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The Effect of Inlet Air Velocity with a Fan on the Outlet Side on the Mass of Water Produced

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Abstract
Water is a very important component for all living things humans, animals and plants. However, in the dry season, some parts of Indonesia experienced drought and clean water crises. Various efforts are made to meet the needs of clean water. One effort to obtain clean water is to present a device called water harvester water. This study aims to determine the performance of water harvester water machines in various variations of incoming air velocity. This research was conducted experimentally using a refrigeration machine with the R134A refrigerant as the working fluid and a 1 pk rotary compressor. The air inlet velocities examined were 3 m/s, 4 m/s, and 5 m/s. The results showed that the highest average water mass obtained was 1,437 kg for 7 hours using a variation of air velocity of 4 m/s. Meanwhile, the highest COP was 4.81, obtained at a variation of 4 m/s air velocity, and the highest total heat flow rate absorbed of 213.17 J/s occurred at the air velocity of 4 m/s. Thus, an air velocity of 4 m/s is recommended for this study.

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

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I. INTRODUCTION

Water is a very important compound for all living things be it humans, animals and plants. However, during the dry season, several areas in Indonesia, such as Gunung Kidul, East Java, NTB and NTT, experience a clean water crisis. One of the ways to overcome the problem of the clean water crisis is to make a water-harvesting machine from the air (air-water harvester). However, this machine produces very little water, so a more comprehensive study is needed.

According to Mirmanto et al. [1] there were 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 harvesting water from the air using a cooling machine as long as there is electricity at that location.

Water harvester machines using cooling machines have been widely researched, such as by Atmoko [2], Winata [3], Prasetya [4], Faroni [5] and Mirmanto et al. [1, 6-8]. However, the research that has been done has been able to produce water at a capacity of 0.6-0.7 kg for 7 hours only. Winata [3] produced 0.5043 kg of water in 7 hours, while Prasetya [4], Faroni [5], and Azari [9] were only able to produce 0.4384 kg, 0.369 kg and 0.44 kg during 7 hours. These results are lower than Winata [3]. Therefore, this water-producing machine still really needs to be researched to increase its water production.

Some of the factors that influence the amount of water mass produced are the RH of the inlet air, the inlet air temperature, the construction of the evaporator, the area of the evaporator, the diameter of the evaporator pipe and the inlet air velocity. This research will examine evaporators with a pipe diameter of 1.7 mm because Faroni [5] states that the smaller the diameter of the evaporator pipe, the more water mass it produces. Therefore this study uses the evaporator with the smallest pipe size which is arranged parallel to the diameter of the pipes 1.7 mm with the number of pipes 138 and the length of each pipe is 40 cm. This evaporator was already available in the lab, made by previous researchers. This research aims to determine the performance of a water harvester machine with a parallel evaporator at various inlet air velocities and a fan installed on the outlet side. The performance in question was the mass of dew produced, COP, and the amount of heat absorbed from the air. Meanwhile, the variation carried out in this research was the incoming air velocity, namely 3 m/s, 4 m/s, and 5 m/s which was measured at the inlet side.

II. MATERIALS AND METHOD

The method used in this research was experimental. 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. All tools and materials were prepared in advance so that there was no confusion in finding tools and materials during the research. The equipment and materials used in this study included accumulators, thermal aluminium foil, anemometers, barometers, data loggers, filters, high-pressure gauges, hygrometers, fans, compressors, condensers, low-pressure gauges, capillary pipes, potentiometers, fan power meters, power meters, compressors, stopwatches, thermocouples, digital scales, vacuum pumps, water storage containers, wooden blocks, plywood, and refrigerant R-134a.

In this research, there were two types of variables, namely: a) the dependent variable was a variable that could not be determined or regulated, and was obtained at the time of data collection and was included in the analysis of research data. The dependent variables included in this study were: Air temperature leaving the evaporator, mass of condensed water, refrigerant temperature T_1 to T_4, refrigerant pressure P_2, P_3 and P_4, and RH air exiting the evaporator, while P_1 was made the same which was around 15 psi. b) Independent variables are variables that can be regulated or determined or that can be changed according to the research objectives. The independent variables in this research were variations in air velocity entering the engine, namely (3 m/s, 4 m/s and 5 m/s).

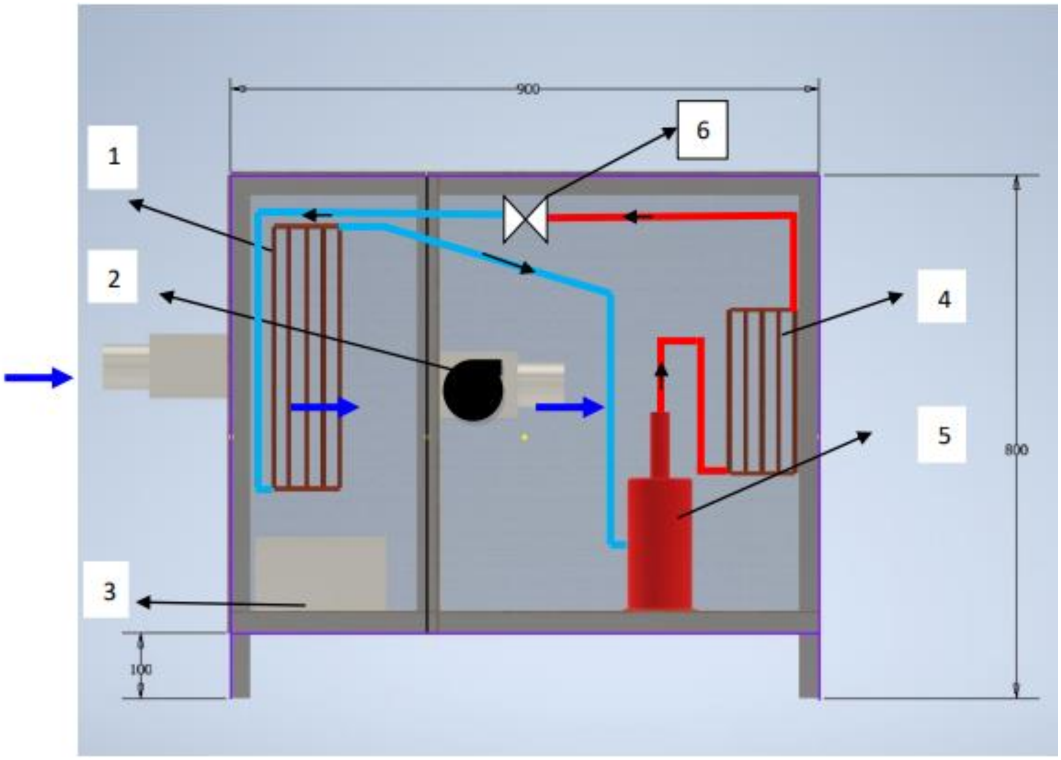

Figure 1: 2D sketch of a water harvester machine. 1. Evaporators, 2. Fan, 3. Water tank, 4. Condenser, 5. Compressor, 6. Capillary tube, unit in mm

Air flow was assisted by a fan at the end of the condensation room or the exit. After air flowed through the evaporator, the air temperatures went down and even lower than the dew point. Consequently, the water vapour in the air condensed. Temperatures were measured using K-type thermocouples connected to Applent AT4524. The refrigerant pressures were detected using pressure gauges in the psi unit. The water was measured using a digital balancer. The compressor specification was 1 pk, and RH, ambient temperature, and ambient pressure were recorded using a digital baro-hygrometer.

To analyze the experimental data, some equations are employed. COP can be predicted using equation (1), which is written as:

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

COP is the indicator of the machine performance. Q_{in} and W_{in} are the heat load (J/kg) and the compressor work (J/kg). How to obtain Q_{in} and W_{in} can be seen in Mirmanto et al. [1] and Cengel and Boles [10]. The water mass just can be obtained by weighing the water resulted in the experiment. The total heat transfer rate, $\dot{Q}_t$, can be estimated using equation (2) and expressed as:

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

$\dot{Q}_{da}$ is the heat transfer rate from the dry air to the evaporator walls (W), $\dot{Q}_v$ refers to the vapour heat transfer rate to the evaporator walls (W) and $\dot{Q}_d$ is the heat transfer rate from the dew to evaporator walls (W). How to attain $\dot{Q}_{da}, \dot{Q}_v$ and $\dot{Q}_d$ can be read in Mirmanto et al. [1].

III. RESULTS AND DISCUSSION

Following the research aims, several stages need to be analyzed both in terms of refrigerant and air side. Data collection was carried out for each air velocity variation of 3 m/s, 4 m/s, and 5 m/s. Data collection was carried out for 7 hours from 09.00 to 16.00 local time. The data displayed on the graphs are the average data from 3 repetitions. The following 3 graphs are displayed, namely the amount of water produced (m_d), the coefficient of performance (COP), and the total heat flow rate absorbed by the condensing unit from the cooled air ($\dot{Q}_t$).

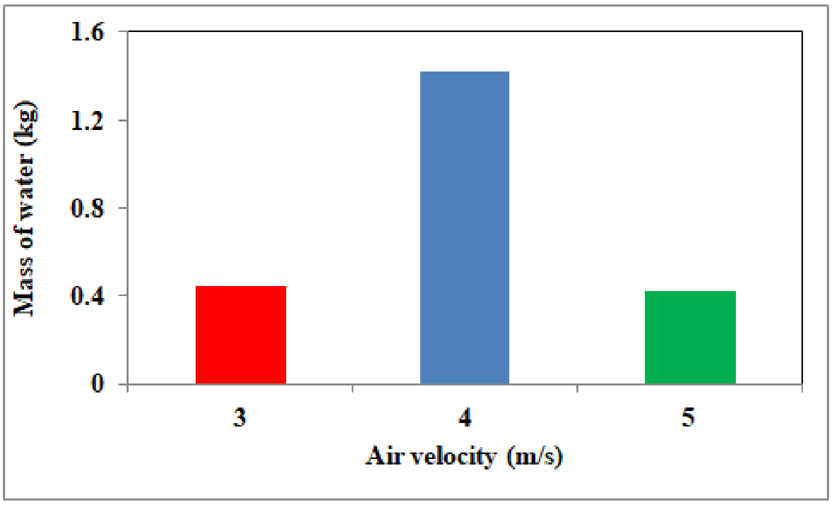

Figure 2: Water mass from 3 variations, each repeated 3 times.

The highest average water mass shown in Figure 2 was produced by variations in air velocity of 4 m/s, with an average water mass for 3 repetitions of 1,437 kg for 7 hours. Then successively continued with air velocity variations of 3 m/s with an average water mass-produced of 0.446 kg for 7 hours and air velocity variations of 5 m/s with an average water mass of 0.418 kg for 7 hours. However, the higher the velocity of air entering the condenser box can affect the mass of water condensed or produced. At a velocity of 4 m/s, the most water mass is obtained. This can happen because the velocity of the air entering the condensation box is probably the optimum velocity not too slow nor too fast, so the exhaled water vapor can condense. It is possible that at a velocity of 5 m/s the water vapor flowing through the condensing unit has not had time to condense but has to flow out because it is too fast. Therefore, the water mass at an air velocity variation of 5 m/s has a lower water mass compared to an air velocity variation of 4 m/s. Meanwhile, with an air velocity variation of 3 m/s, the air capacity entering the condensing unit box is not too much, so the water vapour content in the condensing unit box is small compared to an air velocity variation of 4 m/s.

In Figure 3, the highest COP_{actual} value is shown by an air velocity variation of 4 m/s with an average COP_{actual} value of 3.97, followed by an air velocity variation of 3 m/s with an average COP_{actual} value of 3.24. While the smallest COP_{actual} is shown by the variation in air velocity of 5 m/s with an average COP_{actual} of 2.83. From Figure 3, the value of COP_{rev} is also shown, where the highest COP_{rev} is shown at an air velocity variation of 4 m/s with an average value of 4.81, followed by an air velocity variation of 3 m/s with an average value of 4.59. While the lowest COP_{rev} is indicated by variations in air velocity of 5 m/s with an average of 4.36. COP_{actual} is the ratio of the heat load per mass of refrigerant absorbed by the refrigerant in the condensing unit to the work of the compressor per mass of refrigerant. COP_{actual} is found using the refrigerant enthalpy values h_1, h_2 and h_4. h_1 is the enthalpy at the entrance of the compressor (J/kg), h_2 is the enthalpy at the outlet of the compressor (J/kg), and h_4 is the enthalpy at the entrance of the evaporator (J/kg). h_1 through h_4 are the refrigerant enthalpies. The highest COP_{actual} is obtained from variations in air velocity of 4 m/s, this can happen because the heat absorption in the condensing unit is more optimal compared to other variations.

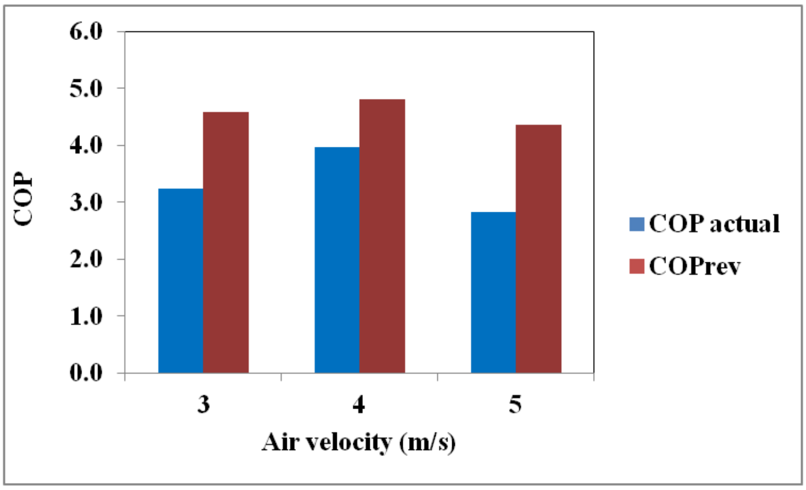

Figure 3: COPs of 3 variations, each repeated 3 times.

The total heat flow rate absorbed by the condensing unit from the air of the 3 variations can be found by adding up $\dot{Q}_{da}$, $\dot{Q}_{v}$, and $\dot{Q}_{d}$. Figure 4 shows that the highest total $\dot{Q}_{t}$ occurs at a variation of air velocity of 4 m/s with a total $\dot{Q}_{t}$ for 3 repetitions of 213.17 J/s, and respectively a total $\dot{Q}_{d}$ of air velocity of 5 m/s, and 3 m/s of, 131.75 J/s, and 91.14 J/s. The highest total heat transfer rate at the velocity of 4 m/s is due to the highest water mass.

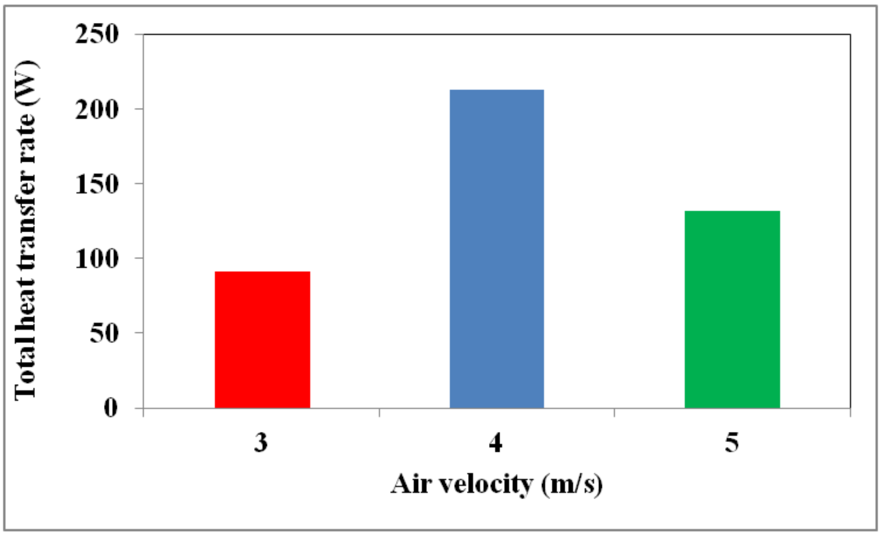

Figure 4: Total heat transfer rate of 3 variations, each repeated 3 times

IV. CONCLUSION

Based on the results of the research and analysis regarding the effect of the inlet air velocity with the fan on the outlet side on the resulting water mass as follows: 1. The results of the study showed that the highest water mass occurred at the variation of the inlet air velocity of 4 m/s with an average mass of water for 3 repetitions of the study of 1.437 kg for 7 hours. 2. The highest COP occurred at a variation in inlet air velocity of 4 m/s with an average COP over 3 repetitions of the study of 4.81. 3. The total heat flow rate absorbed by the condenser unit ($\dot{Q}_{t}$) with the highest value occurring at the inlet air velocity variation of 4 m/s with an average total air ($\dot{Q}_{t}$) value for 3 research repetitions of 213.17 J/s.

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