Abstract

As a broad and complex topic, energy efficiency has drawn an intensive attention in research community. Air Conditioning and Mechanical Ventilation (ACMV) systems in Singapore consume a substantial portion of energy in commercial buildings. Prioritizing high energy-efficiency ACMV system will deliver dramatic energy savings. Compared with conventional mechanical based air dehumidification schemes, liquid desiccant dehumidification system (LDDS) exhibits many advantages and demonstrates its superiority. Dehumidifier and regenerator are two major parts in LDDS, where the dehumidification and regeneration take place. Regenerator re-concentrates the liquid desiccant solution which is diluted by absorbing the excess moisture in the dehumidifier. Majority of energy is consumed by regenerator in system operation in order to keep a suitable regenerating rate. Therefore, this thesis tries to put effort on energy saving of regenerator, which mainly focus on waste heat recovery, modeling, design and operating optimization and performance evaluation. The main contributions of this thesis are summarized as below:

1. The improvement of energy utilization efficiency in regenerator can reduce the amount of energy required to attain demanding regenerating performance. This thesis employs the waste heat recovery technique to increase the energy utilization efficiency of regenerating process. In the regenerator, the direct emission of the exhausted regenerating air, which holds high temperature and humidity, causes a great loss of heat. Thus, this part of heat can be recovered. Two heat recovery device, Heat Pipe Heat Exchanger (HPHE) and Fixed-plate Heat Exchanger (FPHE) are installed in regenerator to transfer heat from the exhausted regenerating air to preheat the incoming air continuously. For the purpose of analyzing the heat recovery process, hybrid heat recovery model is established and validated experimentally. The model is simple and does not need iterative computation. It can be used to monitor and optimize the heat recovery performance in regenerator. The heat recovery efficiency under different working conditions of HPHE and FPHE can be predicted with the hybrid model.

2. To evaluate and compare the regenerator of Liquid Desiccant Dehumidification System (LDDS) without and with heat recovery, the performance analysis is conducted by hybrid heat transfer, mass transfer and heat recovery models, and the simulation results are then

validated by the experimental results. Regenerator without heat recovery, with 4 rows HPHE, with 8 rows HPHE and with FPHE are compared to investigate the relationship between heat recovery rate and the additional fan energy consumption caused by the existence of heat recovery device. Many indexes are defined as the comparing criteria. Effects of air mass flow rate on the regenerating and heat recovery performance are also discussed. The results show that the numerical computation is effective and accurate. With heat recovery device, the regenerating performance is in general improved.

3. Heat recovery device can recover waste heat and save the energy consumption of regenerator. However, its existence causes additional pressure drop. Other than heat recovery device, the structured packing is filled in regenerator tower to increase the contact area between regenerating air and liquid desiccant. It induces dramatic pressure drop due to the remarkable flow resistance. The dimension of structured packing, such as optimal height and diameter, affects the regenerating performance and pressure drop greatly. Optimal geometric dimension of packing can provide sufficient regenerating performance with acceptable pressure drop. Besides the design parameters in the optimization, operating parameters, especially air flow rate, also plays a significant role in energy saving and pressure drop. In order to find out the trade-off way between the regenerating performance and pressure drop, the multi-objective optimization is performed with pressure drop model, heat recovery model, heat transfer model and mass transfer model.