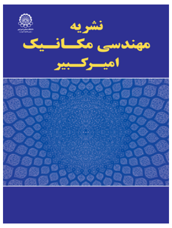

Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 55(1) (2023) 11-14
DOI: 10.22060/mej.2023.21729.7498

Effect of Electrostatic Field on a Fog Harvester Efficiency with Metal Porous Collector

M. R. Alaie[1], S. Emami[1,2]*, M. Hojaji[1,2]

[1] Department of Mechanical Engineering, Najafabad Branch, Islamic Azad University, Najafabad, Iran
[2] Aerospace and Energy Conversion Research Center, Najafabad Branch, Islamic Azad University, Najafabad, Iran

ABSTRACT: Among the different methods of water supply, extracting water from atmospheric fog has recently received more attention from scientific communities due to its advantages and unique features. In this method, water droplets are trapped and separated from the air using metal meshes. The main challenge facing this technology is the low efficiency of water harvesting from humid air. To overcome this issue, the idea of using a metal porous collector has been tested in the presence of an electrostatic field. Parameters such as the porosity percentage of the collector, airflow speed, electric field intensity, and the distance between the emitter and the collector (field distance) on the water harvesting efficiency were studied experimentally. In the range of investigated porosities, the efficiency of the fog collector has its maximum value with a porosity of 95.6%. Also, reducing the field distance increases the efficiency. Investigating the effect of electric field voltage on the efficiency of the device showed that with the increase in voltage from 15 to 24 kV, the efficiency increases from 21% to more than 42%. At this voltage, the phenomenon of voltage saturation has occurred, so that a further increase in voltage does not have much effect on the efficiency. Investigating the effect of flow speed showed that the maximum efficiency of the device was achieved at a speed of 1.1 m/s.

Review History:

Received: Aug. 27, 2022
Revised: Nov. 29, 2022
Accepted: Dec. 27, 2022
Available Online: Jan. 23, 2023

Keywords:

Fog collection
Electrostatic field
Porous media
Porosity percentage
Water harvesting efficiency

1- Introduction

One of the new methods of water recovery is extracting water from fog or dew, or in other words humid air. In this method, water harvesting can be easily done by fine meshes or harps (with vertical metal wires) installed in the path of the fog flow. When the fog hits the mesh, the water particles are trapped in the spaces between the fibers and collected as water droplets in a tank. This device which is named Fog Collector (FC) has usually low efficiency [1]. A significant fraction of the water droplets do not have an effective collision with the fibers and go around the mesh, which is one of the main reasons for the low efficiency of traditional fog collectors. To overcome this problem, in recent years, electrostatic force has been used to charge water droplets and guide them toward the mesh. Reznikov [2] increased the overall efficiency of an FC device by about 16% by using a metal mesh and an electric field. Damak and Varanasi [3] studied the factors affecting collection efficiency. It investigated the effect of single-wire and double-wire emitters and the distance of mesh rows on water collection. In another study, Yan and Sun [4] found that fog droplets floating in the air control the corona discharge process, and the effect of fog droplets is more significant than humidity changes; Also, with the increase in fog concentration, the discharge flow decreases.

This study aims to increase the FC efficiency using the porous metal collector and electrostatic field simultaneously. In this regard, while designing and building high-voltage electrical circuits to create an electromagnetic field and charge water droplets, the effect of factors such as the porosity of the metal collector, the velocity of the wet airflow, the voltage of the electric field, and the field distance on the water harvesting efficiency have been studied.

2- Experimental Setup and Research Method

An experimental setup consisting of three different units of electricity, a humidifier, and a collector. Direct electric current (DC) with high voltage is needed to create a magnetic field with the desired conditions to charge the water droplets in the fog. The electrical unit of the FC includes various components such as an adapter, power box, transformer, voltage multiplier, multi-meter, voltage indicating probe, cables, and insulators.

The humidifier unit, according to Fig. 1 includes a water storage tank, connecting pipes, two piezoelectric vaporizers, a liquid level gauge, an electric variable speed fan, and also a variable adapter. In this part, water vapor is produced by two piezoelectric pieces and the humid air is moved toward the collector by the fan.

Fig. 2 shows the position of the metal porous collector in the experimental setup. The electric device's positive output

*Corresponding author's email: sobhan@pmc.iaun.ac.ir

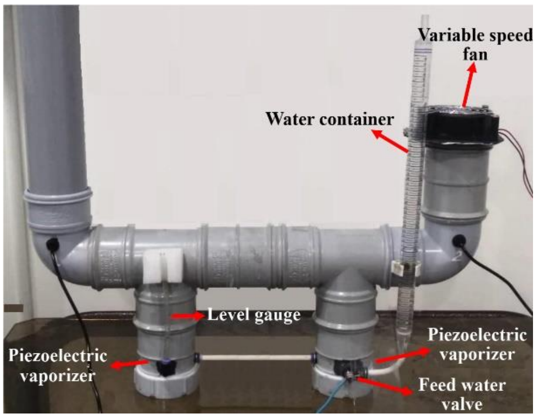

Fig. 1. The humidifier unit of the fog collection device

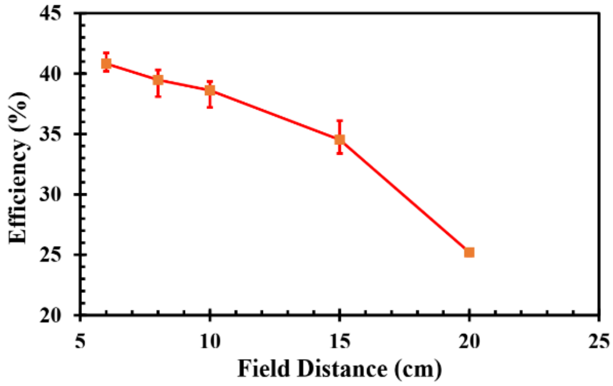

Fig. 3. The effect of field distance on FC efficiency

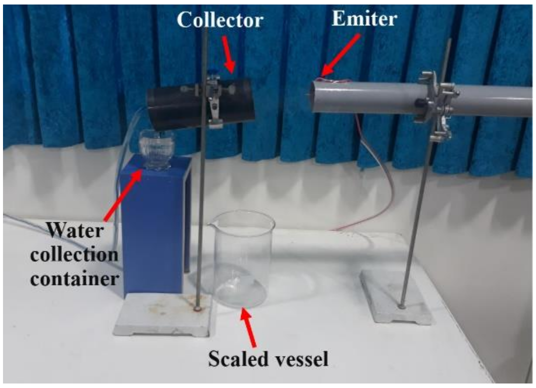

Fig. 2. The position of the electric field electrodes.

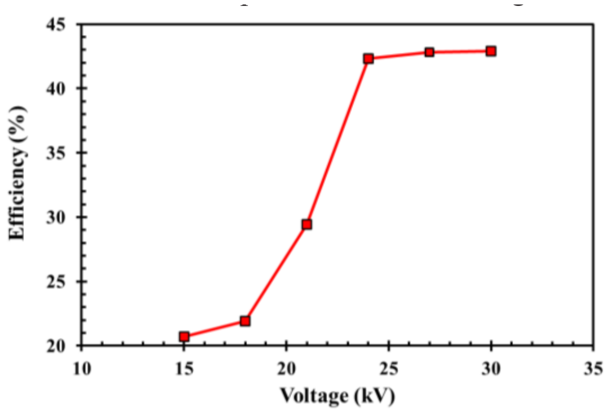

Fig. 4. The effect of field intensity on FC efficiency

is connected to the steam generator's end, and the negative output is connected to the metal porous collector. The fog droplets are charged by a magnetic field formed between the emitter and the collector and attracted to the porous body. Carbon steel interlaced wires were compressed inside a Polyvinyl Chloride (PVC) pipe to make the porous collector.

3- Results and Discussion

The effect of the distance between the emitter and the collector on the harvesting efficiency of the FC device is shown in Fig. 3. The tests were carried out using a collector with a porosity of 95.6. The flow velocity is equal to 1.1 m/s, and the device's voltage is set to 24 kV. According to the figure, the efficiency decreases as the distance increases. One factor affecting the field's intensity is the distance between the two negative and positive poles, that is, the distance between the collector and the emitter. By changing this distance, the force of the electric field on the water droplets also changes. According to the results, as the distance increases, the intensity of the field decreases, and its effect on water droplets floating in the air decreases.

In Fig. 4, the field intensity's effect on the water harvesting efficiency has been investigated. For these tests, a collector with a porosity of 98.1% was used, the flow velocity was set to 1.1 m/s, and the field length was set to 6 cm. The results show that the FC efficiency has increased with the increase in the intensity of the electric field. The increase in efficiency occurred at first with a very large slope, but when the voltage reached 24 kV, it seems that the phenomenon of voltage saturation occurred. In this limit, increasing the voltage will not affect the amount of water extraction.

To investigate the effect of flow velocity on the FC efficiency, the input voltage was set to 24 kV, and the field distance was set to 6, 8, and 10 cm in three separate tests. The results are presented in Fig. 5.

According to this figure, for all field distances, the maximum efficiency has been achieved at the velocity of 1.1 m/s. At velocities higher than 1.1 m/s, the drag force applied to the droplets is such that it overcomes the electric force applied to them and causes the droplet movement path to deviate from the electric field lines and reduce the efficiency of the device.

Four metal collectors with different percentages of porosity were used to investigate the effect of porosity on

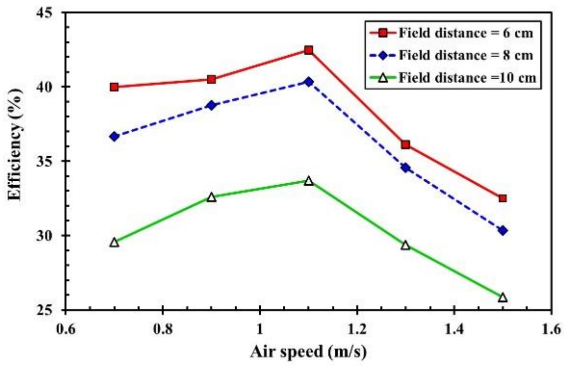

Fig. 5. The effect of flow velocity on FC efficiency

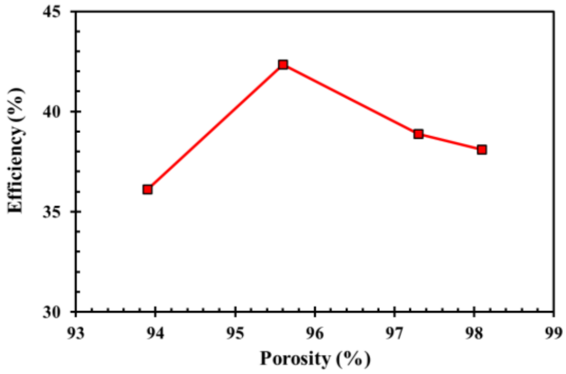

Fig. 6. The effect of porosity on FC efficiency

efficiency. The field length was set to 6 cm, the applied voltage was 24 kV, and the flow velocity was 1.1 m/s. The obtained results are presented in Fig. 6. The results show that the highest amount of extracted

water has been obtained in the metal collector with a porosity of 95.6%. The conflict between the effects of capillarity and the blocking of wet air passageways determines the optimal point in the porous collector.

4- Conclusion

This work studied the effect of factors such as metal collector porosity, wet air flow rate, electric field voltage, and field distance (emitter-collector distance) on the efficiency of dewatering from the fog of an FC device. The highest dewatering efficiency was obtained at the flow rate of 1.1 m/s, a field intensity of 24 kV, and a porosity percentage of 95.6%. The results showed that reducing the distance between the emitter and the collector increases efficiency. Investigating the effect of electric field voltage on the device's efficiency showed that by increasing the voltage from 15 to 24 kV, the device's efficiency increases from 21% to more than 42%.

References

[1] Y. Tu, R. Wang, Y. Zhang, J. Wang, Progress and expectation of atmospheric water harvesting, Joule, 2(8) (2018) 1452-1475.

[2] M. Reznikov, Electrically enhanced condensation I: effects of corona discharge, IEEE Transactions on Industry Applications, 51(2) (2015) 1137-1145.

[3] M. Damak, K.K. Varanasi, Electrostatically driven fog collection using space charge injection, Science Advances, 4(6) (2018) eaao5323.

[4] X. Yan, D. Sun, Corona discharge behavior in foggy environments with flat plate and fin plate electrodes, Chemical Engineering Science, 259 (2022) 117790.

HOW TO CITE THIS ARTICLE
M. R. Alaie, S. Emami, M. Hojaji, Effect of Electrostatic Field on a Fog Harvester Efficiency with Metal Porous Collector , Amirkabir J. Mech Eng., 55(1) (2023) 11-14.

DOI: 10.22060/mej.2023.21729.7498