Abstract

Title: Modeling and control of energy efficient liquid desiccant regeneration system at vacuum condition

Liquid Desiccant Dehumidification System (LDDS) has been one of the potential alternatives to replace the conventional mechanical dehumidification system in building air conditioning system due to its higher energy efficiency. LDDS is able to shift the electrical energy towards the renewable or low grade energy and improve indoor air quality with better humidity control. However, the conventional adiabatic packed bed requires higher regeneration temperature to regenerate higher desiccant solution concentration. This limits the use of the renewable or low-grade energy as the heat source in the regeneration system of LDDS. Therefore, a novel Absorption-based Liquid Desiccant Regeneration (ALDR) system which operates in vacuum condition is proposed in this work.

In our research work, the feasibility of the proposed desiccant regeneration system operating in vacuum condition is our concern. Therefore, the system regeneration performance and the regeneration temperature should be determined to validate its feasibility and compared with other existing desiccant regeneration systems. The ALDR system is first designed and built in the laboratory. A Singapore patent application of the proposed ALDR system has been filed. The regeneration performance of the ALDR system is then investigated and a regeneration performance prediction model is then developed. The prediction model is verified with the experimental data and the experimental results agree well with the predicted results. In addition, the regeneration performance of the newly proposed ALDR system is also compared with those of the conventional adiabatic type liquid desiccant regenerator from available literatures. The regeneration temperature of the ALDR system is found to be significantly less than those of other existing desiccant regeneration systems which is around 35-40^{o}C.

The difference between the evaporation and condensation rate at respective generator and condenser side is found to be affecting the regeneration performance and energy efficiency of the ALDR system. Therefore, the system energy efficiency is closely dependent on the thermodynamic states of desiccant solution, and heating and cooling sources. A proper regulation of the relevant thermo-physical variables and dynamic behavior can result in energy-efficient operation of the ALDR system. These variables will be modulated so as to affect the mass transfer process and hence increase the regeneration performance of the ALDR system at maximum energy efficiency. Therefore, the role of each component in affecting the overall system behavior must be clarified in advance. In order to realize the control of the various inputs so as to achieve the control objectives, an understanding of the dynamic behavior in each component of the ALDR system is indispensable.

An effective model is developed to describe the dynamics of the ALDR system for the purpose of designing a model-based control applicable to the system. The dynamic model is developed based on the internal and external enthalpy balances and mass balances in the components and it accounts for dynamic behavior due to the heat and mass transfer process in the components. This approach is simpler as detailed enthalpy at each state point can be avoided. The developed dynamic model is verified using the data obtained from the experimental platform built in the laboratory.

The dynamic response of the simulation results are in good agreement with the experimental data. This model is able to predict the relevant parameters such as the temperature, concentration and mass flow of the desiccant solution and also temperature of the heating and cooling sources when a step change of inlet water temperature is applied to system. The developed model is then used to design a control strategy to balance the evaporation and condensation rate in the enclosed regenerator tank so as to achieve the control objective of increasing the energy efficiency of the system. Control methods for the regeneration process in ALDR system are presented and the control performance of the proposed system is also investigated.