Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 61 (2014) 180 – 183

Energy Procedia

The 6th International Conference on Applied Energy – ICAE2014

CFD simulation of the liquid flow on structured packing in the liquid desiccant dehumidifier

Yimo Luo, Hongxing Yang*, Lin Lu

[a]Renewable Eneregy Research Group (RERG), Department of Building Services Engineering, The Hong Kong Polytechnic University, Hong Kong, China

Abstract

Te liquid flow has great impact on the heat and mass transfer behavior in the liquid desiccant dehumidifier. However, there is limited investigation on the liquid flow conditions in the dehumidifier. Thus, the paper investigated the liquid flow behavior on a flat and corrugate plate, respectively. The minimum liquid flow rate for wetting the whole surface, surface axial velocity, surface radial velocity, and surface shape under different liquid velocities are analyzed in detail.

Keywords: CFD, liquid flow, structured packing, dehumidifier

1. Introduction

The liquid desiccant air conditioning system has gained more and more acceptance as one of the promising candidates for traditional vapor compression air conditioning system. The performance of the air dehumidifier is critical to determine the overall performance, size, and cost of the system. Thus, lots of researches have been done on the dehumidifier in terms of simulation and experiment [1, 2]. Even so, seldom literature has been reported about the liquid desiccant flow condition in the dehumidifier.

As a matter of fact, the air dehumidifier is a typical absorber, where the liquid desiccant absorbs the moist from the air. Many literatures have verified that the liquid flow in the absorber has great impact on the heat and mass transfer process for the absorbers [3]. A large number of studies had been done about the liquid films to analyze the influence of the flow regimes, geometries, and boundary conditions in the absorber [4].

* Corresponding author. Tel.: +852-2766-5863.
E-mail address: hong-xing.yang@polyu.edu.hk.

doi:10.1016/j.egypro.2014.11.1053

Nevertheless, there are seldom literatures about the liquid flow status in the air dehumidifier of liquid desiccant air conditioning system, especially on the structured packing. Thus, the objective of the paper is to model the flow behavior through structured packing by means of CFD software Fluent and analyze the influences of various parameters on the flow behaviors.

2. Model

2.1. Physical model

In the paper, a flat plate and a plate-type structured packing Mellapak 250Y were chosen as the modeled objectives. Numerical simulations were conducted for the unsteady two-phase flow with free liquid surface in the channel between two flat or corrugated plates. The simplified geometric constructions are presented in Fig. 1. The length of the plates is 150 mm and the distance between the plates is 20 mm. The liquid desiccant solution and air flow counter-currently in the two channels.

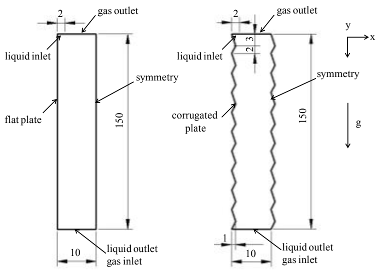

Fig. 1. Schematic of the simplified physical model

2.2. Simulation strategy

The relevant simulation strategy can be found in the literature [5].

3. Results and discussion

3.1. The wetting performance

In the dehumidifier, the wetting performance has been considered as one of the important factors which influence the final absorption performance. However, the relevant knowledge is still limited and it requires further experimental and theoretical work. In previous work [5], it is found that the minimum solution flow rate to wet the whole flat plate is about 108 m^3•m^{-2}•h^{-1}. According to the calculation results of this paper, it is concluded that the solution flow rate for the corrugated plate is 324 m^3•m^{-2}•h^{-1}, about three times of that of the flat plate under the same simulation conditions. It demonstrates that it is more difficult to wet a corrugated vertical surface than a flat one.

3.2. Surface axial velocity

In theory, the wave of the falling film can enhance the mass transfer in two ways, one is by increasing the contact surface, and the other one is by grasping the mass with the rolling wave. Since the surface velocities play great role in determining the film wave, their local distribution are investigated.

For a free surface film flow down a vertical flat wall, it is always unstable even under very small Reynolds number. In Fig. 2, the distribution of the liquid surface axial velocity and the film thickness are presented. As the liquid inlet size of physical model is 2 mm, there is a sharp change of the film thickness at the liquid inlet. But after that, a flat interface appears, yet only over some distance at the liquid inlet, following by big fluctuation. It is also observed that the axial velocity increases with the enhancement of the wave, and it will reach the maximum value at the crest of the wave. The results show consistence with those in the literature [6].

For the corrugated plate, the axial velocity is less than that of the flat plate, resulting from the support of the surface. It demonstrates that the corrugated plate can offer much longer contact time for the mass transfer in the dehumidifier. In addition, the change of the axial velocity is also less than that of the flat plate. The corrugated structure can help to stable the liquid flow in the axial direction under the present operating condition.

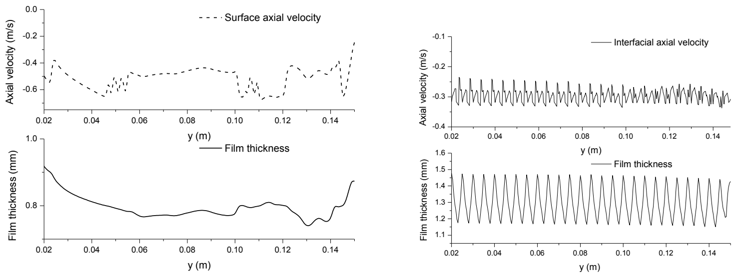

Fig. 2. Film thickness Vs Axial velocity (a) Flat plate; (b) Corrugated plate

3.3. Surface radial velocity

It is found that for the flat plate, unlike the surface axial velocity, there is not obvious change of the surface radial velocity. Thus, it is concluded that for the flat plate, the surface wave has great relationship with the surface axial velocity rather than the radial velocity. On contrary, the change of the surface radial velocity is much bigger, which is determined by the shape of the wall. Whether it will impact the mass transfer needs further investigation.

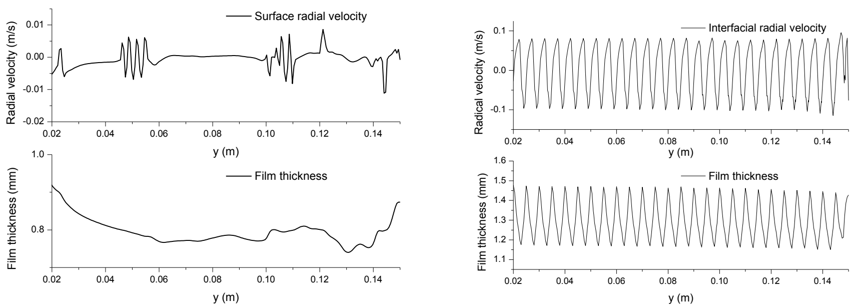

Fig. 3. Film thickness Vs Radical velocity (a) Flat plate; (b) Corrugated plate

3.4. The surface shape under different liquid velocities

The Film shape on the flat plate under different liquid velocities has been investigated in previous work [5]. Under the case of a corrugated vertical wall, it is found that the shape of the wave changes periodically. The film thickness will reduce a litter at the beginning and then increase with the increase of the inlet solution velocity. In addition, the phase angle reduces with the increase of the inlet solution velocity. When the solution velocity reaches a certain value, the shape of the liquid film becomes similar to the wall surface.

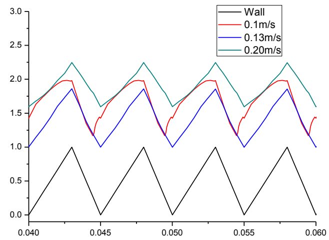

Fig. 4. Film shape on the corrugated plate under different liquid velocities

4. Conclusion

In the work, the two-dimensional VOF model is presented to study the flow of liquid solution on a flat and corrugated sheet of packing, respectively. Several conclusions are drawn on the basis of the calculation results.

- The liquid solution flow rate should be larger for wetting the whole surface of the corrugated sheet of packing than that of the flat plate.
- For the flat plate, the surface shape has greater relationship with the surface axial velocity than the radial velocity.
- The corrugated structure can help to stable the liquid flow under the present operating condition.
- The shape of the wave changes periodically for the corrugated plate surface.

Acknowledgements

The work described in this paper was supported by the Hong Kong PhD Fellowship Scheme.

References

[1] Luo YM, Yang HX, Lu L. Liquid desiccant dehumidifier: Development of a new performance predication model based on CFD. *Int J Heat and Mass Tran* 2014;**69**:408–16.

[2] Qin F, Shao SQ, Luo YM, Tian CQ, Zhang GY. Investigation of performance of fin-tube internally heated regenerator in liquid desiccant air conditioning system. *International Conference on Applied Energy 2012*, Suzhou, China.

[3] Frisk DP, Davis EJ, The enhancement of heat transfer by waves in stratified gas–liquid flow. *Int J Heat and Mass Trans* 1972;**15**:1537–52.

[4] Min JK, Park S. Numerical study for laminar wavy motions of liquid film flow on vertical wall. *Int J Heat and Mass Tran* 2011;**54**:3256-66.

[5] Luo YM, Yang HX, Lu L. Microscopic Simulation of the flow and mass transfer processes in a liquid desiccant dehumidifier, *International Conference on Applied Energy 2013*, Jul 1-4, Pretoria, South Africa.

[6] Cui XT, Li XG Li, Sui H, Li H. Computational fluid dynamics simulations of direct contact heat and mass transfer of a multicomponent two-phase film flow in an inclined channel at sub-atmospheric pressure. *Int J Heat and Mass Tran* 2012;**55**:5808-18.