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The performance of the water harvester machine at various pressures of the condensing unit

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ABSTRACT: An existing air-water harvester machine reported in the literature cannot produce freshwater optimally. For that, it is necessary to do research on this machine to increase its freshwater production. This study examined the effect of the evaporator pressure on the freshwater production and the heat transfer rates. Three different pressures were tested; 20 psi, 30 psi and 40 psi. The results showed that the highest freshwater mass was obtained at a pressure variation of 20 psi with an average freshwater mass of 0.71 kg for 7 hours. The highest average total heat transfer rate absorbed by the evaporator from the cooled air was found at a variation of 40 psi of 35.84 W. The highest efficiency was obtained at 40 psi variation of 2.37%.

KEYWORDS: Air – Water Harvester, Freshwater,Rate of Heat Transfer, Efficiency of evaporator

I. INTRODUCTION

Water is a basic human need that is very important and must be fulfilled in everyday life. During the dry season, a number of areas in Indonesia experience droughts, which result in scarcity and difficulties in obtaining clean water. In fulfilling this water, humans make various efforts to get it. Sources that are usually used to obtain this water include rain water, river water, lake water, springs, or well water. Some of these water sources certainly required processing beforehand so that the water was suitable for consumption as also written in Atmoko, [1], Mirmanto et al. [2-4].

One of the ways to obtain clean water is by capturing water from the air. According to Damanik [5] and Mirmanto et al. [2-4] there were currently several methods of capturing water from the air, including:

a) Windmills catch water from the air. This windmill was devoted to producing water instead of electricity. It had several drawbacks, namely it required a height and an installation location that had a high wind speed to be able to move the mill, it really depended on the weather, wind speed, altitude and wind direction. The cost of installation was also quite expensive.

b) Mist water catcher nets. It was a tool used to catch water from fog by using the help of nets designed in such a way that it can catch water from fog. The net is made of woven plastic which is then connected to small pipes. This method has the disadvantage that the water obtained is relatively small.

c) Machines producing water from air using a vapour compression cycle component. It was a machine that produced water from the air that used components from a cooling machine including: compressor, condenser, capillary tube and evaporator. Dew water was produced in a section called the evaporator or condensing unit.

Mirmanto et al. [2] examined the effect of the number of evaporators on water production and the performance coefficient of harvesting water from air. Water was obtained on the walls of the evaporator in the modes of free convection and condensation heat transfer. They carried out experiments at a low pressure of 40 psi and a high pressure of 180 psi. On the outer wall of the evaporator, air flowed naturally and some of the moisture in the air condensed. Three variations of evaporators were tested with case A (one evaporator), case B (two evaporators), and case C (three evaporators). Maximum water production and evaporator efficiency achieved were respectively 0.51 L per day and 13%. Increasing the number of evaporators could increase fresh water production.

One of the factors that affected the amount of dew water mass was the evaporator pressure. The higher the evaporator pressure, the higher the temperature of the evaporator so that water vapour

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in the air that was in contact with the evaporator could not condense. Likewise, the lower the evaporator pressure, the lower the evaporator temperature, which could cause freezing on the entire surface of the evaporator. The water vapour in the air flowed and condensed on the walls of the evaporator.

These very cold outer walls of the evaporator absorbed heat from the air that touched it, so that some of the water vapour in the air condensed. That was why it was called a condensing unit because in this study the evaporator functioned as a condensing unit for water vapour in the air. From the references above, there had been research that examined the effect of pressure on the mass of water produced as conducted by Prasetya [6]. However, the evaporator used was in the form of a coil/spiral pipe with a forced convection system. Therefore, the author was interested in reviewing the performance of the air-water harvester machine by varying the pressure of the condensing unit as done by Prasetya [6], but the evaporator forms were parallel pipes and a natural convection system. The pressure variations used were 20 psi, 30 psi and 40 psi. The reason for using this pressure variation was due to Prasetya [6]. Prasetya [6] stated that the lower the pressure, the greater the mass of water produced. Therefore, it was very necessary to examine the pressure below 30 psi, whether it produced a larger mass of water or not.

II. MATERIAL AND METHOD

The method used in this research was the experimental method. This type of research method could be used to test a treatment or a new design by comparing one or more test groups with treatment and no treatment. All tools and materials are prepared in advance so that there is no confusion in finding tools and materials during the research. Equipment and materials used in this study include compressors, condensers, condensing units, capillary pipes, thermocouples, digital thermometers, refrigerant R-134a, data loggers, scales, water storage containers, air.

In this study there are two kinds of variables, namely:

a) Independent variables are variables that can be adjusted or varied. The independent variables in this study are pressure variations in the condensing unit, namely 20 psi, 30 psi and 40 psi).

b) The dependent variable is a variable that cannot be regulated or cannot be determined and is obtained in data collection and is included in data analysis. The dependent variables included in this study were the temperature of the air leaving the condensing unit, the mass of condensed water, the high pressure in the condenser (this pressure will adjust to the evaporator pressure), the RH of the air leaving the condensing unit.

The experiments were conducted using the following procedures: 1. Research preparation, 2. Record the temperature, RH, and mass of water before the engine starts, 3. Turn on the data logger and press the start button to record, 4. Turn on the water-water harvester machine, 5. Set the pressure of the first variation of the condensing unit to 20 Psi, 6. Record temperature, compressor power, RH, and water mass every hour, 7. After 7 hours, the experiment was stopped, 8. The experiment was repeated 3 times for each pressure variation, 9. Repeat procedures 1 to 8 for other pressure variations of the dewing unit. The experimental apparatus is shown in Figure 1.

Figure 1. Schematic and position of the air-water harvester machine. 1. The condensing unit, 2. Pressure gauge outlet to compressor, 3. Condenser, 4. Compressor outlet pipe to condenser, 5. Pressure gauge inlet to compressor, 6. Inlet pipe to the compressor from the condensing unit, 7. Compressor, 8. Wall insulator, 9. Pipe from the condensing unit to the compressor, 10. Capillary pipe from the condenser to the condensing unit, 11. Where the dripping dew flows into the reservoir, 12. Reservoir.

The parameter that can be presented directly in the form of graph is mass of freshwater. This parameter was obtained by measuring the mass of dew in the experiments. The mass of dew was symbolized by m_w. Meanwhile the heat transfer rate of the dew can be seen in equation (1).

$$\dot{Q}_w = \dot{m}_w h_{fg} \quad (1)$$

$\dot{Q}_w$ is the heat transfer rate from the dew (W), h_{fg} is the heat of evaporation or condensation (J/kg), and $\dot{m}_w$ is the mass flow rate of the dew (kg/s). The heat transfer rate of the dry air can be predicted using equation (2).

$$\dot{Q}_{dw} = \dot{m}_{da} c_{pda} (T_i - T_o) \quad (2)$$

$\dot{Q}_{dw}$ is the heat transfer rate from dry air (W), $\dot{m}_{da}$ indicates the mass flow rate of the dry air (kg/s), c_{pda} is the heat capacity (J/kgK), and T_i and T_o are the inlet and outlet of the air (°C). The heat transfer rate from the vapour can be estimated using the equation (3). Then finally, the total heat transfer rate is calculated using equation (4).

$$\dot{Q}_v = \dot{m}_v c_{pv}(T_i - T_o) \quad (3)$$

$$\dot{Q}_t = \dot{Q}_d + \dot{Q}_{da} + \dot{Q}_v \quad (4)$$

The last parameter investigated is the efficiency of the evaporator. The efficiency can be elucidated using equation (5).

$$\eta = \frac{\dot{Q}_t}{\dot{Q}_i} x100\% \quad (5)$$

$\dot{Q}_i$ is the heat absorbed by the refrigerant inside the tube of evaporator (W). Equations (1-4) can be found in [2-4, 6].

III. RESULTS AND DISCUSSION

This research was to determine the effect of evaporator pressure on the amount of freshwater produced from the air in the air-water harvester machine. Therefore there were several stages that need to be analysed both from the refrigerant side and from the air side.

Data from the online psychrometric chart, free online psychrometric calculator [7] could be identified by inputting several parameters such as the average air temperature entering and leaving the condensing unit, and the average relative humidity of the air entering and leaving the condensing unit, RH_{in} and RH_{out}. The data obtained from the online psychrometric chart were w_1 and w_2.

Prior to calculating the heat flow rate, several parameters need to be calculated first, namely the mass flow rate of condensed water ($\dot{m}_w$), the portion of water vapour condensed (w*), the mass flow rate of dry air ($\dot{m}_{da}$), the mass flow rate of incoming vapour ($\dot{m}_v$), total air mass flow rate ($\dot{m}_t$). Furthermore, the heat flow rate of the dew water, the heat flow rate of the cooled water vapour, the heat flow rate of dry air, and the total heat flow rate of the air absorbed by the condensing unit could be determined.

The data that used to find the enthalpy in the thermodynamic table included: refrigerant pressure entering the compressor, refrigerant pressure leaving the compressor, compressor inlet temperature, and compressor outlet temperature and refrigerant leaving the condenser. By reading the thermodynamic table, the refrigerant enthalpy could be calculated. The enthalpy included: enthalpy when leaving the condenser unit, enthalpy when entering the condenser, enthalpy when leaving the condenser, enthalpy when enter the condenser unit.

The results of tests that had been carried out to determine the amount of water produced from the air using the vapour compression cycle air-water harvester machine are presented in Figure 2. Data collection was carried out for each variation 3 times for a total of 9 days. Data collection was carried out for 7 hours starting from 09.00 to 16.00 local time. The data displayed on the graph is the average data from 3 repetitions in one variation. The following 4 graphs are displayed, namely the amount of water produced (m_w), in Figure 2, the total heat absorbed by the evaporator from the cooled air ($\dot{Q}_t$), in Figure 3, and the evaporator efficiency (η), in Figure 4. The maximum of the freshwater is 74 g for 7 hours. This was less than that of Mirmanto et al. [2-4]. This was due to the smaller evaporator tested.

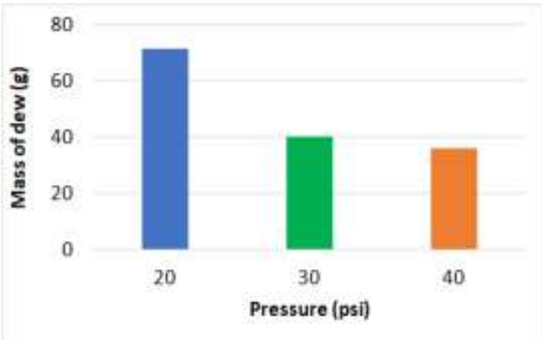

Figure 2. The average water produced from 3 variations, each of which was repeated 3 times.

The total heat absorbed by the evaporator from the cooled air of 3 variations could be found by adding up $\dot{Q}_{da}$, $\dot{Q}_v$ and $\dot{Q}_w$ where the calculated data can be seen in Figure 3.

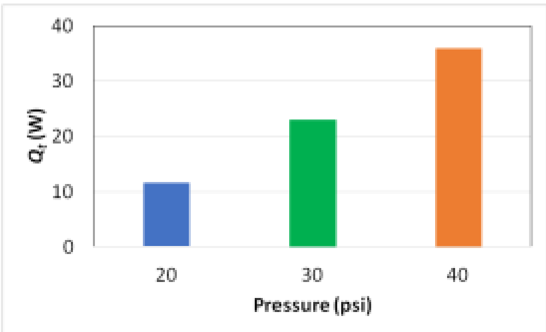

Figure 3. Total heat flow rate ($\dot{Q}_t$) of air absorbed by the condensing unit in 3 variations, each of which was repeated 3 times.

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Figure 3 above shows that the highest average total heat absorbed by the evaporator from cooled air is at 40 psi 35.84 W. This was due to the difference in the temperature of the inlet and outlet air at a pressure variation of 40 psi.

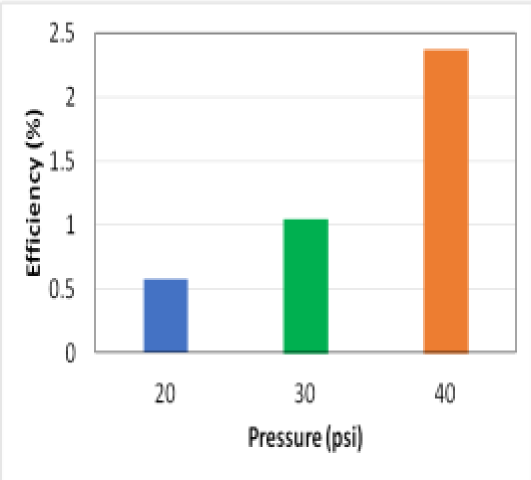

Figure 4. The average efficiency of the 3 variations, each of which was repeated 3 times.

Figure 4 indicates that the difference in efficiency is significant, meaning that the difference is large, especially at 20 psi and 40 psi. The highest efficiency occurs at 40 Psi of 2.22%. This was because of the average value of the total heat transfer rate. Meanwhile, efficiency is not based on the mass of water produced alone, but on the total heat transfer rate ($\dot{Q}_t$). Even though the mass of water produced is large, if the total $\dot{Q}_t$ is low, then the efficiency is also low, this is in accordance with the efficiency equation. This phenomenon was also found by Mirmanto [2], Dirgantara [8], Winata [9], Azari [10], and Faroni [11], Mirmanto et al. [12].

IV. CONCLUSION

Based on the results of research on the effect of the pressure of the condenser unit on the mass of water produced from the air-water harvester machine for ½ PK compressor and 134-a refrigerant, the following conclusions can be drawn.
1. The lower the pressure of the condensing unit, the more mass of water will be produced.
2. The highest water mass of 0.071 kg/7 hours was produced using a pressure variation of the 20 psi condensing unit.
3. Total heat absorbed by the condensing unit from the highest air occurs at the pressure variation of the 40 psi condenser unit, which is 35.84 W.
5. The highest efficiency of the condenser unit is at the pressure variation of the 40 Psi condenser unit, which is 2.22%.

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