

Combined Sorption Dehumidification and Evaporative Cooling (CoSDEC) for Simultaneous Dehumidification and Cooling Using Ultra-Low- Grade Heat

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論 文 名	Combined Sorption Dehumidification and Evaporative Cooling (CoSDEC) for Simultaneous Dehumidification and Cooling Using Ultra-Low-Grade Heat (超低品位熱を利用した同時除湿・冷却のための複合収着除湿・蒸発冷却)			
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論 文 審 査 の 結 果 の 要 旨

Thermally-driven desiccant and evaporative cooling-based air conditioning technologies are promising alternatives to compressor-based systems due to its separate handling of latent and sensible loads. Achieving comfortable levels of humidity and temperature, however, requires regeneration at high temperatures which limit the dehumidification performance of the desiccant and hence the downstream evaporative cooling system. Dehumidification with internal cooling can decrease the operating and regeneration temperature but is limited by the temperature of the coolant and its heat capacity. The optimum system configuration and operation require intensive study on the complex system.

In this context, the study proposed the concept of Combined Sorption Dehumidification and Evaporative Cooling (CoSDEC) where air was simultaneously dehumidified via sorption and cooled via evaporative cooling in a pair of adjacent desiccant-coated and water-wet channels. A CoSDEC proof-of-concept was designed, fabricated, and tested for its performance, and then the dynamic heat and mass transfer were analyzed mathematically. The main findings of the study are summarized below.

- By a 900 mm prototype employing mesoporous silica gel desiccant regenerated at 40 °C. It was proved that the proposed system had remarkably high performance in terms of dehumidification and cooling. It was also shown that further enhancements were achieved by controlling flow velocity.
- Heat and mass transfer analysis revealed that pressure swing adsorption and pressure swing evaporation were the governing moisture transfer mechanisms at the entrances of the desiccant and wet channels, respectively, whereas heat exchange between exothermic sorption and endothermic evaporation allowed further mass transfer downstream via

temperature swing adsorption and temperature swing evaporation, respectively. The utilization of the pre-dehumidified and precooled air as the working air in a single-stream configuration of CoSDEC resulted in the sustained high rates of heat and mass transfer at the desiccant channel exit, which led to the continuous decrease in temperature and humidity.

- Parametric analysis of CoSDEC predicted that further performance enhancement could be achieved by increasing the rate of sorption to rate of moisture inflow by decreasing air flowrate, increasing regeneration temperature, increasing system length, decreasing the channel hydraulic diameter, increasing the amount of desiccant, and to some extent, increasing the thermal conductance of the plate. These strategies resulted in a thermal COP range of 1-2 and continues to increase with increasing cycle time.

In conclusion, the study proposed a novel dehumidification and cooling system, and revealed the performance characteristics based on the heat and mass transfer analyses. The main findings of the study will lead to a carbon neutrality of air conditioning technologies and contributed greatly to the progress of thermal engineering. Therefore, the author of the thesis deserves to receive Doctor of Philosophy.