KnE Materials Science
ASRTU Conference on Alternative Energy
Sino-Russian ASRTU Conference Alternative Energy:
Materials, Technologies, and Devices
Volume 2018

Knowledge E
Engaging minds

Conference Paper

Study on Active and Passive Integration Humidification–Dehumidification Solar Desalination

L. X. Zhang, Y. Z. Jiang, and X. J. Zhang

School of Engine and Energy, Northwestern Polytechnical University, 710072 Xi'an, China

Abstract

A humidification–dehumidification (HDH) solar desalination process with active and passive air circulation is proposed, in which the phase change material (PCM) is used to recover the latent heat of vapor condensation to increase the fresh water production. The experiments show that the cost of fresh water is 23.47 Yuan/t, the gain output ratio of the unit is 13.37, and the water production is increased by 84.4% compared with the dehumidifier without using PCM. The heat transfer between the heat pipe and the PCM (I) (paraffin) and the high thermal conductivity PCM (II) are tested and simulated.

Keywords: humidification–dehumidification, solar desalination, PCM, numerical simulation

Corresponding Author:
L. X. Zhang
zhanglixi@nwpu.edu.cn

Received: 14 September 2018
Accepted: 1 October 2018
Published: 14 October 2018

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the ASRTU Conference Committee.

1. Introduction

The method of HDH is the most efficient one in solar desalination, and it is suitable for small and medium-sized unit. By combining phase change heat storage with HDH solar desalination, one can solve the problem of using latent heat of water vapor condensation in dehumidification process, in order to increase the utilization of heat energy and fresh water production.

In the existing solar desalination process, PCM is mainly used to recover excess solar thermal energy [1–4], and there are few processes using PCM for recovering latent heat of wet air. Paraffin wax is a commonly used PCM. By adding materials, such as expanded graphite to paraffin, its heat transfer performance and latent heat of phase can be changed [5, 6].

The heat transfer rate between the heat source and PCM can be effectively improved by using heat pipe [7, 8], and the temperature distribution is more uniform [9].

How to cite this article: L. X. Zhang, Y. Z. Jiang, and X. J. Zhang, (2018), "Study on Active and Passive Integration Humidification–Dehumidification Solar Desalination" in *Sino-Russian ASRTU Conference Alternative Energy: Materials, Technologies, and Devices*, KnE Materials Science, pages 201–208. DOI 10.18502/kms.v4i2.3053

In this article, an HDH solar desalination process using active and passive air circulation integrated with PCM for heat storage is proposed, and the heat transfer process between heat pipe and PCM is studied.

2. HDH Solar Desalination Process with Active and Passive Integration

Figure 1 shows the HDH solar desalination process with active and passive integration. In the process, the active humidification dehumidification process and the passive humidification dehumidification process jointly produce fresh water. By using PCM, the latent heat of water vapor condensation released by active air circulation during dehumidification is recovered to supply the passive HDH process.

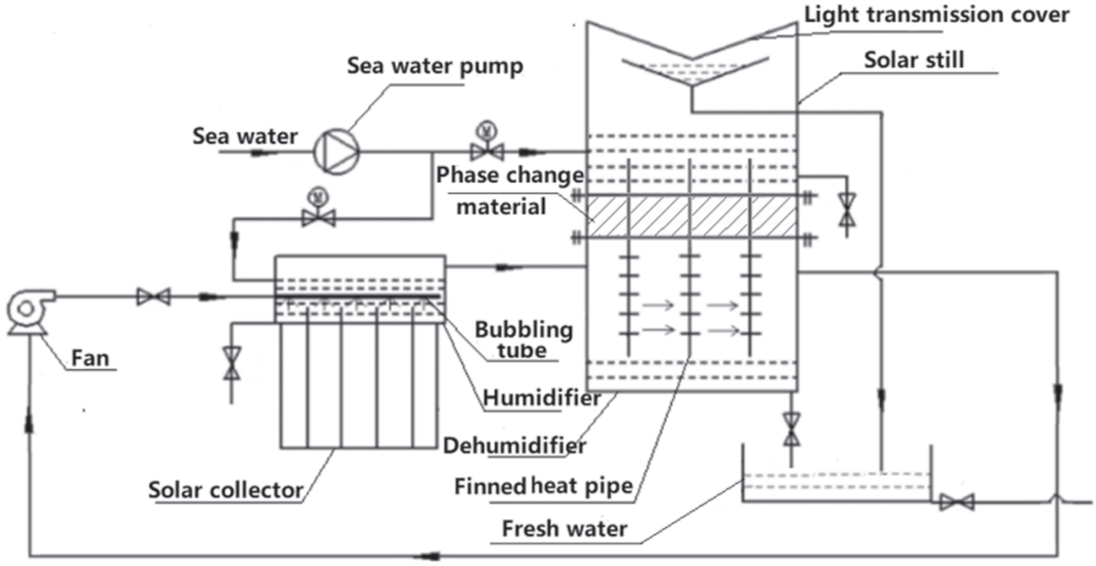

Figure 1: Process diagram of HDH solar desalination with active and passive integration.

This process has simple structure and small investment. By recycling and using most of the latent heat of wet air, one can obtain a high water production ratio. Furthermore, it is easy to operate and control.

3. Experimental Research on the Dehumidifier with Phase Change Heat Storage

In the dehumidifier, 1 kg of PCM (I), or paraffin, was placed at the upper end of the heat pipe, the phase change temperature of PCM was 45°C. The heat source of dehumidifier was the saturated air at 65°C, and the air flow rate was 5 m^3/h. There were 10 heat pipes, which outer diameter and length were 25 and 210 mm, respectively. The temperature field of the PCM (I) upper surface at different running times is shown in Figure 2, where the left side is the hot humid air inlet side, and the right side is the cold air outlet side.

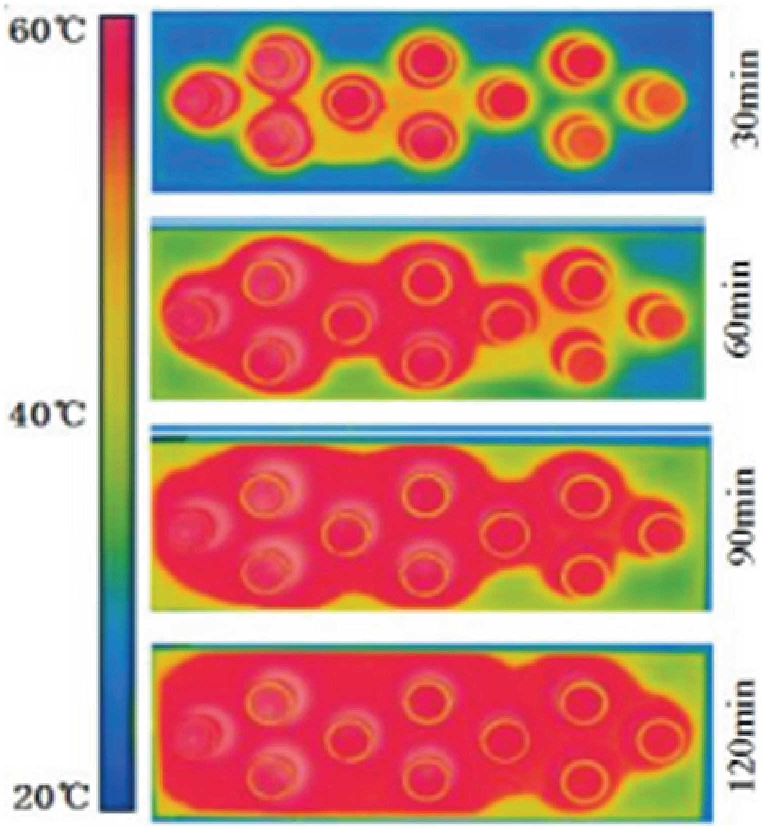

Figure 2: Temperature field on the surface of PCM (I).

When the cross-sectional area of the dehumidifier is 200×200 mm^2, and the initial water weight in the distiller is 1 kg, the test results have shown that the water yield is 200 mL/h, which is equivalent to the cost of water production that is 23.47 yuan/t, and the water production ratio GOR is 13.37. Compared with the distiller without using PCM under the same conditions, the water production is increased by 84.4%.

4. Heat Transfer Test Between Heat Pipes and PCM

The heat transfer performances between heat pipes and two kinds of PCM were investigated. The PCM (I) is the common paraffin; the PCM (II) is the mixture with volume fraction 50% of expanded graphite, 1% of oleic acid triethanolamine, and 49% of ordinary paraffin.

DOI 10.18502/kms.v4i2.3053

Figure 3 is the heat transfer test schematic diagram of a heat pipe placed vertically in PCM. The outer diameter of heat pipe is 25 mm, and its height is 210 mm. Water is used as the working medium in the heat pipe. The upper part of the heat pipe is buried in the PCM with a height of 30 mm, and the lower part of the heat pipe is in a constant temperature water bath at 70°C. The outer surface of the test device is insulated with a sponge insulation material.

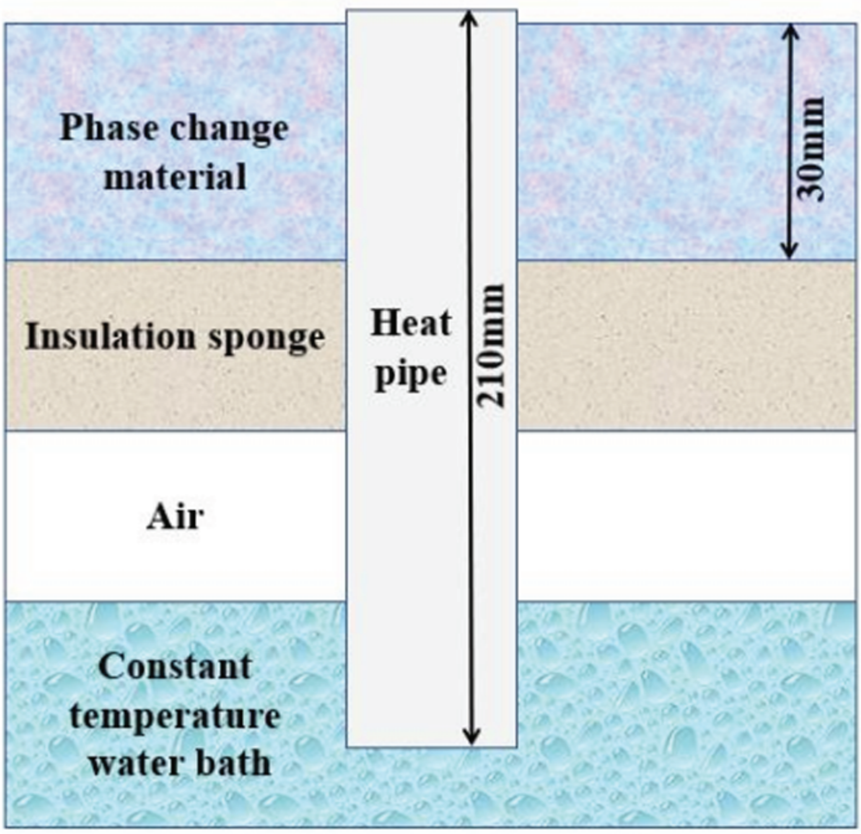

Figure 3: Heat pipe test schematic diagram.

In the test, the phase change process of the two PCMs is shown in Figure 4. After the tests were carried out to 30, 60, and 90 min, the melting range of PCM (I) along the radial length in the outside of heat pipe were 13, 20, and 26 mm, respectively; and that of PCM (II) were 5, 7, and 9 mm, correspondingly.

The surface temperature fields of PCMs were photographed by a high-precision infrared thermal imager, they are shown in Figure 5. Since PCM (I) had a relatively small thermal conductivity, the heat transferred to the outer region of the heat pipe is less, and the phase change region around the heat pipe was large. The PCM (II) had a relatively high thermal conductivity, the heat transferred to the outer region of the heat pipe was faster, so the temperature field distribution around the heat pipe was relatively uniform.

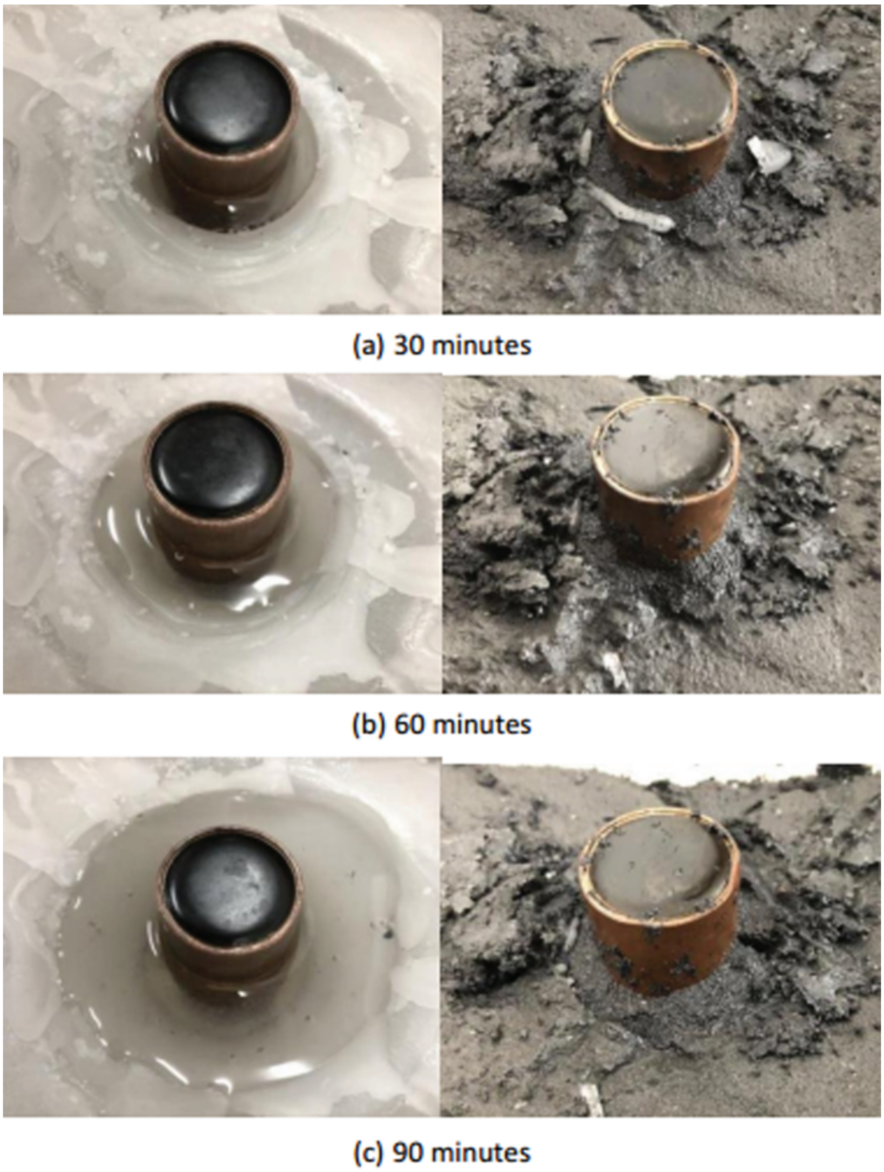

Figure 4: Phase transition process of PCM (I) and PCM(II).

5. Heat Transfer Numerical Simulation of Heat Pipe Coupled PCM

In the heat transfer numerical simulation, the number of pipes is taken 10, the outer diameter of the pipe is 25 mm, and they are in a forked row. Referring to the heat transfer experiment results of a single heat pipe, the heat pipe spacing is taken 25 mm. A triangular unstructured mesh is used, and the wall temperature of the heat pipe is 65°C.

Figure 6 is the numerical simulation of the phase transition between PCM (I) and heat pipes. It can be seen from the figure that the paraffin near the heat pipe was first

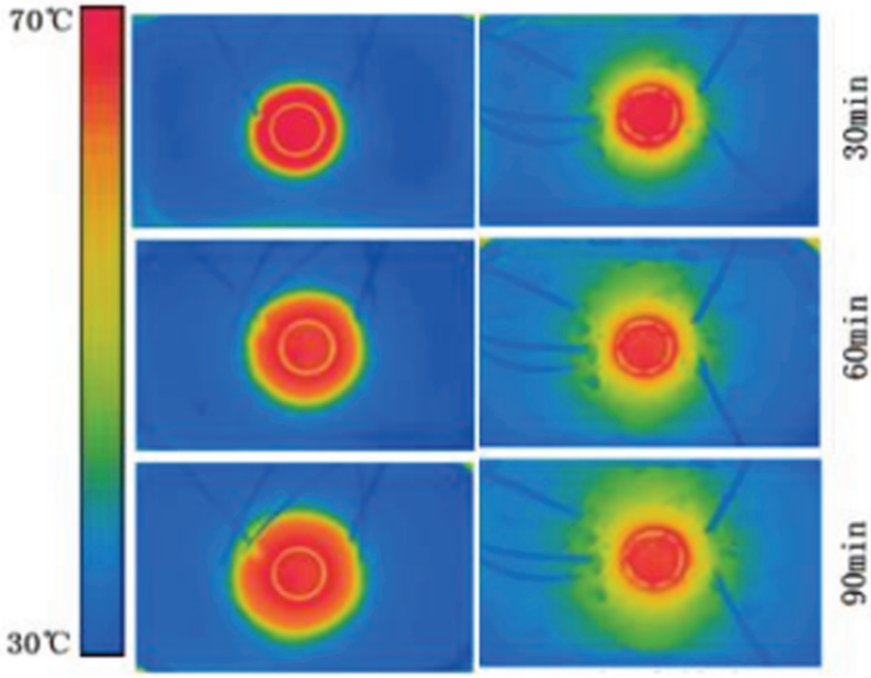

Figure 5: Temperature field of PCM (I) and PCM(II).

melted, and as the heat transfer time increases, the phase change region gradually increases. When the heating process was carried out to 90 minutes, the phase change range substantially covered the entire surface except for the corner regions.

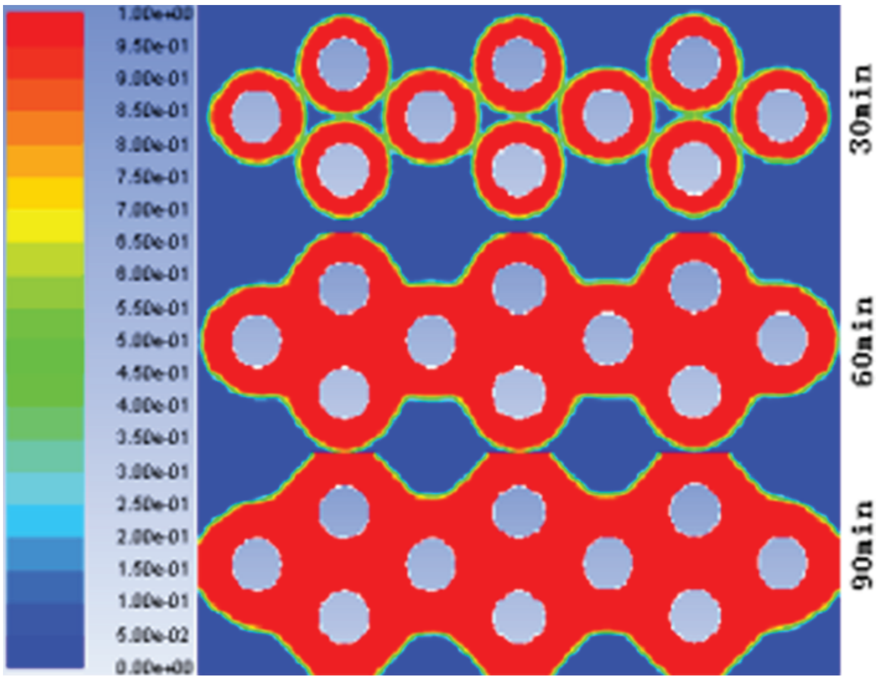

Figure 6: Phase change process of PCM (I).

6. Conclusion

The experimental study shows that in the certain conditions, the water capacity is 200 mL/h, the water production cost is 23.47 Yuan/t, and the water production ratio is 13.37. Compared with the distiller without using PCM under the same conditions, the water production is increased by 84.4%.

Under the same heating conditions, the PCM (I) had a larger phase transition region, while the PCM (II) had a stronger thermal conductivity. And the numerical simulation of heat transfer between PCM (I) and multi-heat pipes showed that when the wall of the heat pipe is maintained at 65°C and the distance of the tube is 25 mm, the PCM (I) had basely melted after heating for 90 min.

References

[1] Ansari, O., Asbik, M., Bah, A., et al. (2013). Desalination of the brackish water using a passive solar still with a heat energy storage system. *Desalination*, vol. 324, pp. 10–20.

[2] Arunkumar, T., Denkenberger, D., Ahsan, A., et al. (2013). The augmentation of distillate yield by using concentrator coupled solar still with phase change material. *Desalination*, vol. 314, pp. 189–192.

[3] Kabeel, A. E. and Abdelgaied, M. (2016). The performance of a modified solar still using hot air injection and PCM. *Desalination*, vol. 379, pp. 102–107.

[4] Asbik, M., Ansari, O., and Bah, A. (2016). Exergy analysis of solar desalination still combined with heat storage system using phase change material (PCM). *Desalination*, vol. 381, pp. 26–37.

[5] Chen, C., Zhang, H., Gao, X., et al. (2016). Numerical and experimental investigation on latent thermal energy storage system with spiral coil tube and paraffin/expanded graphite composite PCM. *Energy Conversion and Management*, vol. 126, pp. 889–897.

[6] Korti, A. I. N. and Tlemsani, F. Z. (2016). Experimental investigation of latent heat storage in a coil in PCM storage unit. *Journal of Energy Storage*, vol. 5, pp. 177–186.

[7] Lohrasbi, S., Miry, S. Z., Gorji-Bandpy, M., et al. (2017). Performance enhancement of finned heat pipe assisted latent heat thermal energy storage system in the presence of nano-enhanced H_2O as PCM. *International Journal of Hydrogen Energy*, pp. 1–21.

[8] Motahar, S. and Khodabandeh, R. (2016). Experimental study on the melting and solidification of a PCM enhanced by heat pipe. *International Communications in Heat & Mass Transfer*, vol. 73, pp. 1–6.

[9] Kim, T. Y., Hyun, B. S., and Lee, J. J. (2013). Numerical study of the spacecraft thermal control hardware combining solid-liquid PCM and a heat pipe. *Aerospace Science & Technology*, vol. 27, pp. 10–16.