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Effect of the number of turns of a coil evaporator on water production

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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 is an air-water harvester.
This study was conducted to determine the effect of the number of turns of the evaporator on the water production of an air-water harvester. The number of turns of the coil evaporator used in this study was 5 turns, 10 turns and 15 turns and the machine used refrigerant R134a as the working fluid.
This research was conducted three times for each variation of the number of turns of the coil evaporator. Based on the results of this study, the recommended number of turns of the evaporator is 10 turns because it produces the highest mass of water production, which is 0.519 kg. While the number of turns 5 produces 0.267 kg of water and the number of turns 15 produces 0.466 kg of water.
Key Word*: Air-water harvester; Coil evaporator; Number of turns; Mass of water production*

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I. Introduction

Indonesia is a country that has a water area larger than the land area. With an area of 7.81 km^2 consisting of 2.01 km^2 of land, 3.25 million km^2 of ocean, and 2.55 million km^2 of the exclusive economic zone. However, despite having a large area of water, several areas in Indonesia still lack a source of clean water. Water is a basic human need that is very important in everyday life. In the fulfilment of clean water, various efforts are made to obtain it.

Sources of clean water are generally obtained from the ground through the excavation process. In certain areas, the source of clean water in the soil is reduced. People choose to use clean water sources from PDAM (Regional Drinking Water Company). One alternative is to get clean water with a machine that can produce clean water sources from the air in the surrounding environment. Basically, in the air, there is water vapour content[1,2,3,4].

The alternative used to produce water from the air uses the water cooler principle. It works on the adiabatic cooling principle. An air conditioning process was carried out by allowing direct contact between air and water vapour so that heat changes from sensible heat to latent heat[1,5,6,7].

Research on a water-catching machine from the air with a fan rotation speed of 400 rpm and 450 rpm had been provided[6]. The results showed that the variation of the fan rotation speed of 450 rpm reached the highest COP of 4.7. The ideal COP of 5.57 was reached at 450 rpm fan rotation variations. The greatest efficiency is obtained at 450 rpm fan rotation of 84.42%. The amount of water produced by the water catching machine from the air at 450 rpm fan rotation variations is 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 to the condenser per unit mass of refrigerant is 211 kJ/kg.

Research on water-catching machines from the air using components from an AC 1.5 PK engine and an additional fan used to compress the air with a power of 72.6 W had been performed[7]. The highest compressor work that can be achieved by the machine was 40 kJ/kg obtained at 0 rpm fan rotation. The released heat obtained was 214 kJ/kg and the absorbed heat obtained was 177 kJ/kg. The highest efficiency value that can be achieved by the engine was 85.63% with the amount of water produced as much as 4280 ml/h at a fan rotation variation of 250 rpm or an air velocity of 2.64 m/s.

Research by adding 2 fans to the condenser and 1 fan in front of the evaporator as an air compactor by using a fan/motor regulator (dimmer) on the air compactor fan placed in front of the evaporator consisting of fan rotations of 300 rpm and 350 rpm also was conducted[7]. The highest heat absorbed was 176 kJ/kg at 350 rpm. The highest heat rejection was 213 kJ/kg and the efficiency was 85.8%. The water production at a fan rotation speed variation of 350 rpm was 4.3 liters/h. This proved that the high rotational speed of the air compactor fan affected the amount of water produced by the machine.

Recently a researcher[8] conducted a study on the effect of the position of the evaporator on the amount of dew water produced. The differences in the position of the evaporator were vertical, 45º, and horizontal. The results showed that the highest amount of water of 0.3537 kg was produced by the evaporator in the vertical position. Meanwhile, at the 45º evaporator position, the water obtained was 0.2511 kg, and the lowest water production of 0.1212 kg was attained in the horizontal evaporator position. The highest COP of 9.9 was found for the vertical evaporator position.

Similarly, a study[2,9] had been conducted to determine the effect of the number of vertical evaporator pipes on the mass flow rate of water condensed from the air. However, the study did not investigate the cold air that came out of the engine. The machine was operated using refrigerant R134a with a compressor power of 0.5 PK. The study employed evaporator pipes of 25, 50 and 75. The results showed that the 75-pipe evaporator produced water of 0.5043 kg.

Based on the above paragraphs, the number of turns of the coil evaporator has not been examined, therefore, this study continued the research[7], however, the evaporator used was a copper coil and the variation used in this study was the number of turns on the coil evaporator, i.e. 5 turns, 10 turns, and 15 turns.

II. Material And Methods

The experimental apparatus for this study is presented in figure 1. The apparatus contains a condenser, an evaporator, a compressor, an expansion valve (capillary tube), and a condensing chamber. Dependent variables were variables that could not be adjusted, and their values were obtained at the time of data collection and included in data analysis. The variables included were the mass of condensed water, and the temperature of the air entering and leaving the condensing chamber. The independent variables were variables that could be regulated or could be changed according to the research objectives. The independent variables in the study were 5 turns, 10 turns, and 15 turns. All temperatures were measured using K-type thermocouples with an uncertainty of ± 0.5°C, while the pressures were measured using pressure gauges with a resolution of 5 psi. The mass of the drinking water was measured using a digital balancer with an uncertainty of ± 1 g.

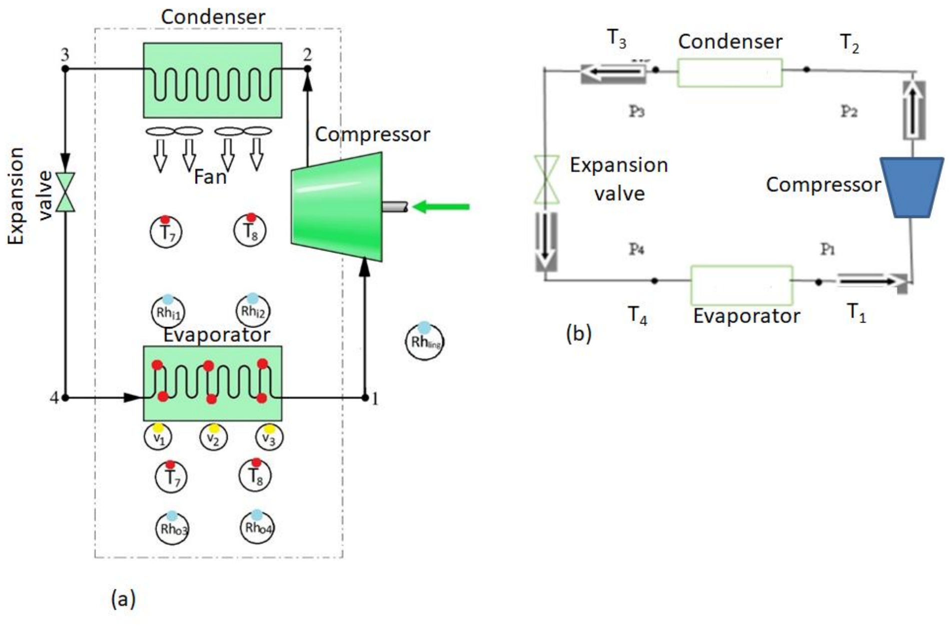

Figure 1. The experimental apparatus; (a) a schematic diagram, (b) a schematic process

In figure 1, the ambient air flows through the condenser due to fans, so the air temperature flowing toward the evaporator has a high value. On the evaporator, the air is cooled so that the air temperature decreases. Due to the low temperatures of evaporator walls, then a part of air water vapour condenses. The air velocity was measured directly using a digital anemometer series GM816.

III. Result

The test results are processed and displayed in the form of graphs to make it easier to analyze the data. The results of the tests that have been carried out to determine the amount of water production from the air using an air-water harvester are presented and discussed here. The following 4 graphs are displayed, namely, the amount of water produced ($\dot{m}_w$), the coefficient of achievement (*COP*), the total heat absorbed by the evaporator from the cooled air ($\dot{Q}_t$), and the efficiency of the evaporator (η). The water production is presented in figure 2. The effect of the number of turns on water production seems unclear. From 5 turns to 10 turns, the water production increases however from 10 turns to 15 turns, it decreases. Hence, the trends of water production concerning the number of turns deteriorate. This probably was due to the maximum heat transfer area. Increasing the number of turns increases the area of the heat transfer. The heat transfer area relates to the amount of dew, however, when the maximum area has been achieved, adding the area cannot increase the amount of water production. The comparison of the average water produced can be seen in figure 2, which shows that the variation in the number of turns of 10 produces the largest amount of water, namely 0.519 kg, while the number of turns 5 is 0.267 kg and the number of turns 15 is 0.466 kg. However, this phenomenon was also found by the researcher [10]. In [10], the effect of diameter sizes (6.35 mm, 8 mm and 10 mm) on water production was also found that at the diameter size of 8 mm, the water production was the highest.

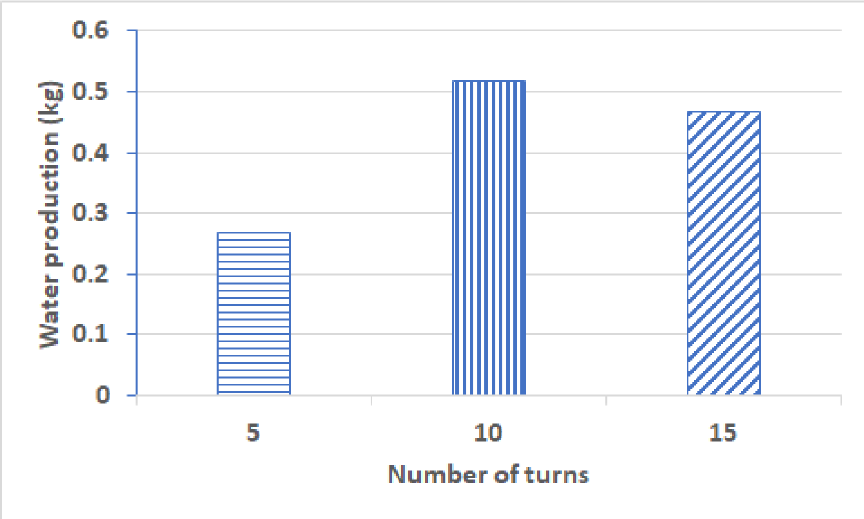

Figure 2. Water production ($\dot{m}_w$)

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The performance of the machine can be seen from a parameter called the coefficient of performance (*COP*). *COP* is defined as a comparison of the energy absorbed by the evaporator to the compressor work. The experimental *COP* is given in figure 3 for the three cases. From the *COP* parameter, the effect of the number of turns is also unclear, it decreases and then increases concerning the number of turns. This needs to be examined further comprehensively. It is opposite to the trends in water production. However, the trends are not related to the water production, because the water production is strongly dependent on the evaporator wall temperatures, while the trends of the COP mainly depend on the energy absorbed by the evaporator and the compressor work. Nevertheless, the COP relates to the evaporator pressures. Increasing evaporator pressure levelling the evaporator temperatures and vice versa. In this study, due to the uncertainty of the evaporator pressure setting, at the 10 turns, the average evaporator pressure is down to 45 psi, while at other turns, it is approximately 40 psi, hence, the compressor work becomes higher. Increasing evaporator pressure increases the compressor work. Increasing the compressor work at the same energy absorbed by the evaporator decreases the COP. From the comparison results in figure 3, it can be seen that the highest COP value occurs in the variation of the number of turns 15, which is 15.71. The average value of compressor work with the number of turns of 5, 10 and 15 is 21.05 kJ/kg, 22.76 kJ/kg and 7.71 kJ/kg respectively. Meanwhile, the calorific value absorbed by the evaporator with the turns of 5, 10, and 15 is 141.61 kJ/kg, 153.12 kJ/kg and 169.1 kJ/kg, respectively.

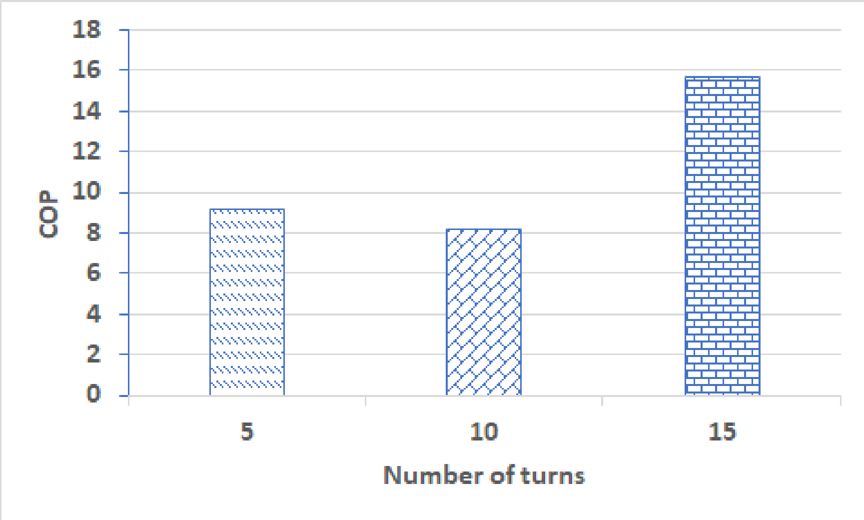

Figure 3. COP versus the number of turns

Based on figure 4, it can be concluded that the average total heat absorbed by the evaporator from the cooled air, the highest value is found in the number of turns of 10 and the lowest average total heat absorbed by the evaporator from the cooled air is in the variation of the number of turns of 5. This is due to the difference in the temperature of the inlet and outlet air and the higher mass flow rate in the variation of the number of turns of 10 compared to other variations. The average value of the heat flow rate absorbed from dry air, vapour and dew for variations in the number of turns of 10 is 401.14 J/s. Similarly to water production, the total heat transfer trend is unclear, it increases from 5 turns to 10 turns, but decreases from 10 to 15 turns. However, this is logical because at 10 turns the machine produces the highest amount of water production; it means that the evaporator absorbs much heat compared to that of other turns.

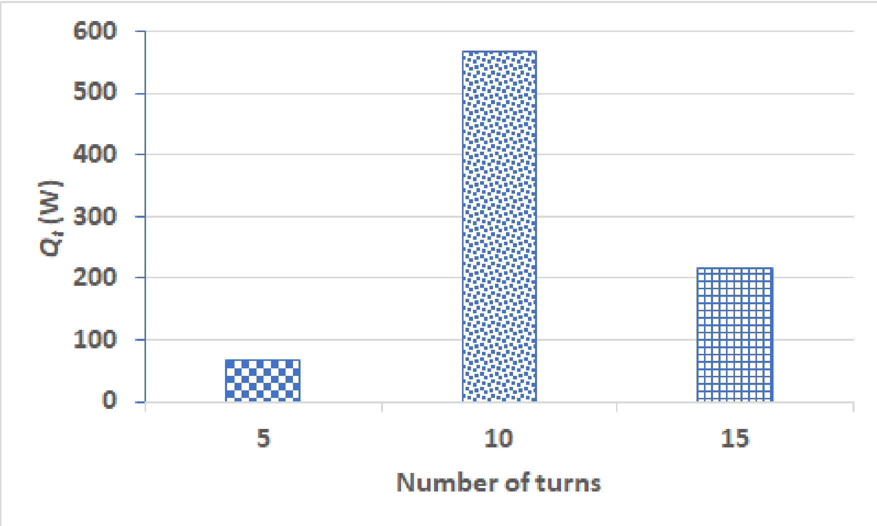

Figure 4. Total heat transfer from the air to the evaporator

Based on figure 5, the efficiency difference of 5 turns, 10 turns and 15 turns is significant. The highest efficiency value occurs in variations in the number of turns of 10, this is because the average value of the air heat rate absorbed by the evaporator is higher than the others. However, the trend is the same as water production and the total air heat rate.

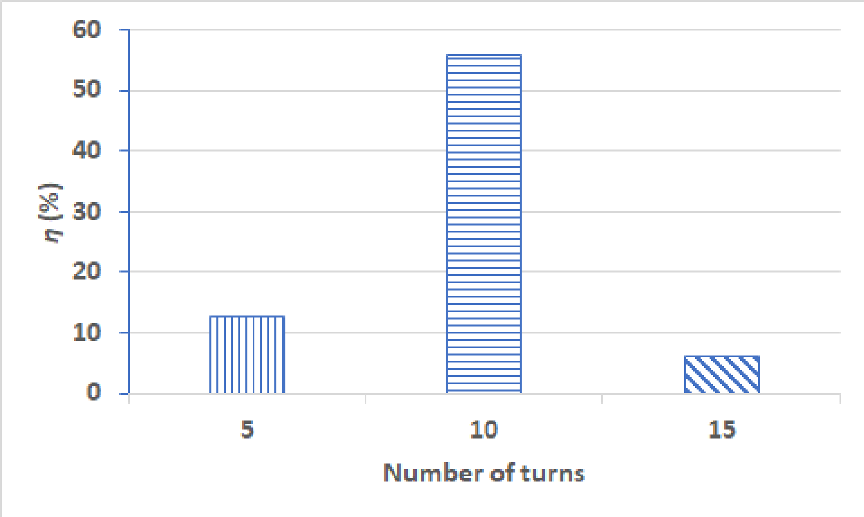

Figure 5. Total heat transfer from the air to the evaporator

IV. Conclusion

The study of the effect of the number of turns of the coil evaporator on water production was conducted under normal ambient conditions. Based on the results of research and discussion, some conclusions can be drawn as follows: the effect of the number of turns is not clear, however, the best performance is the machine with 10 turns. The highest water production achieved using the 10 turns is 0.519 kg, while the lowest water production is 0.267 kg obtained by the 5 turns. The results indicate that this study needs more comprehensively.

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