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Water Production Of An Air-Water Generator With 10 Coils Of A Condensation Unit

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Abstract—Water is very important for everyday life both in use for household needs, agricultural irrigation, plantations, ponds, and so on. In various parts of the world, especially in Indonesia, the problem of lack or difficulty in getting clean water is a problem that always repeats itself in the dry season. Therefore, to overcome these problems, it is necessary to use technological advances as a tool to produce water. One of the tools that can produce water from air using a vapour compression system is an air-water generator. This study was conducted to determine the performance of an air-water generator with 10 coils of a condensation unit. The machine used refrigerant R134a as the working fluid. The results show that the highest water production was 0.519 kg.

Keywords—water production; air water generator; condensation unit

I. INTRODUCTION

Indonesia is a country that has a larger water area than its land area. With an area of 7.81 km^2 consisting of 2.01 km^2 of land, 3.25 million km^2 of the sea, and 2.55 million km^2 of the Exclusive Economic Zone (EEZ). However, with a large water area, several regions in Indonesia still lack sources of clean water in the dry season. People in NTT walked a long way to get clean water. Therefore, it is necessary to provide a device that can produce water. Some studies showed how to obtain fresh water from salty water using desalination or distillation process, e.g. Abdullah [1], Faisal [2], Mirmanto et al. [3-5]. Other studies exposed obtaining water using reverse osmosis, capturing water using nets and so on. However, they have disadvantages themselves. For example, capturing water using a net is only good when the nets are placed in foggy areas. Distilling salt water to become fresh water cannot work for people in a high places where there is no beach or far from the sea, Mirmanto et al. [3-5]. The simple device that can be used for obtaining water in any condition and place is an air water generator (AWG) running using a refrigeration machine.

Previous studies of AWG using an air conditioning machine were conducted, e.g. Talarima [6], Prasetyo [7], and Mirmanto et al. [8-10]. However, the device was still limited and it produced less fresh water. Therefore, it needs a more comprehensive further investigation. Kumar and Yadav [11] conducted an experimental study of solar-powered water production from atmospheric air using $CaCl_2$ composite drying materials or wood saws. The amount of water production depended on the concentration of CaCl2 inside. The maximum amount of water produced with a composite concentration of 60% was 180 ml/kg/day. However, all that had been studied were only useful if you lived in coastal areas. The idea to obtain water by condensing air using a vapour compression system (cooling machine) prevailed.

Riswoko [12] conducted research on a water-catching machine from the air with a fan rotation speed of 400 rpm and 450 rpm, the result was that the fan rotation speed of 450 rpm reached the highest COP_{actual}, namely 4.7. The COP_{ideal} reached the highest value of 5.57 at 450 rpm. The greatest efficiency of 84.42% was obtained at 450 rpm fan rotation. The amount of water produced by the water catcher machine from the air at 450 rpm fan speed variation was 4,450 litres/hour with the amount of heat energy absorbed by the evaporator per unit mass of refrigerant of 174 kJ/kg and the amount of heat energy released by the condenser per unit mass of refrigerant was 211 kJ/kg. Prasetyo [7] has conducted research on a water-catching machine from the air using components from a 1.5 PK AC engine and an additional fan used to compress the air with a power of 72.6 W. The highest freshwater production was 4280 ml/hour at a fan speed variation of 250 rpm or an airflow rate of 2.64 m/s.

Atmoko [13] conducted research by adding 2 fans to the condenser and 1 fan in front of the evaporator as an air compactor using a fan/motor regulator (dimmer) on the air compaction fan placed in front of the evaporator consisting of 300 rpm and 350 rpm fan rotation. The freshwater production by this machine with a fan speed of 350 rpm was 4.29 litres/hour.

In this final project research, the study was carried out to continue the work of Atmoko [13]. However, the evaporator used was a copper coil with 10 coils. This study had a different evaporator from the study of Atmoko [13]. Atmoko [13] used the real AC machine while this study used a custom machine produced by the lab.

II. MATERIALS AND METHOD

The experimental device is presented in figure 1. The device consisted of a compressor, an evaporator, a condenser and a capillary tube. The method used in this research is the experimental method. Some parameters were recorded, e.g. temperatures, pressures, air velocity and relative humidity (RH).

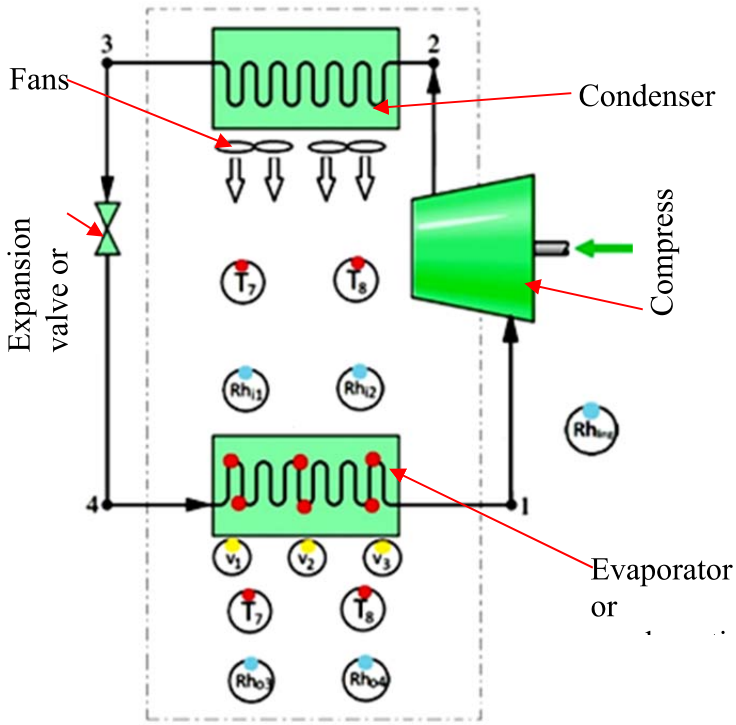

Fig. 1. Experimental apparatus

This machine worked by sucking air from the environment and then blowing it in through the condensing chamber where the evaporator was located. The room was called the condensation room because the process of condensation of water vapour carried by air occurred there. The air touched the walls of the evaporator which had a low temperature so some of the water vapour in the air condensed, and the condensate dripped into the water bucket. Then the air flowed down through the tiny holes and was finally blown out with the fan below. According to Mirmanto et al. [8-10], the heat transfer rate from the dry air could be written as:

$$\dot{Q}_d = \dot{m}_d c_{pd} \left(T_{ai} - T_{ao}\right) \quad (1)$$

$\dot{Q}_d$ is the heat rate from dry air (W), $\dot{m}_d$ is the mass of dry air (kg), c_{pd} is the specific heat energy for the dry air (J/kg K), and T_{ai} and T_{ao} are the inlet and outlet air temperatures (°C).

In addition to the heat of dry air, there is also heat from water vapour is cooled and heat from water vapour becoms water.

$$\dot{Q}_v = \dot{m}_v c_{pv} \left(T_{ai} - T_{ao}\right) \quad (2)$$

$\dot{Q}_v$ is the heat rate from the water vapour absorbed by the evaporator (W), $\dot{m}_v$ is the vapour mass flow rate (kg/s), c_{pv} and represents the specific heat of the vapour (J/kg K). The value of c_p is evaluated at T_{aa} (average air temperature).

$$T_{aa} = \left(T_{ai} + T_{ao}\right)/2 \quad (3)$$

$$\dot{Q}_w = \dot{m}_w h_{fg} \quad (4)$$

$$\dot{m}_w = m_w / t \quad (5)$$

$\dot{Q}_w$ is the heat from the condensed vapour (W), $\dot{m}_w$ is the mass flow rate of water production (kg/s), m_w is the mass of water production (kg), t is the total time of running AWH machine (s), and h_{fg} is the evaporation/condensation energy (J/kg).

The total heat absorbed by the evaporator from the cooled air can be calculated using the equation:

$$\dot{Q}_t = \dot{Q}_d + \dot{Q}_v + \dot{Q}_w \quad (6)$$

$$\dot{m}_a = \rho A V \quad (7)$$

$$\dot{m}_a = \dot{m}_v + \dot{m}_w \quad (8)$$

$$\dot{m}_v = m_1^* \dot{m}_d \quad (9)$$

$$\dot{m}_a = m_1^* \dot{m}_d + \dot{m}_d$$

$$\dot{m}_d = \frac{\dot{m}_a}{1 + m_1^*} \quad (11)$$

$\dot{m}_a$ is the total air mass flow rate (kg/s), m_1^* is the amount of water vapour in the air (kg_v/kg_d), v represents the vapour and d refers to dry. ρ is the density (kg/m³) of the air at the inlet temperature. *A* is the frontal area of the air entrance (m²), and *V* is the air velocity coming into the machine (m/s). The equations (1) to (11) could be obtained in Mirmanto et al. [8-10].

III. RESULTS AND DISCUSSION

The experimental results are presented here. Figure 2 shows the tree heat transfer parameters, e.g. $\dot{Q}_v$, $\dot{Q}_w$, and $\dot{Q}_d$. $\dot{Q}_v$ is the heat transfer from the water vapour in the air (W), see equation (2), $\dot{Q}_w$ represents the heat transfer from the condensed water vapour (W), see equation (4), and $\dot{Q}_d$ is the heat transfer from the dry air (W), see equation (1). In this study, the heat transfer rate was dominated by sensible heat transfer. This was due to the flow of the air. The total air mass flow rate was huge, and it was calculated using equation (7). Therefore, the sensible heat transfer rate was high. Meanwhile, the latent heat transfer depended on the amount of freshwater gained. Using the 10 coils of the evaporator, the machine produced 0.519 kg. The temporary and accumulated freshwater production can be seen in figure 3.

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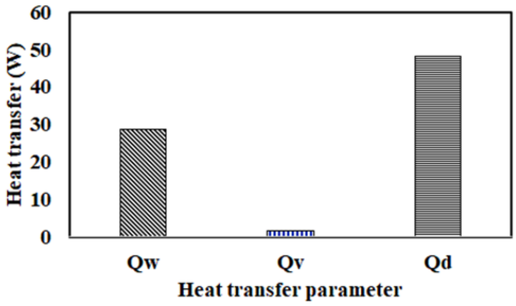


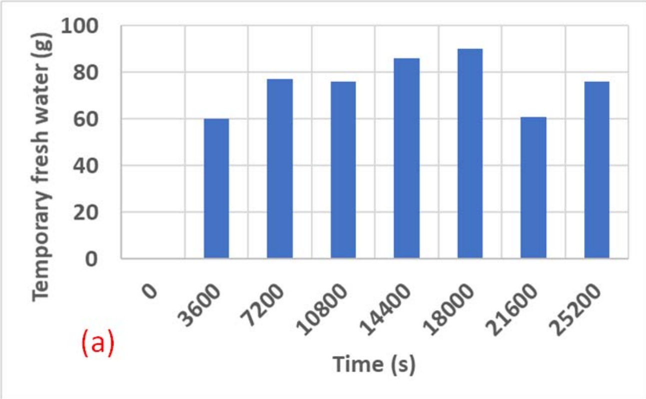
Fig. 2. Heat transfer from the air on the evaporator

The temporary fresh water production at every hour was not constant. It was scattered, however, the accumulated freshwater increased with time. The scattered amount of temporary fresh water was due to the changes in ambient temperature and RH throughout the day or with time, see figure 4. However, this was also found by Mirmanto et al. [8-10] and other researchers, e.g. Azari [14], Faroni [15], and Prasetya [16]. Hence, the study is on the right track, however, the freshwater production obtained was still less. It needs further modification of the machine and investigation. RH sometimes increased and decreased with time. RHout was always higher than RHin and the ambient RH was always the highest. RHin was measured at the outlet of the condenser, therefore, the temperature at the location was higher, and consequently, RHin is the lowest one. Higher temperature is lower the RH because RH is a temperature function. The phenomenon of RH was revealed in [8-10].

The parameter m_1* could be found in the online psychometric chart http://www.hvac-calculator.net/index.php?v=2 by inputting the dry bulb temperature and RH data. In this study, the dry bulb temperatures and RH were recorded directly in experiments. Then after the m_1* was found, the mass flow rate of the dry air could be calculated. Once the dry air mass flow rate was attained, the mass flow rate of the vapour also was found. The mass flow rate of the vapour, fresh water and dry air is presented in table 1. The experiments were repeated three times to get the average values of the investigated parameters. Hence, from table 1, it is clear that the repeatability of the experiment is good.

Table 1. Mass flow rate parameters

Day	$\dot{m}_d$ (g/s)	$\dot{m}_v$ (g/s)	$\dot{m}_w$ (g/s)
1	69	1.3	0.021
2	68	1.2	0.022
3	69	1.3	0.019



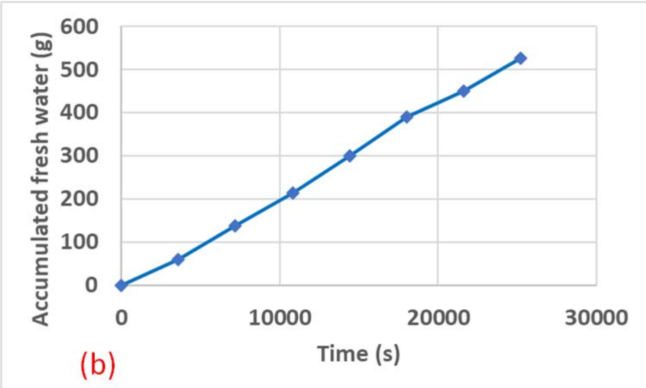


Fig. 3. Temporary (a) and accumulated (b) freshwater

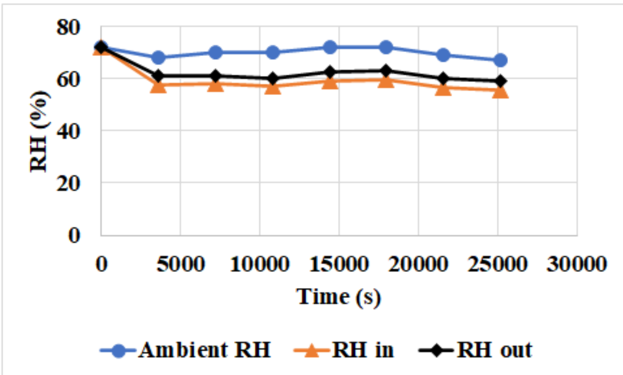


Fig. 4. RH parameters versus time

IV. CONCLUSION

Based on the research results, it can be concluded that the performances of the 10-coil air water harvester need to be improved because the freshwater production of this machine is still less. The maximum freshwater production is 0.519 kg for 7 hours. The experiments show repeatability because the experiments are conducted three times and the results are nearly the same. The heat transfer rate is dominated by sensible heat transfer. The temporary freshwater production is scattered. The accumulated freshwater production increases with time.

V. ACKNOWLEDGEMENT

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