Study on the Transient Performance of a Liquid Desiccant Dehumidifier under Changing Boundary Conditions †

Dan Zhong, Yi Chen and Yimo Luo *

Faculty of Science and Technology, Technological and Higher Education Institute of Hong Kong, Hong Kong 999077, China; dzhong@peacockedu.com (D.Z.); yichen@vtc.edu.hk (Y.C.)

* Correspondence: yimo.luo@vtc.edu.hk; Tel.: +852-2176-1887


Published: 29 October 2018

Abstract: It was found that there were still very limited studies for the dynamic operation and transient performance of the dehumidifier. Besides, the coupling study of heat, mass and flow was not comprehensive and lots of assumption was made to start the simulation. Lack of accurate prediction, the guidelines of control system design and operation cannot be put forward appropriately. Therefore, the paper established a reliable dynamic model for the dehumidifier. With the model, it obtained the transient response performance of the dehumidifier under changing boundary conditions, such as response time and response curves of outlet parameters. The magnitudes of the influences of various inlet parameters was analyzed, providing reliable and effective predication of the transient response performance of the dehumidifier.

Keywords: liquid desiccant dehumidification; transient performance; changing boundary

1. Introduction

The dehumidifier is a very important component of the liquid desiccant air conditioning system. During transient operation, the transient response performance of the dehumidifier will have great influence on the performance of the whole system. To realize the effective and stable operation of system, it requires reliable control of the dehumidifier [1], which relies greatly on accurate prediction of their transient response. However, the previous studies mainly focused on the steady-state heat and mass transfer processes, and research in the aspect of transient performance was still very limited for the dehumidifier [2–4]. Therefore, in the present paper, a dynamic model was developed to render the predication of the transient response performance of the dehumidifier.

2. Development of the Dynamic Model

The physical model and governing equations could be referred in the literature [2]. The initial and final value of the inlet boundaries are presented in Table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Air</th>
<th>Desiccant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$T_{\text{a, in}}$ (K)</td>
<td>$x_{\text{a, in}}$ (g/kg dry air)</td>
</tr>
<tr>
<td>Initial value</td>
<td>307</td>
<td>2.0</td>
</tr>
<tr>
<td>Final value</td>
<td>304</td>
<td>1.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Air</th>
<th>Desiccant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$T_{\text{a, in}}$ (K)</td>
<td>$x_{\text{a, in}}$ (g/kg dry air)</td>
</tr>
<tr>
<td>Initial value</td>
<td>307</td>
<td>2.0</td>
</tr>
<tr>
<td>Final value</td>
<td>304</td>
<td>1.8</td>
</tr>
</tbody>
</table>
3. Simulation Results

3.1. Step Change of Air Inlet Temperature

In Figure 1, it showed the air outlet humidity and temperature response curves under the step change of air inlet temperature. When the air inlet temperature was decreased from 307 K to 304 K, both of the air outlet humidity and temperature experienced fluctuations. It could be observed that the response time was 2.2 s for air outlet humidity and 1.8 s for air outlet temperature, respectively. Besides, there was a lag for both outlet parameters after the change of air inlet temperature. The time would be around 1.0 s for air outlet humidity and 0.5 s for air outlet temperature, which meant that the air outlet temperature was more sensitive to the change of air inlet temperature.

![Figure 1. Humidity and temperature variation under step change of air temperature. (a) air outlet humidity; (b) air outlet temperature.](image)

3.2. Step Change of Air Humidity

In Figure 2, it showed the air outlet humidity and temperature response curves under the step change of air inlet humidity. When the air inlet humidity was decreased from 0.020 to 0.018 kg/kg dry air, both of the air outlet humidity and temperature decreased ultimately. It could be observed that the response time was 1.5 s for air outlet humidity and 1.2 s for air outlet temperature, respectively. Besides, there was a lag for both outlet parameters after the change of air inlet temperature. The time would be around 0.5 s for air outlet humidity and 0.4 s for air outlet temperature, which meant that the two parameters showed almost the same sensitivity to the change of air inlet humidity.

![Figure 2. Humidity and temperature variation under step change of air humidity. (a) air outlet humidity; (b) air outlet temperature.](image)
3.3. Step Change of Air Inlet Velocity

In Figure 3, it showed the air outlet humidity and temperature response curves under the step change of air inlet velocity. Unlike air inlet temperature and humidity, both of air outlet temperature and humidity reacted faster to the change of air inlet velocity. There was not any lag for both outlet parameters after the change of air inlet velocity. It was found that the response time was 0.7 s for air outlet humidity and 1.0 s for air outlet temperature, respectively. Therefore, it was concluded that the response time for the dehumidifier to the increase of air velocity was much shorter than to the change of air temperature and humidity.

![Figure 3](image)

**Figure 3.** Humidity and temperature variation under step change of air velocity. (a) air outlet humidity; (b) air outlet temperature.

3.4. Step Change of Solution Temperature

As shown in Figure 4, it presented the air outlet humidity and temperature response curves under the step change of solution temperature. Similar to the change of air inlet velocity, there was not any lag for both outlet parameters after the change of solution temperature. It was caused by the adverse current configuration of present dehumidifier. As the outlet air contacted directly with the inlet liquid desiccant solution, the sudden change of inlet solution temperature should have an immediate impact on the outlet air. The above explanation was also applicable to the change of solution concentration and solution inlet velocity in Section 3.5. Besides, it was found that the response time was both 1.5 s for air outlet humidity and for air outlet temperature.

![Figure 4](image)

**Figure 4.** Humidity and temperature variation under step change of solution temperature. (a) air outlet humidity; (b) air outlet temperature.

3.5. Step Change of Solution Concentration

As shown in Figure 5, similar to the change of solution temperature, there was not any lag for both outlet parameters after the change of solution temperature. The reason was pointed out in the above section. The response time was both 1.5 s for air outlet humidity and for air outlet temperature.
Figure 5. Humidity and temperature variation under step change of solution concentration. (a) air outlet humidity; (b) air outlet temperature.

4. Conclusions

In the paper, it established a dynamic model to get the transient performance of the dehumidifier. Some findings were highlighted as follows: (1) Air outlet humidity and air outlet temperature showed almost the same sensitivity to the change of air inlet humidity. (2) The response time for the dehumidifier to the increase of air velocity was much shorter than to the change of air temperature and humidity. (3) For the dehumidifier of adverse current configuration, there was not any lag for both outlet parameters after the change of solution parameters.

Author Contributions: D.Z. and Y.C. established the simulation model; Y.L. wrote the UDF files, analyzed the data and wrote the paper.

Acknowledgments: The work described in this paper was supported by a grant from the Research Grants Council of the Hong Kong SAR, China (UGC/FDS25/E10/16). The authors appreciated the financial supports.

Conflicts of Interest: The authors declare no conflict of interest.

References


© 2018 by the author. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).