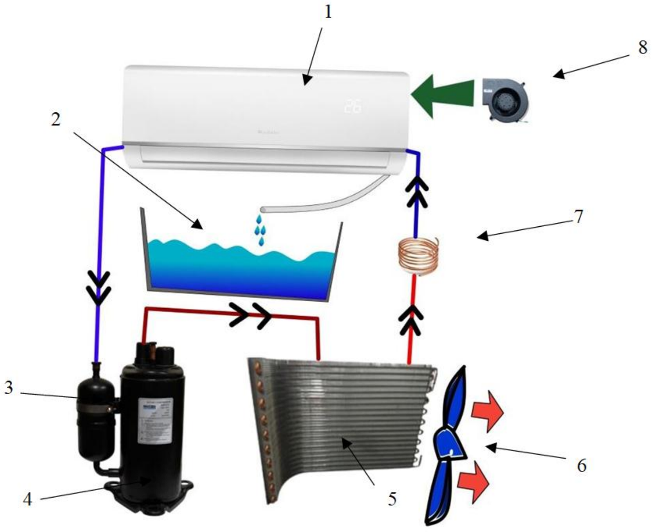

Figure 1: Refrigerant flow schematic. 1. Evaporator, 2. Water tank, 3. Accumulator, 4. Compressor, 5. Condenser, 6. Condenser fan, 7. Capillary tube, 8. Fan.

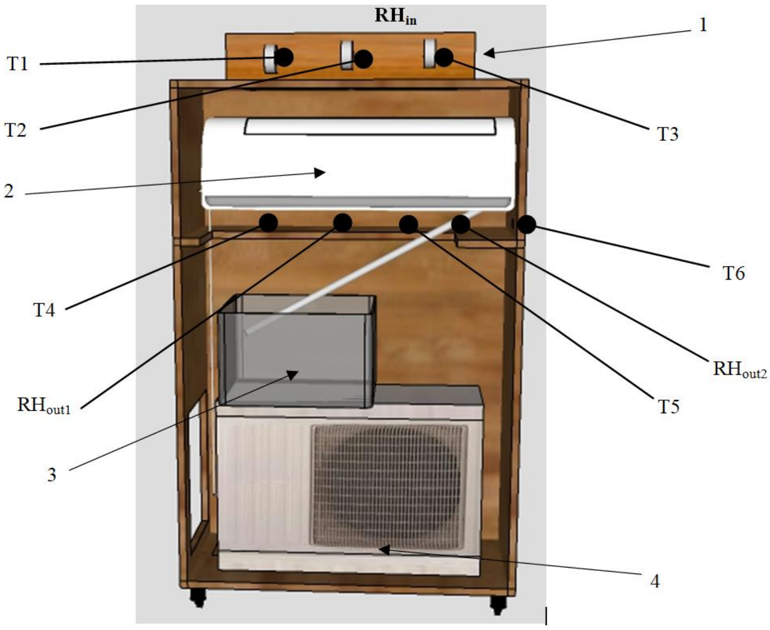

Figure 2: Components of the experimental apparatus. 1. Fan box, 2. Evaporator, 3. Water tank, 4. Outdoor. T1 – T3 are air inlet temperatures, T4-T5 are air outlet temperatures, RH_{in} is the air inlet relative humidity, RH_{out1} and RH_{out2} are the air relative humidity at the exit.

III. RESULT AND DISCUSSION

The results of the tests that have been carried out using the AWHM which aims to determine the amount of the freshwater mass produced, and the total heat dissipated by the evaporator from the air. Data collection was carried out the air velocity variations of 2 m / s, 3 m / s and 4 m / s. The data shown in Figure 3 and Figure 4 are amount of freshwater produced (m_d) and Figure 5 shows the total heat transfer rate absorbed by the evaporator from the dry air.

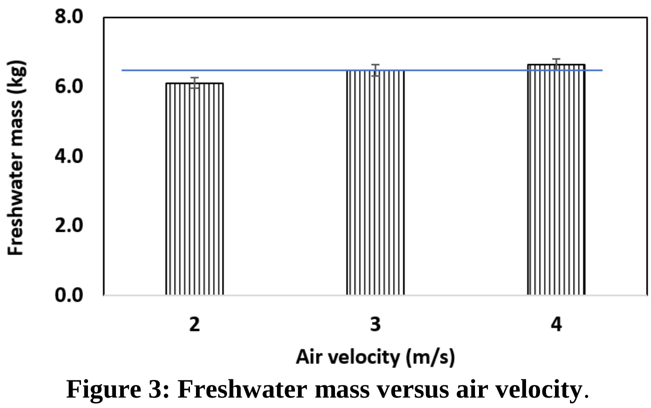

Figure 3: Freshwater mass versus air velocity.

Figure 3 shows the results of the average mass of water in each variation of air velocity, the highest mass of freshwater produced is 6.64 kg obtained at the air velocity of 4 m/s. At the air velocity of 3 m/s, the freshwater obtained is 6.47 kg, and at the air velocity of 2 m/s, the freshwater attained is 6.11 kg. The difference of freshwater mass at 2 m/s, 3 m/s and 4 m/s based on figure 3 is significant because all the error bar legs do not touch the same horizontal lain. This means that the difference is more than 5%. This finding agreed with the results of Suriatman [3]. Suriatman [3] stated that increasing the air velocity leveled the freshwater mass. Meanwhile, Tarmizi [14] found that the effect of air velocity ranging from 4 m/s to 6 m/s was not clear because Tarmizi [14] obtained the amount of freshwater was not different significantly. As the machine used by Tarmizi [14] was the same as the machine used by this study, it meant that probably the optimal air velocity at this experimental condition was 4 m/s. Similarly, Maulana [15] found that the effect of air velocity was clear.

Maulana [15] applied the air velocities of 0, 3, 4, 5, and 6 m/s. However, at the air velocity of 5 m/s and 6 m/s there was no significant difference of the freshwater mass.

Figure 4 shows the value of total heat transfer rate from the air to the evaporator walls. The total heat transfer rate is calculated using eq. (8). This equation was also used by Mirmanto et al. [8-12] and other researchers mentioned above, such as Prasetyo [1], Setiawan [2], Suriatman [3], Ramadhan [4], Firdaus [5], Ahsani [6], Handaru [7]. At the air velocity of 2 m/s, the total heat transfer rate obtained was 1009 W, at the air velocity of 3 m/s and 4 m/s, the total heat transfer rates attained were 1169 W and 1758 W.

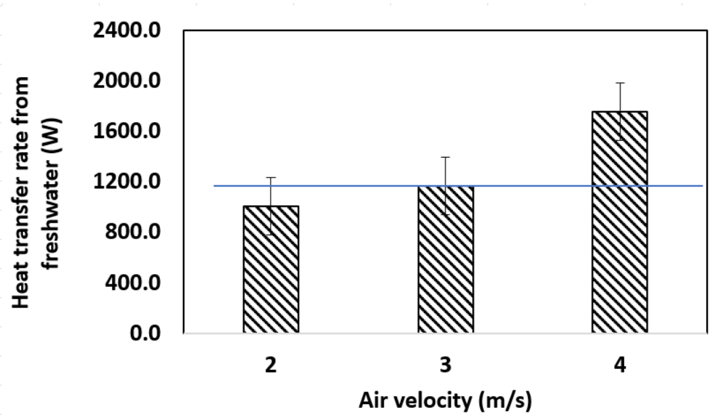

Figure 4: Total heat transfer rate versus air velocity.

Figure 4 indicates that increasing air velocities raises the total heat transfer rate. However, at the velocity of 2 m/s and 3 m/s the difference of total heat transfer rate is not significant, because the error bar legs touching the same horizontal line. Again, this study indicates that the optimum air velocity is 4 m/s. This does not agree with the results of Suriatman (2023). Suriatman [3] stated that increasing the air velocity leveled the total heat transfer rate. The similar study conducted by Mari [16] revealed that the total heat transfer rate increased with the increase in the air velocity. Mirmanto et al. [12] also found contra productive results. Some studies stated the effect of air velocity was clear but others stated the effect of the air velocity was not clear. Hence, the effect of air velocity at the entrance needs to be investigated further with the gap range of the air velocity is larger enough, such as 1 m/s, 3 m/s, 5 m/s and 7 m/s.

IV. CONCLUSION

Based on the results of research and analysis of the effect of air velocity on the performance of the air-water harvester machine with two coil evaporators, the following conclusions are obtained: (i) the results of the study show that the variation of inlet air velocity of 4 m/s produces the highest mass of water, namely 6.64 kg, (ii) the highest total air heat transfer rate absorbed by the evaporator occurs in the variation of the air velocity of 4 m/s with an average value of 1758 W. (iii) the air velocity variation of 4 m/s is recommended to be used at these experimental conditions. (iv) the study of the effect of air velocities needs more clarifications.

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