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Increasing Efficiency of Peltier Module and Parametric Study of Water Extraction from Air Using Peltier Module

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Abstract - *Atmospheric water generator using two thermoelectric coolers was designed and experimentally investigated in this study. Different inlet air relative humidity (RH) and air flow rates were investigated to obtain their impacts on the amount of generated water and condensation rate. The amount of generated water and condensation rate increased with increase in RH. The amount of generated water increased with increase in air flow rates, but the condensation rate had opposite trend. The maximum amount of generated water was 12 ml each hour with 0.0033 m2condensation surface and 128.88 W input power. This system had medium size and could work at medium air flow rates which was suitable for outdoor use. This study had a guiding role in designing and optimizing the atmospheric water generation*.

Key Words: Portable atmospheric water generator; peltier material; atmospheric vapor condensation; water generation rate.

1. INTRODUCTION

Water is indispensable for human life; however water resources are declining recently. Nowadays, about 768 million people are lack of drinking water in the world, and there will be 3 billion people live in water-stressed countries in the future 2025.[1] Even though in water-rich areas, it is still difficult for people to find clean water in Even though in water-rich areas, it's still difficult for people to find clean water in remote outdoors. Great efforts have been made to solve these problems [2][3], and there were several water generating methods among which atmospheric vapor processing attracted researcher's attention. The atmosphere was estimated to contain over 12.9×1012 m^3 of renewable water and extracting water from air was potential and attractive.[3] During the past decades, thermoelectric (TE) technology has drawn attention around the world. TECs take use of Peltier effect to produce temperature difference when direct current (DC) is applied. Without moving parts, refrigerant, and emission gases, TECs are quiet, reliable and environmental-friendly. The TECs are also small, light and can be directly powered by photovoltaic (PV) panels. Researchers studied and improved the performance of TECs from materials, system structure, heat dissipation method and so on.[4][5][6] Integrating TECs into atmospheric vapor harvesting is an attractive way to design a portable water generator. Many works investigated vapor extracting performance by TECs. Different inlet RH and small air flow rates were experimentally investigated to study their impacts on generated water and condensation rate. This paper also analyzed some factors influencing the condensation rate and gave some tips to improve the performance of system.

2. MATERIAL AND METHODS

The experimental system contained a humidifier, a mixing chamber, an air channel, baffles, conical sheet, and a TE water generator. The air channel was 1.05 m and insulated by polystyrene foam. The humidifier was linked to the mixing chamber (0.324 m^2) to control the RH. Air flow rates were controlled by an axial fan. The TE water generator was connected tin the middle of the air channel. The heat dissipation of TE module used a axial flow fan. The condensed droplets were collected by a water beaker. The schematic diagram of experimental system and TE water generator were shown in Fig.1.The thermal slug of hot and cold side was 0.18 m×0.18 m, and the height of fins were 0.014 m. The total areas of fins were 0.456m^2. Three baffles and two conical shaped sheets were attached on the TECs.

Fig-1: Setup of Water Extraction from Air

3. THEORY

Air flowed into the mixing chamber by the crossflow fan and then be humidified. Different RH of inlet air was controlled by the humidifier. Then the humidified air flowed through TECs by an inlet air channel, and the temperature of inlet air was reduced by TECs to its dew point. Condensate droplets would grow on the conical sheet and finally created water droplets dropped down to the water beaker. Collected water was measured every hour manually. Input power source was controlled as 5 A, 12 V throughout the experiments. Three different flow rates were controlled by a cross flow fan and were measured by an anemometer. Temperature (T) and RH of inlet and outlet air were measured by hygrothermographs. The temperature of fins was measured by thermocouples.

4. RESULTS AND DISCUSSIONS

After varying several parameters and performing various experiments, the optimum result obtained on the system is as follows:

Table-1: Data of condensation experiment without suction fan, without baffles:

TIME (mins)	DBT(⁰C)	WBT (⁰C)	RH(%)	DPT(⁰C)	TEC HOT (0C)	TEC COLD (⁰C)	WATER (ml)
0	27	19	46.57	14.59	29.6	26.2	0
5	31	24	56	21.18	31.6	24.3	1
10	36	30	64	28.28	32.3	21.8	2
15	42	38	77.53	37.24	33.2	19.7	3
20	45	42	83.5	41.5	35.2	18.3	4

The amount of collected water at different RH was shown in Fig. 2. The amount of hourly collected water was increased with time went on. After 6 or 7 hours, the amount of collected water gradually became constant and the average hourly generated water was shown in Fig. 3. This behaviour could be explained that the condensate droplets were small in the beginning, and the disturbance of inlet air and effect of gravity could not offset the adhesion. So, the droplets were adhered on the conical sheet. The condensation rate was shown in Fig. 4. The amount of condensate water and condensation rate was both proportional to RH. When inlet air temperature, flow rate and input power kept constant, the increased RH led to rising moisture content. The increased RH also led to the rising dew point temperature of inlet air. As a result, temperature difference (ΔT) between inlet air and its dew point decreased with rising RH, as shown in Fig. 5. The declining ΔT led to more easy condensation. In summary, increased inlet RH was beneficial and brought increased amount of generated water and condensation rate.

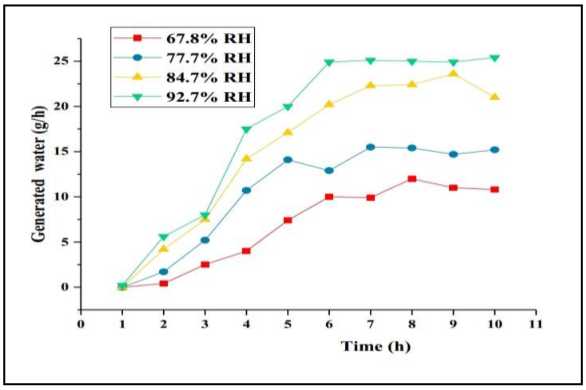

Fig-2: Variation of generated water with time at different RH. [12]

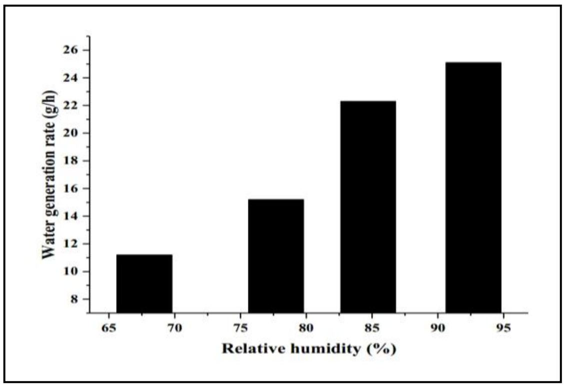

Fig-3: Water generation at different RH [12]

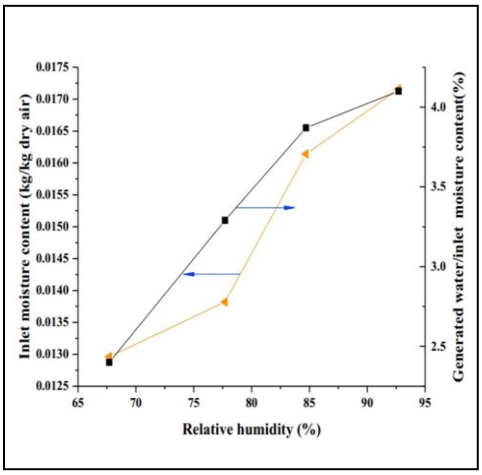

Fig-4: Inlet moisture content and generation ratio at different RH [12]

The impact of air flow rates:

Water production at different flow rates was shown in Fig. 6, and average hourly generated water after stabilization was shown in Fig. 7. In the beginning, the amount of condensed water at 29.6 m^3/h was more than that of the air flow at 50.4 m^3/h and 70.6 m^3/h. The high temperature of fins may explained the less water generation amount at high flow rate in the beginning as shown in Fig. 8. After 8 hours, the generated water gradually stabilized and rose with increased flow rates. This was explained by a fact that the temperature of cold side fins decreased with time went by and the rising flow rate increased the amount of vapour content in the channel.

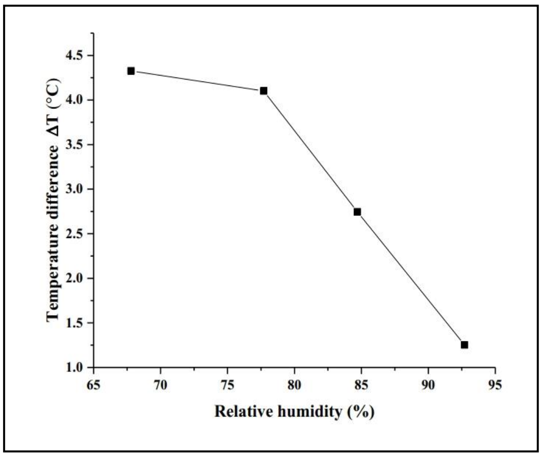

Fig-5: ΔT at different RH [12]

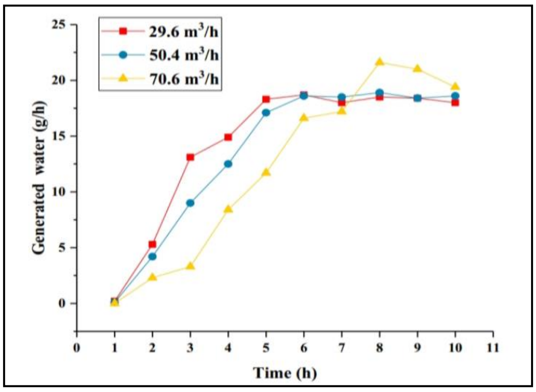

Fig-6: Generated water at different air flow rates[12]

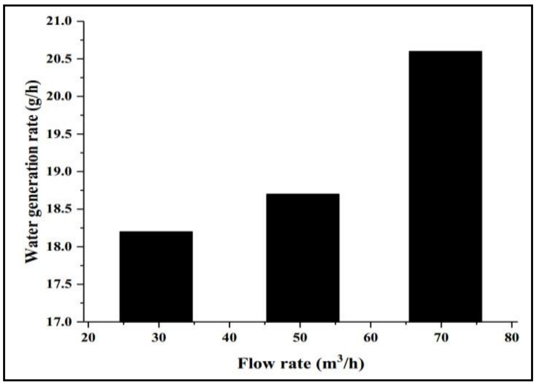

Fig-7: Generated water at different air flow rates[12]

From Figs. 7 and 9, the rising inlet air flow rate resulted in increased water amount but declining condensation rate. On the one hand, increased air flow rate brought more inlet moisture and stronger disturbance. But the system with two TE modules couldn't supply enough cooling capacity with increased air flow rate, so the condensation rate decreased. On the other hand, increased air flow rate also led to insufficient contact time between moist air and condensate surface. These both led to reduced temperature of cold side fins and temperature difference of inlet and outlet air, as shown in Figs. 8 and 9, which may accounted for the declining condensation rate.

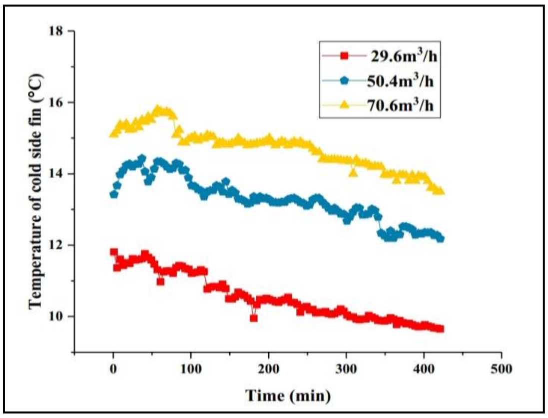

Fig-8: Temperature of cold side fin at different air flow rates[12]

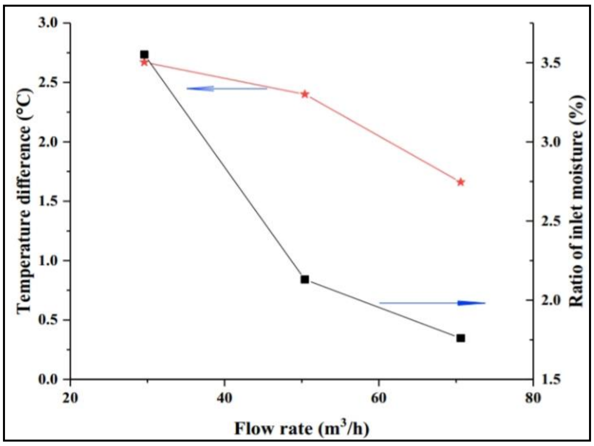

Fig-9: Temperature difference and condensate rates[12]

Analysis of different models performance: The several experiments performed are tabulated in Table 2. shown below:

Table-2: Data of condensation experiments

Type of system	Inlet Parameters			System Performance	
	Temp (0C)	RH(%)	Flow rate m/s	Power(w)	Water (ml) in 1 hour
Without suction fan, with baffles	35	83.5	0	128.88	10
With suction, with baffles	35	74	0.5	150.88	8
With suction, with baffles	26	53	3.1	150.88	5
With suction, without baffles	28.5	45	2.5	150.88	6

Water production at different parameters are shown. The trend follows that when the suction fan is at low speed or totally closed then the amount of generated water will be slightly higher. As the velocity of fan increases the air do not comes much in contact with the TEC causing lack of condensation effecting lower extraction of water.

5. CONCLUSION

The main conclusions of the study may be presented in a short Conclusions section. This study designed an atmospheric water generator with TE method. The system was experimentally investigated at different inlet air flow rates and RH. The amount of generated water increased with rising inlet RH and inlet air flow rate and the maximum generated water was 12 ml/h. The condensation rate increased with rising RH but decreased with increased air flow rate. Small cooling capacity, small condensation surface, single pass structure and adhesion of droplets on condensate surface were the main reasons for low condensation efficiency. The water generator could be supplied by a PV panel directly without operation cost, which was energy-saving. In the future, more efforts need be done to optimize the system structure to increase contact surface and time between air and cold side of TE modules. To promote dropwise condensation improving heat transfer and condensation process the wetting property of condensate surface also needs modification.

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