SINTEK JURNAL: Jurnal Ilmiah Teknik Mesin
ISSN: 2088-9038, e-ISSN: 2549-9645
Homepage: http://jurnal.umj.ac.id/index.php/sintek

# OPTIMISATION OF AIR-WATER HARVESTER MACHINE PERFORMANCE WITH VARIATIONS OF INLET AIR FLOW VELOCITIES

**Mirmanto[1,*], Made Wirawan[1], Ahmad Tarmizi[1]**
[1]Department of Mechanical Engineering, Faculty of Engineering, Universitas Mataram,
Jl. Majapahit No. 62, Mataram, Nusa Tenggara Barat, 83125, Indonesia
[*]E-mail: mmirmanto@gmail.com

Accepted: 22-09-2024 Revised: 20-11-2024 Approved: 01-12-2024

**ABSTRACT**

In the dry season, some parts of Indonesia experience drought and clean water crisis which results in scarcity and difficulty in drinking water. One way to overcome this problem is to present a water-producing device from air called a water harvester machine. The purpose of this study was to examine the effect of the inlet air velocity of 4 m/s, 5 m/s, and 6 m/s on the mass of water produced and the rate of heat transfer. This study was conducted experimentally with R134a refrigerant working fluid, and a 1 PK rotary compressor and centrifugal fan. The results showed that the highest water mass, which was 5.99 kg, was obtained at an air velocity of 6 m/s. The highest heat transfer rate, which was 2080.2 W, was also obtained at a speed of 6 m/s. This can be caused by the high inlet air velocity, the inlet air mass flow rate is also high so that the water vapor content that enters is greater. As a result, the mass of water produced is greater and the rate of heat transfer that occurs is also greater.

**Keywords**: air-water harvester; air velocity; water mass; heat transfer

***ABSTRAK***

*Pada musim kemarau sebagian wilayah Indonesia mengalami kekeringan dan krisis air bersih yang mengakibatkan kelangkaan dan kesulitan air minum. Salah satu cara untuk mengatasi masalah tersebut adalah dengan menghadirkan alat penghasil air dari udara yang disebut mesin air water harvester. Tujuan dari penelitian ini adalah mengkaji pengaruh kecepatan udara masuk yaitu 4 m/s, 5 m/s, dan 6 m/s terhadap massa air yang dihasilkan dan laju perpindahan panas. Penelitian ini dilakukan secara eksperimen dengan fluida kerja refrigran R134a, dan kompresor 1 PK jenis rotary dan kipas sentrifugal. Hasil penelitian menunjukkan bahwa massa air tertinggi, yaitu 5,99 kg, didapatkan pada kecepatan udara 6 m/s. Laju perpindahan panas tertinggi yaitu 2080,2 W juga diperoleh pada kecepatab 6 m/s. Hal demikain dapat disebabkan karena kecepatan udara masuk yang tinggi, laju aliran massa udara masuk juga tinggi sehingga kandungan uap air yang masuk lebih banyak. Akibatnya, massa air yang dihasilkan lebih besar dan laju perpindahan panas yang terjadi juga lebih besar.*

***Kata Kunci**: air-water harvester; kecepatan udara masuk; massa air; perpindahan panas*

## 1. Introduction

During the dry season, many regions in Indonesia face drought and a crisis in clean water availability, leading to significant challenges in accessing potable water. To address this issue, various methods have been explored to meet the growing demand for clean water. One promising approach is the development of devices capable of harvesting water directly from the atmosphere. According to Damanik [1], several methods are available for capturing water from the air, such as windmill-based systems, fog nets, and machines employing vapor compression systems. Among these, the air-water harvester using a vapor compression cooling system is the simplest and most practical option for operation in diverse conditions.

Research on air-water harvesting using cooling systems has been conducted extensively, as documented by Fauzan [2], Firdaus [3], Ramadan [4], Suriatman [5], Handaru [6], and others. However, a common limitation of these systems is their low water mass production, necessitating further improvements to enhance their efficiency.

**Previous Studies on Air-Water Harvesting**

Several studies have investigated the performance of air-water harvesting machines to optimize their water mass output. Fauzan [2] explored the effect of varying inlet air velocities (0 m/s, 1.5 m/s, 3 m/s, and 4.5 m/s) using a parallel evaporator. The maximum water mass obtained was 0.869 kg over 7 hours at an air velocity of 3 m/s, indicating limited performance. Firdaus [3] experimented with a shell-spiral evaporator at air velocities of 3 m/s, 4 m/s, and 5 m/s, achieving a maximum water mass of 0.622 kg over 7 hours at 5 m/s, which was even lower than Fauzan's results.

Ramadan [4] investigated the influence of fan position using the same evaporator as Fauzan [2] and reported improved performance, with a maximum water mass of 0.977 kg over 7 hours. In contrast, Suriatman [5], who employed an evaporator constructed from small pipes, reported a lower water mass production of 0.728 kg over 7 hours at an air velocity of 4.5 m/s. Handaru [6] attempted to enhance performance using a coil evaporator, but the water mass produced remained low at 0.653 kg over 7 hours.

**Air-Water Harvesting in Broader Contexts**

Beyond these studies, other researchers, such as Dalai et al. [7], Ahmad et al. [8], and Tu and Hwang [9], have highlighted the potential of air-water generators in diverse environmental conditions, including arid regions. Dalai et al. [7] demonstrated that modifying a window air conditioner and increasing the airflow volume could enhance freshwater production. Ahmad et al. [8] found that air temperature and relative humidity significantly influenced freshwater yield. Tu and Hwang [9] emphasized that refrigeration-based systems were among the most effective technologies for harvesting water from atmospheric air.

**Research Objective**

Based on the reviewed literature, the primary limitation of existing systems is their low freshwater production, often attributed to the custom evaporators used. To address this issue, this study aims to investigate the performance of an air-water harvester machine utilizing a commercially available air conditioner with a power of 1 PK. The study focuses on varying inlet air velocities (4 m/s, 5 m/s, and 6 m/s) to determine their impact on water mass production. This approach is expected to provide significant improvements in freshwater yield, contributing to the development of more efficient atmospheric water harvesting technologies.

## 2. Methods

This study employed an experimental method, which is suitable for testing new treatments or designs by comparing results from treated and untreated groups. The air-water harvester machine used in this study included components similar to those in a standard air conditioning (AC) system. Key components such as the compressor, condenser, fan, and capillary tube were part of the outdoor unit but are not shown in the schematic diagram (Figure 1). The machine comprised an evaporator, inlet fans, and a water collection bucket, with the evaporator and outdoor unit each having a capacity of 1 PK.

**Measurement Instruments and Parameters**

- Temperature: Measured using K-type thermocouples calibrated with an uncertainty of ±0.5°C.
- Air Velocity: Measured using a digital anemometer.
- Water Mass: Measured with a digital scale with a resolution of 1 g.
- Relative Humidity (RH): Monitored using digital hygrometers with a measurement range of 30–100%.
- The inlet air temperature ranged from 27°C to 30.8°C, and the RH ranged from 71% to 80%.

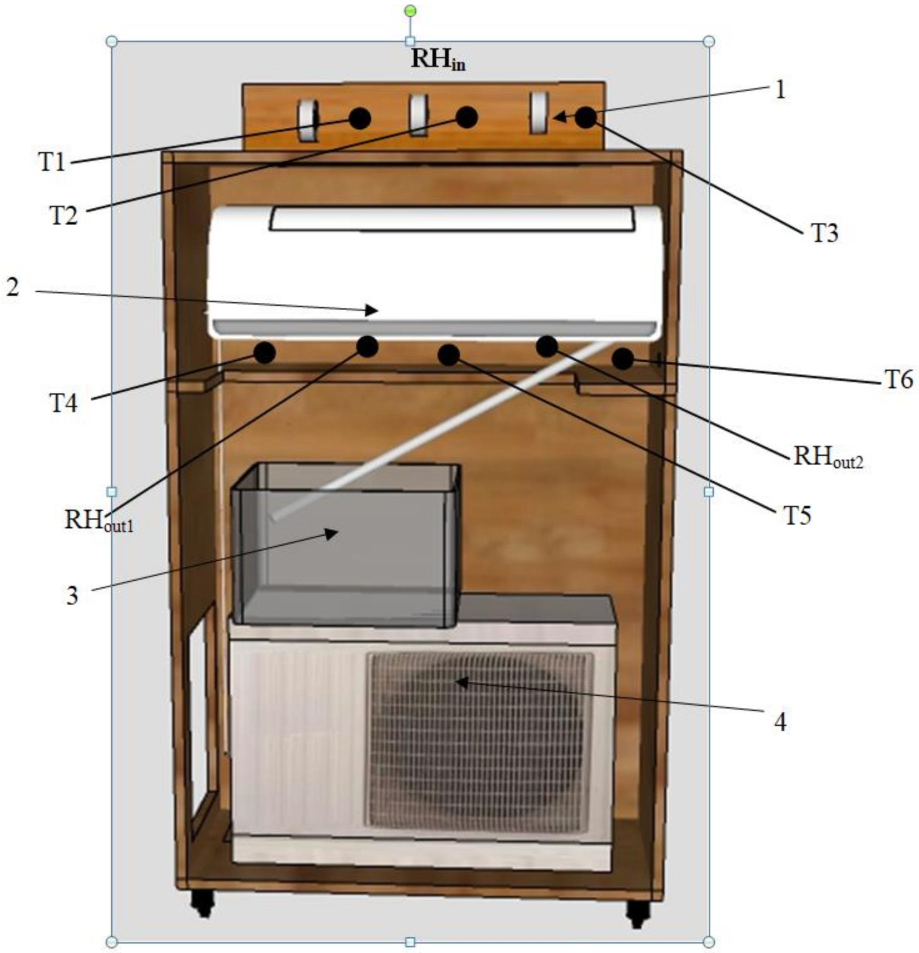
**Machine Operating Principles**

The machine's air velocity was controlled using potentiometers or dimmer switches, enabling precise adjustment of fan rotation speed to achieve desired inlet air velocities (4 m/s, 5 m/s, and 6 m/s). Three fans were installed at the evaporator inlet, each controlled by a digital power meter and potentiometer. The air entering the evaporator was cooled by its low-temperature walls, causing water vapor in the air to condense.

**Experimental Procedure**

To collect data, the following steps were performed:

- Turn on the data logger (Applent AT45-24) to record temperatures and relative humidity.
- Start the inlet fans and adjust air velocity to the desired value.
- Turn on the air-water harvester machine and record data (temperatures, RH, and water mass) hourly.
- Stop the experiment after 7 hours.
- Repeat the above steps for each air velocity setting.




1. Inlet fans.
2. Evaporator.
3. Bucket.
4. Outdoor.

T1 to T3 are thermocouples to measure the inlet temperatures.
T4 to T6 are thermocouples to measure the air outlet temperatures.
$RH_{in}$ is the hygrometer to record the inlet air relative humidity.
$RH_{out1}$ and $RH_{out2}$ are hygrometers for measuring the outlet air relative humidity.

**Figure 1.** Schematic Diagram of the Research

**Data Analysis**

To analyze the data some equations below are used and the result comparators are executed graphically. The equations used for analyzing the data are: (1) mass flow rate formulations, (2) heat transfer equations. The total mass flow rate of the air entering the evaporator can be estimated using equation (1). The electrical power for machine and for fans were measured directly in Watt using digital power meters.

$$\dot{m}_t = \rho_{in} A_{in} V_{in} \tag{1}$$

$\dot{m}_t$ is the total mass flow rate coming into the machine (kg/s), $\rho_{in}$ is the density of the air (kg/m³), $A_{in}$ is the inlet cross sectional area (m²), and $V_{in}$ is the velocity of air at the inlet (m/s). The mass flow rate of dry air can be obtained when the part of the air vapour ($w_1$) in the air is known. $w_1$ can be found using a psychrometric chart or online psychrometric chart [10] with input parameters of dry temperature and relative humidity. Hence, the dry air mass flow rate can be calculated as:

$$\dot{m}_{da} = \frac{\dot{m}_t}{w_1 + 1} \tag{2}$$

$\dot{m}_{da}$ is the dry air mass flow rate (kg/s), $w_1$ is part of water vapour in the air ($kg_v/kg_{da}$). The mass flow rate of the vapour is:

$$\dot{m}_v = w_1 \dot{m}_{da} \tag{3}$$

$\dot{m}_v$ is the mass flow rate of the vapour entering the machine (kg/s). The dew mass flow rate can be formulated as:

$$\dot{m}_d = \frac{m_d}{t} \tag{4}$$

$\dot{m}_d$ is the dew mass flow rate (kg/s) and $m_d$ is the dew or freshwater mass (kg) which is measured directly in the experiments using digital scale, $t$ is the time for running the machine (s). The heat transfer rate from the air to the walls of evaporator can be estimated as:

$$\dot{Q}_{da} = \dot{m}_{da}(h_i - h_o) \tag{5}$$

$\dot{Q}_{da}$ is the heat transfer rate of dry air (W), $h_i$ and $h_o$ are the enthalpies (J/kgK) at the inlet and outlet. The heat transfer rate from the vapour to the evaporator can be distinguished becoming two. Firstly, the sensible heat transfer rate, which is formulated as:

$$\dot{Q}_v = \dot{m}_v c_{pv}(T_i - T_o) \quad (6)$$

$\dot{Q}_v$ is the heat transfer rate from the air vapour (W), $c_{pv}$ is the heat capacity of the vapour (J/kg°C). $T_i$ and $T_o$ are the inlet and outlet temperatures (°C) of the air. Secondly, the heat transfer rate of vapour that condenses, It is called latent heat transfer rate that can be calculated as:

$$\dot{Q}_d = \dot{m}_d h_{fg} \quad (7)$$

$\dot{Q}_d$ is latent heat transfer rate (W), $h_{fg}$ is the enthalpy of evaporation (J/kg). Then the total heat transfer rate from the air to the evaporator walls is written as:

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

$\dot{Q}_t$ is the total heat transfer rate (W). All equations above can be found in Mirmanto et al. [11-13], Sunaryo [14], Irhami [15].

## 3. Results and Discussion

### Freshwater Mass Production

The results are presented in the form of graphs so that comparations can be made easily. The results of the tests that have been carried out using the air-water harvester machine with free parameters of air velocities of 4 m/s, 5 m/s and 6 m/s. The aim of this experiment was to determine the amount of freshwater mass production ($m_d$), and the heat transfer rate from the air to the evaporator ($\dot{Q}_t$). Data collection was carried out 3 times for each variation. Data collection was carried out for 7 hours/day starting at 09.00 to 16.00 local time. The data displayed in Figure 2 are the freshwater obtained in the experiments. Increasing the air velocity increases the freshwater mass production. However, the difference of freshwater mass for all air velocities is not significant. It is indictaed by all error bar legs touching the horizontal red line. This is shown that from air velocity of 4 m/s to 6 m/s the freshwater mass resulted increases but still in the range of errors. However, this can be tested again at the higher air velocity difference, so the freshwater mass resulted becomes significant. The different freshwater mass at several air velocities are not significant due to the low range of air velocities. Unfortunately, the fan speeds were already at the maximum values. Hence, this study still can be extended by improving the fan to have higher air velocities. However, Damanik [1], Firdaus [3] and Ramadhan [4] found the relationship between the air velocity and the freshwater results. Damanik [1], Firdaus [3] and Ramadhan [4] found that increasing the air velocity elevated the freshwater production. Figure 2 also indicates that the freshwater mass resulted at the air velocity of 4 m/s is 5.76 kg, while at the air velocity of 5 m/s the freshwater obtained is 5.92 kg, and at the air velocity of 6 m/s, the freshwater mass attained is 6 kg. Using error bars of 5%, the results at the three air velocities are not significant.

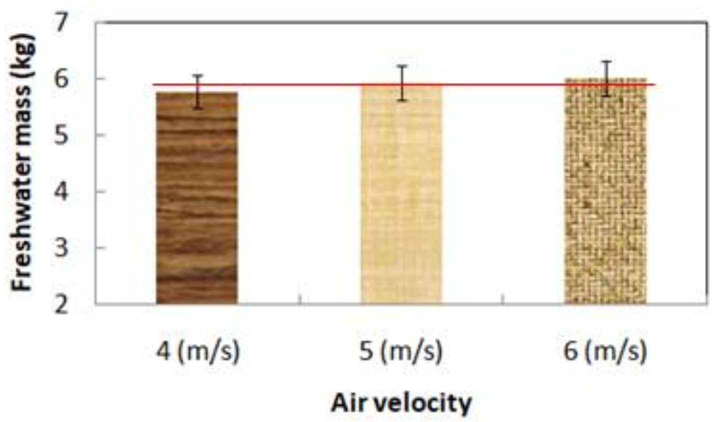



**Figure 2.** Freshwater Obtained at Several Air Velocities

The freshwater mass of this study is much higher than the previous studies. Firdaus [3] found the freshwater mass of 0.622 kg, while Ramadhan [4] obtained freshwater mass of 0.977 kg. The possible reason for this big difference was due to the different evaporator type. Firdaus [3] and Ramadhan [4] used custom evaporators while in this study, the fabricated evaporator was utilized.

### Total Air Mass Flow Rate

Figure 3 shows the total air mass flow rate coming into the machine. Here, it is clear that increasing the air velocity raises the total mass flow rate of the air. This can be seen also from equation (1) that can be obtained in Mirmanto et al. [11-13]. The phenomenon was also found by Firdaus [3], Ramadhan [4] and Mirmanto et al.

[11-13]. They all explained that increasing the air velocity raised the mass flow rate of the air. Figure 3 shows the value of dry air at an air speed variation of 4 m/s of 39.25 g/s, the value of dry air at an air speed variation of 5 m/s of 48.71 g/s, and at an air speed variation of 6 m/s it produces a dry air value of 59.35 g/s. The difference of air mass flow rate at the different three air velocities is also significant. As shown in Figure 3, the error bars at the air velocities of 4 m/s and 6 m/s do not touch the horizontal line.

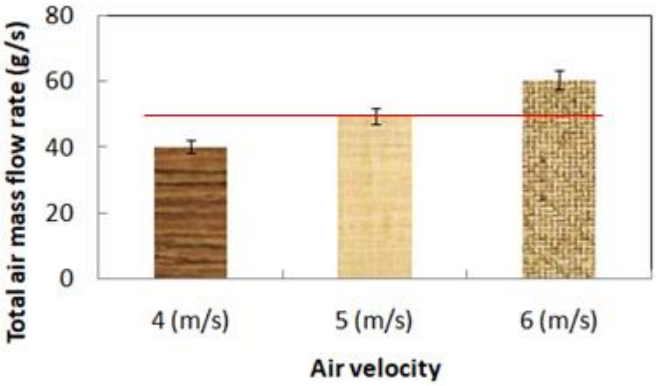



**Figure 3.** Total Air Mass Flow Rate at Various Air Velocities

### Heat Transfer Rate

Figure 4 shows the total heat transfer rate $\dot{Q}_t$ at all air velocity variations. At an air velocity of 4 m/s produced total heat transfer rate of 1561.4 W, at an air velocity of 5 m/s the total heat transfer rated obtained was 1857.2 W, and at a an air velocity of 6 m/s, the total heat transfer rate gained was 2076.6 W. Hence, increasing the air velocity levels the total heat transfer rate from the air to the evaporator walls. This was due to the increase in the dry air mass flow rate with the air velocity. In Figure 4, it can be seen that the air velocity of 6 m/s has the highest total heat transfer rate.

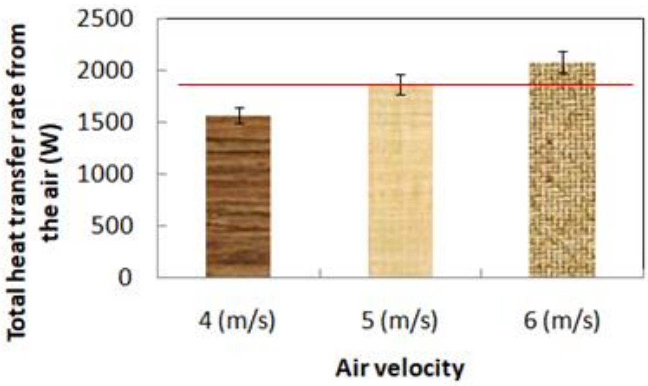



**Figure 4.** Total Heat Transfer Rate at Various Air Velocities

However, Figure 4 indicates an agreement with results obtained in [3-4], and [16-20]. Using freshwater results to take a temporary conclusion, the air velocity of 5 m/s is enough for this study, while based on the results of total heat transfer rate, air velocity 6 m/s is recommended for the machine used in this study.

### Recommendations for Future Research

Although the current study demonstrates a clear relationship between air velocity, freshwater production, and heat transfer, the results are constrained by the limited range of air velocities tested. Future research should investigate broader velocity ranges and consider optimizing fan performance to achieve higher velocities. Additionally, exploring alternative evaporator designs may further improve efficiency and enhance freshwater production.

## 4. Conclusion

This experimental study investigated the effect of air velocity variations on freshwater production and total heat transfer rate in an air-water harvester machine. The findings revealed that while freshwater production increased with higher air velocities, the differences among the tested velocities (4 m/s, 5 m/s, and 6 m/s) were not statistically significant due to the narrow range of air velocity variations. The highest freshwater mass obtained was 6.00 kg at 6 m/s, while the lowest was

5.76 kg at 4 m/s. This suggests that the range of velocities tested may not sufficiently highlight the impact of air velocity on freshwater production.

In terms of thermal performance, the total heat transfer rate increased consistently with air velocity. The maximum heat transfer rate of 2080.2 W was achieved at 6 m/s, indicating improved heat exchange efficiency at higher air velocities. Based on the findings, an air velocity of 5 m/s is sufficient for freshwater production, while 6 m/s is recommended for optimizing heat transfer performance. These results demonstrate the potential of air velocity optimization in improving the efficiency of air-water harvesting systems.

Future research should focus on testing a wider range of air velocities, such as 4 m/s, 10 m/s, and 16 m/s, to better understand the relationship between air velocity and freshwater production. Additionally, improvements in fan performance and evaporator design could further enhance system efficiency and provide more significant insights into the interaction between air dynamics and thermal transfer. These advancements will help optimize air-water harvesting technology for practical applications.

## Acknowledgements

The authors express their gratitude to the Department of Mechanical Engineering, Faculty of Engineering, University of Mataram, for providing the necessary facilities. Special thanks are extended to the SINTEK JURNAL editorial team, research collaborators, and supporters for their invaluable contributions, which have significantly enhanced the quality of this work.

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