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Original Article

IoT Enabled Double Chamber Air Water Harvester

Muhammad Omar[1], Ahmed Arif[1], Farhan Shams[1], Muhammad Usman[1], Husnain Siddique[1], Stephen Larkin[2]

[1]*Technosense 21, Islamabad, Pakistan.*
[2] *Africa New Energies Limited, London, United Kingdom.*

[2]*Corresponding Author : ahmed@ts21.tech*

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Abstract *- The world is facing a serious crisis in fresh water. Especially remote areas are greatly affected by this problem. Special measures are required to fulfil the drinking water demand in this critical situation. Keeping in view the gravity of the problem, a novel geometry of air-water harvester is proposed that is capable of producing more than 2 liters of water a day. The air-water harvester operates between 50W to 150 W. The system operates on the principle of thermoelectric cooling and contains a combination of Peltier devices and PWM fans. The effect of different factors like humidity, heat sink geometry, and current on water production is also determined, and the results are documented in the paper.*

Keywords *- Air-water harvester, Condensation, Peltier cooler, Peltier effect, Thermoelectric cooling.*

1. Introduction

According to experts, water is the next gold. Like fuel and other natural resources, water is also limited and a potential reason for future wars [1]. Water is essential for survival and plays a vital role in the agricultural sector as well [2]. Unfortunately, the water reservoirs are gradually decreasing due to the increase in population, global warming, wrong policies in the agricultural sector, and industrial pollution [3]. It was found that about two-thirds of the world's population faces water shortage at least a month a year. While half a billion face water shortages throughout the year [4]. Water scarcity is not restricted only to remote areas; the water-rich areas are also affected badly due to pollution and climate change. It is challenging for scientists and researchers to find methods to harvest drinking water [5]. The power required for the water harvesters multifold the problem's complexity.

Glaciers and ice contribute largely to the earth's water. The agriculture sector uses 70% of the water, while the humans and the industrial sector use only 10% [6]. Water covers over 70% of the earth's surface, of which only 3% is used as freshwater [7]. In developing countries, the crisis is more severe as people cannot afford expensive water for basic needs [8]. One of the examples is the current water stress situation in South Africa. Cape Town, the city of South Africa, faced a severe water crisis in 2017-18 due to drought, supply management problems, and poor governmental policies. It is predicted that Cape Town may face another water crisis if special measures are not taken in time [9]. Therefore, a suitable solution is required to fight against the water problem.

Different air-water harvesting methods are available but have limitations [10]. The mechanical parts in compression-based systems cause damage to the system [11]. Therefore, periodic maintenance is needed, which makes the design very expensive [12]. Besides this, the vapour compression cycle uses a refrigerant that is not favourable to the environment [13]. Also, these methods require an external power source for the operation, making them unsuitable for remote areas [14].

In recent years, much research has been conducted related to water harvesting using Peltier coolers and heat sinks [15]. The advantage of Peltier devices over conventional devices is that they consume less power for operation [16]. The major limitation of these designs is that they operate only in specific weather conditions [17], and power is not efficiently managed.

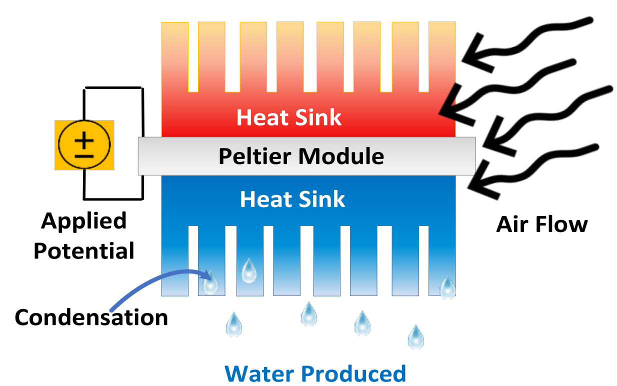

Fig. 1 The block diagram of the Proposed System

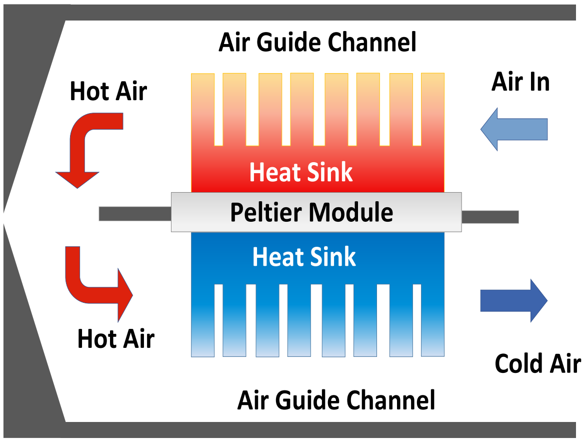

Fig. 2 Air-guided Structures

Some systems can produce more than 10 litres of water daily but draw huge power [18]. All these types of designs work on the principle of the vapour compression cycle. The major problem with this mechanism is that it is unsafe for the environment and is very expensive [19].

Before introducing the design and working of the proposed novel air-water harvester, it is necessary to understand the working of Peltier devices. The block diagram of the Peltier module-based condenser is shown in Figure 1. A pair of heatsinks help to maintain the temperature difference produced due to the applied potential. When current flows through the Peltier module, heat is released from one side and absorbed by the other side [21]. As a result, one side of the Peltier device becomes hot, and the other becomes cold [22]. When air passes through the cold side heatsink, the water drops accumulate on the cold side of the heatsink and fall under the effect of gravity. The advantage of using the Peltier effect for water production is that this method is economical and consumes very less power [23]. The Peltier cooler consumes only 50 to 70 watts of power for its operation.

The Peltier module-based condensation is a very slow process [24]. The efficiency can be increased through guided structures. The primary focus of the air-guided structures is to pass air in such a way that hot air from the hot side passes to the cold side, as shown in Figure 2. When hot air sticks with a cold surface, the water drops in the air, gets heavier and accumulates at the cold surface. This type of condensation can be noticed in the winter on the glass windows [25]. The same process can potentially be exploited to produce fresh water from the air.

The paper is structured as follows. Section 2 describes the design and working of the double chamber air-water harvester. Section 3 explains the measurements and experiments. Section 4 demonstrates the IoT-based system. Section 5 discusses the results and Section 6 concludes the paper.

2. Double Chamber Air Water Harvester

In this work, a novel Double Chamber Air Water Harvester (DCAWH) is proposed, shown in Figure 3. The DCAWH solves the problems of previous designs and can produce enough water depending upon the requirement. The three modes of operation are shown in Figure 4. Unlike the previous designs, the proposed system provides an air-guided geometry and efficient power management. The blower is used to dissipate heat generated by the hot side heat sink, and the pulse width modulation (PWM) fan is used to speed up the condensation process on the cold side heat sink.

The harvester consists of two chambers. Each chamber contains one PWM fan, one blower, and two heat sinks. The blower fan dissipates the heat dissipated by the hot side heat sink. The PWM fan takes the heated air of the hot side heat sink and throws it on the cold side heat sink. As a result, the process of condensation boosts up, and more water droplets can be produced. The double chamber air-water harvester solves the problems of previous designs and provides a sufficient amount of water for drinking purposes. Unlike previous air-water harvester systems [26], the proposed design can work in all weather conditions and provides effective power management. The air-water harvester is designed so that it can operate in three different modes depending upon the water requirement in the specific area. The three modes of the harvester are described below:

2.1. Economy Mode

In the economy mode of operation, only one blower and one PWM fan will be operational. The harvester is operated in this mode when the water demand is less. Thus, power generated by renewable sources can be saved and used as a backup in case of a problem in the system.

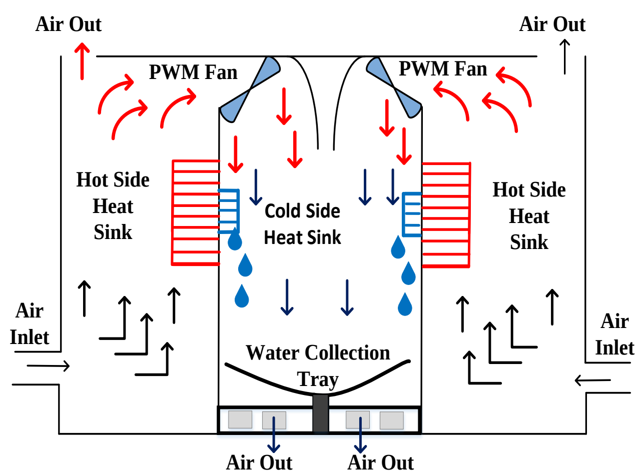

Fig. 3 Conceptual Diagram of Proposed Double Chamber Air Water Harvester (DCAWH). The harvester contains two Peltier modules, two pairs of heatsinks, two fans and two blowers.

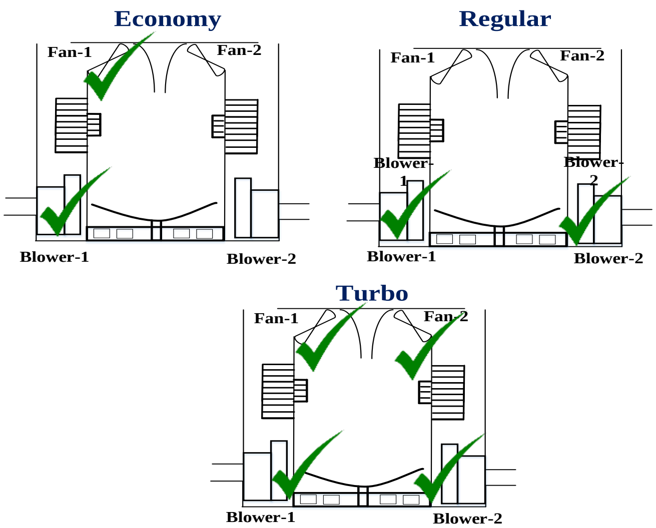

Fig. 4 Three modes of operation.

2.2. Regular Mode

The air-water harvester operates in regular mode when the water requirement is moderate in the region. In this mode, only two blowers from both geometry sections are operational and provide better heat dissipation to the hot side of the device.

2.3. Turbo Mode

The need for turbo mode arises in areas with extreme water shortages. In this mode, all fans are operational, and the system runs at full efficiency. The obtained water can be used for drinking or cleaning purposes.

The 3D design of the double chamber air-water harvester is designed in Solidworks, as shown in Figure 5. The water collector chamber is made at the bottom. The water produced falls down and gets collected in the water collection area under the effect of gravity.

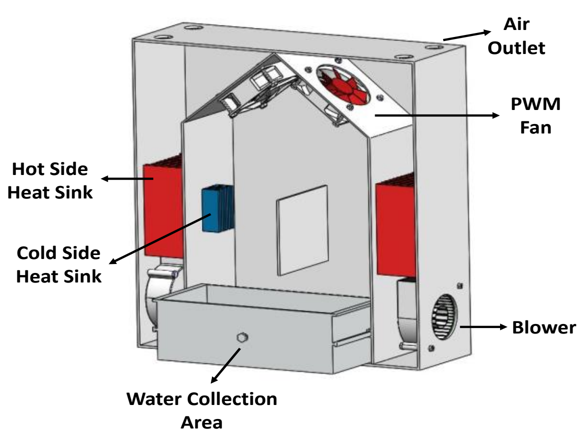

Fig. 5 3D CAD model of DCAWH

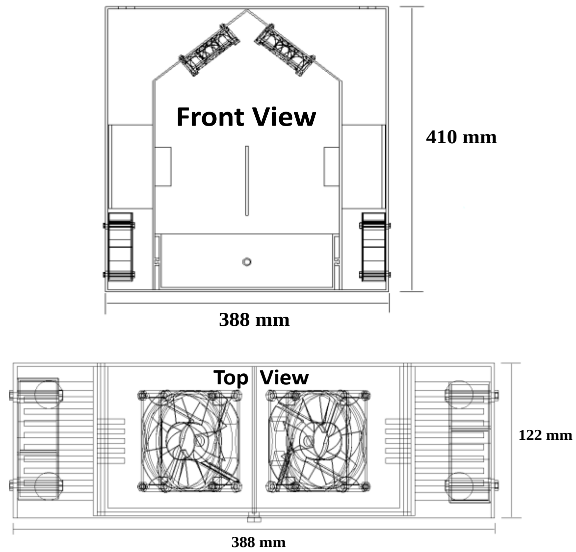

Fig. 6 2D views of proposed Air Water Harvester

The front, and top view of the DCAWH, along with the dimensions, are shown in Figure 6. The final design of the DCAWH manufactured with the acrylic sheet is shown in Figure 7. The two blowers were placed at the extreme bottom ends, and the PWM fans were fixed on the top ends above the heat sinks. The peltier device was placed in the space by cutting the acrylic sheet, and the heat sinks were placed on both sides of the peltier.

3. Measurements and Experimentations

Some parametric experiments were carried out to analyse the working of the DCAWH. In addition, water production's dependence on the heat sink's geometry was also studied. Pin fin heat sinks performed better than plate-fin heat sinks in terms of heat dissipation. The effect of different factors like current, humidity, and heat sinks on water production was determined by experimentation and is discussed below.

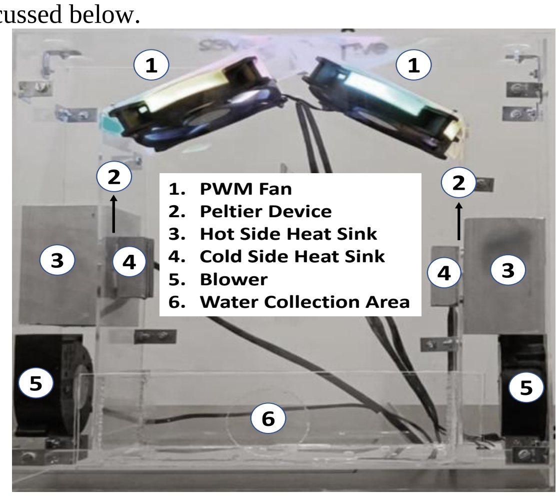

Fig. 7 Manufactured DCAWH

3.1. Effect of Current on Water Production

The current flowing through the Peltier device also determines the amount of water production. It can be seen in Figure 8 that initially, no water is produced with the increase in current. After some time, water production increases exponentially with the current increase.

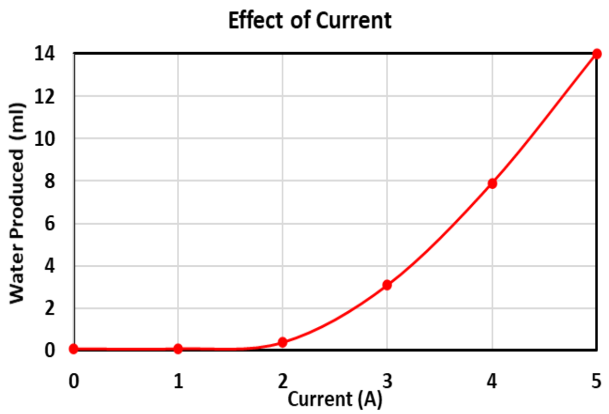

Fig. 8. Effect of current on water production

3.2. Effect of Humidity on Water Production

Humidity also plays a vital role in water production. Greater is the humidity; more will be the water generation. The effect of humidity on water production is shown in Figure 9.

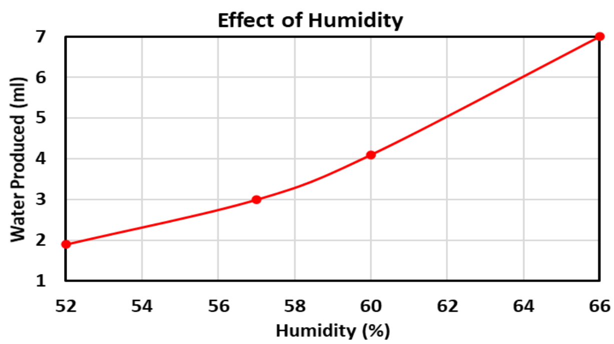

Fig. 9 Effect of humidity on water production

3.3. Effect of Heat Sink Geometry on Heat Dissipation

The heat sinks with and without hollow pin fins were compared regarding heat dissipation ability. It was found that the hollow pin fin heat sink provides better heat dissipation than the heat sinks without hollow fins. The temperature contour of the heat sinks is shown in Fig. 10.

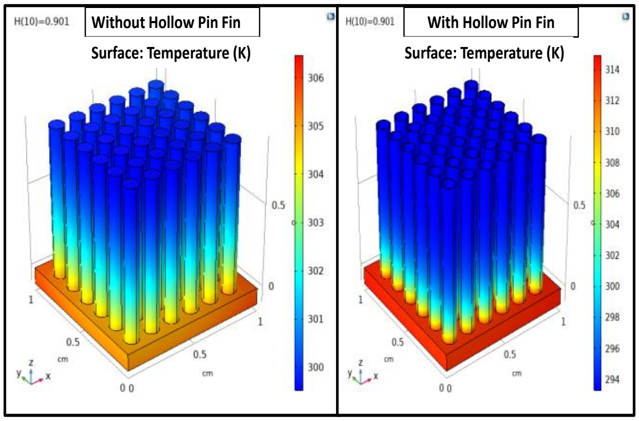

Fig. 10 Comparison of heat sinks in terms of heat dissipation

Table 1. Parameters used for the proposed design

Parameter	Magnitude
Temperature	22.7 ºC – 24.2 ºC
Relative Humidity	51% – 54%
Peltier Devices (x2)	TEC1 - 12706
Airflow at Hot Side	45 CFM
Airflow at Cold Side	35 CFM
Peltier Coolers Input Power	3.17 A x 14 V = 44.38 W (x2)
Blowers Input Power	0.24 A x 12 V = 2.88 W (x2)
PWM DC Fans Input Power	0.12 A x 12 V = 1.44 W (x2)
Total Input Power	97.4W

4. IoT-based Monitoring of the Parameters

A mobile application was developed to monitor temperature, humidity, and current parameters remotely. The sensors take real-time values of different parameters and send them back to the mobile application with the Internet of Things (IoT). After the final fabrication of the system, the air-water harvester was operated in three modes, and the water production in each mode was measured. The parameters considered during the testing of the air-water harvester are given in Table 1.

The integration of IoT in the system provides efficient controlling and monitoring of the air-water harvester. The user interface of the mobile application is shown in Fig. 11.

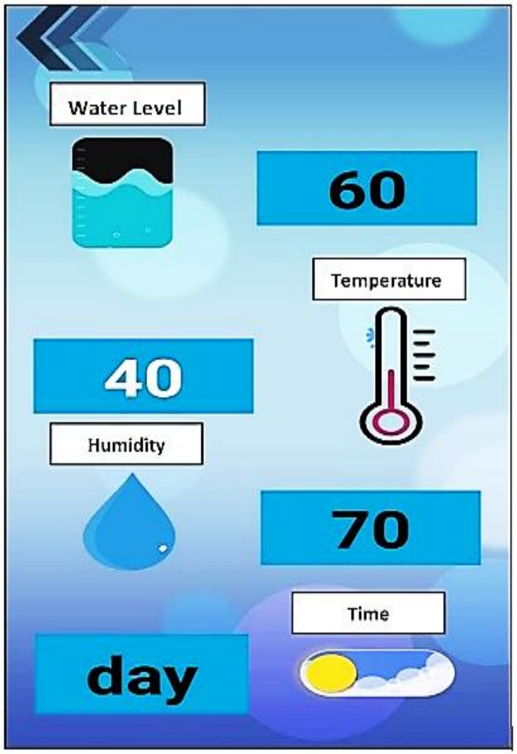

Fig. 11 The user interface of the mobile application

5. Results and Discussion

The comparison of water produced during each mode of operation was compared. Figure 12 shows that when the air-water harvester operates in economy mode, about 1 liter of water is produced. In regular mode, 1.35 liters of water is obtained that can be used for drinking purposes. Likewise, about 1.6 liters of water can be obtained if the air-water harvester operates in turbo mode.

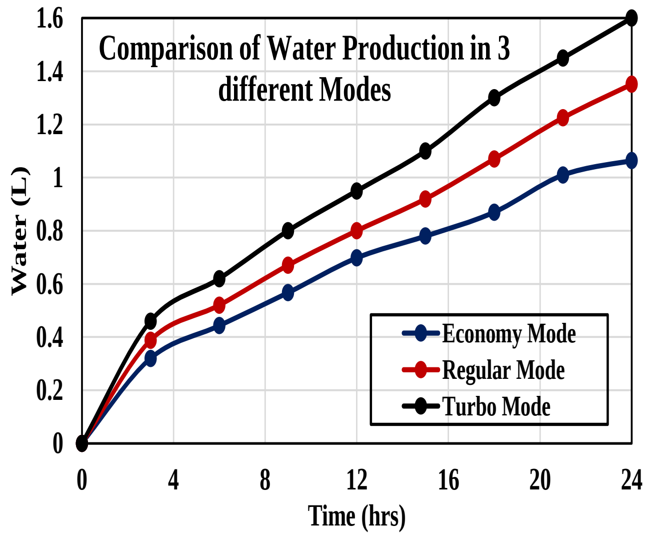

Fig. 12 Comparison of water production in three modes

6. Conclusion

This paper successfully provided the solution to the clean water harvesting problem. The designed geometry of the air-water harvester solves the problems of previously designed air-water harvesters. It can produce at least 2 liters of clean water per day at the cost of low power consumption. The three different modes of operation were successfully implemented, and the amount of water produced was monitored using the mobile application. Integrating the Internet of Things (IoT) in the design enables the user to remotely monitor and control the different parameters of the double chamber air-water harvester. Furthermore, the amount of water production can be increased using the bioinspired heat sink designs.

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