THERMOPHYSICAL AND ADSORPTION CHARACTERIZATION OF FUNCTIONAL AND PORE MODIFIED ADSORBENTS

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論 文 内 容 の 要 旨
Thesis Summary

Cooling and refrigeration systems are inevitable in chemical productions, pharmaceutical industries, data center cooling, factories and manufacturing plants, preservation of food/beverage/agricultural products, and to attain thermal comfort in residential/commercial buildings. Most of the conventional cooling/refrigeration systems are vapor compression based and consume a huge amount of electricity. This electricity is generated from centralized power plants which are predominantly fossil fuel based and ultimately releases greenhouse gases during power generation. Hence, conventional cooling/refrigeration systems are indirectly accountable for global warming by consuming electricity. Moreover, the working fluid of those systems are basically high GWP (global warming potential) refrigerants. A significant percentage of working fluid is leaked from the high-pressure side of the system and thus directly contribute to global warming. The summation of indirect and direct warming impact namely, total equivalent warming impact (TEWI) of these systems are alarmingly high. A high performance thermally-powered adsorption cooling system (ACS) can resolve this critical environmental concern.

From the above mentioned perceptions, this research work rigorously focuses on – (i) quantitative assessment of global warming: conventional vs. adsorption cooling systems, (ii) adsorbent characterization (surface area, pore volume, pore size distribution, specific heat capacity) for next generation cooling systems, (iii) modification of pore structure to enhance the quality of carbon based adsorbent, (iv) investigation of adsorption characteristics of novel adsorbent/adsorbate pairs.

A quantitative assessment of global warming has been performed by evaluating the TEWI for conventional and adsorption cooling systems considering similar operating conditions. The results reveal that, the environmental adversity of existing conventional cooling systems is significantly higher with compared to adsorption cooling systems. Employment of an adsorption cooling system instead of a conventional one in

residential applications can cut the environmental impact to half or even more than that. Approximately, 70% to 85% global warming impact reduction is conceivable for medium and low temperature applications. However, COP values of the current adsorption cooling systems are very poor. There are huge prospects to enhance the performance by deploying superior adsorbent/adsorbate pair. Therefore, next objective of this research is to determine various porous and thermophysical properties of adsorbent materials to identify the best adsorbent.

High surface area and pore volume of adsorbent leads to higher adsorption capacity. Whereas, low specific heat capacity is expected for faster desorption. Hence, porous properties (surface area, pore volume, pore size distribution) and specific heat capacity of six different types of silica gel (total thirteen samples including subcategories) have been experimentally investigated with temperature ranging from 30 to 100 °C. Specific heat capacity of four types activated carbon (Maxsorb III, H_2 treated Maxsorb III, KOH–H_2 treated Maxsorb III, KOH treated spherical phenol resin) and two thermal conductivity enhancer (EC–1000 and EC–1500) have been measured. The specific heat capacity data are successfully fitted with Green and Perry equation. These porous properties and specific heat capacity data are essential to design and simulate adsorption cooling systems.

As of the adsorbents for adsorption heat pump (AHP) application, activated carbon sample possesses very high surface area and high adsorption affinity for refrigerant vapor. However, they contain a significant percentage of ultramicropores (< 0.7 nm). Commonly used refrigerant molecule clusters are unable to enter into such tiny pores and no adsorption occurs there. Hence, these ultramicropores decrease thermal conductivity and increase specific heat capacity of the material which ultimately degrade the performance of an adsorption cooling system. Chemical vapor deposition (CVD) of various carbonaceous materials has been performed at elevated temperature to block those unusable pores. Porosity analysis of these modified activated carbon samples has been carried out to compare the adsorbent quality improvement than parent sample. Pyrolization of methane (T_{pyr} = 1000 °C, □ = 50 mL/min, t = 30 min) and benzene (T_{pyr} = 800 °C, □ = 25 mL/min, t = 10 min) removes the ultramicropores and most of the mesopores in activated carbon and improves its suitability in AHP applications.

Finally, adsorption isotherm and isosteric heat of adsorption of two novel adsorbent/adsorbate pairs have been investigated. The selected working fluid is HFC32 having low GWP and two adsorbents are activated carbon synthesized from biomass (mangrove wood and waste palm trunk). The experimental data shows remarkably high uptake for both the pairs. The Dubinin Astakhov (D–A) and Tóth models are efficaciously employed to correlate the adsorption isotherms of the assorted pairs. A modified Clausius–Clapeyron model is adopted to determine the isosteric heat of adsorption (Q_{st}) data. Change of Q_{st} with respect to surface coverage is also reported.