

Study on Finned Tube Type Adsorber Employing Activated Carbon-Ethanol Pair for Cooling Applications

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(活性炭-エタノール系吸着冷凍システム用フィンチューブ吸着器に関する研究)

Title

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論 文 内 容 の 要 旨

Thesis Summary

Cooling system has great importance for growing and sustainable global economy. It contributes significantly to food and drug conservation, thermal comfort, etc. However, greenhouse gases (GHG) emissions from this sector represent 7.8% of total emissions. Conventional vapor compression system employs refrigerants with high global warming potential (GWP) such as CFCs, HCFCs and HFCs gases produced 37 % of the emissions and the remaining 63% is caused indirectly by the energy consumption of conventional cooling systems.

In this context, to consider energy and environmental conservation, adsorption cooling systems (ACS) can be a feasible alternative to vapor compression cooling systems. ACS is driven by low-grade waste heat (below 100°C) or solar thermal energy. Moreover, they employ natural and environment-friendly refrigerants such as water, ethanol, methanol, ammonia, CO₂, etc. Therefore, the widespread development of adsorption cooling system will help to solve various energy and environment-related problems.

Although ACS has several advantages, but it is often impaired by low performance and bulkiness issues comparing to conventional vapor compression system. Consequently, these issues hinder the thermally driven ACS from the widespread commercialization. Therefore, one of the big challenges for ACS is to increase the system performance. There are three main ways to improve the system performance such as material's adsorption characteristics improvement, heat transfer improvement in the adsorber bed and system parameters optimization. Therefore, one of the key ways of performance improvement is to enhance the heat and mass transfer inside the adsorber bed Adsorber heat exchanger design improvement and thermal conductivity enhancement of adsorbent are two common techniques to ensure good heat transfer inside the bed.

In this present work, adsorption characteristics of spherical activated carbon (SAC) and methanol pair have been checked experimentally by gravimetric adsorption measurement apparatus. The results showed that the effective adsorption amount of methanol at 30°C temperature is lower than that of ethanol. Conversely, though the effective adsorption amount is high in case SAC-ethanol pair, however, methanol showed better performance below 80°C desorption temperature as the heat of evaporation in case of methanol is higher than that of ethanol.

Besides, an extensive literature review on the heat transfer improvement in the adsorption bed has been made to highlight the importance of heat exchanger design parameters on system performance. Besides, different types of existing heat exchanger design have been reviewed. It is found that commonly used heat exchanger in adsorption system is finned and tube type adsorber.

The main objective of this study was to find out the optimum fin shape for finned tube type adsorber. However,

adsorber bed design optimization is very difficult to perform experimentally due to higher cost and huge time requirement. Therefore, a two-dimensional axisymmetric CFD model has been developed for the performance investigation of finned tube type adsorber using activated carbon and ethanol as the working pair. The operating conditions of the cooling system were almost 15, 20 and 80 for evaporation, cooling and heating temperatures, respectively. The developed CFD model showed good agreement between experimental and simulated temperature and pressure profiles.

Then, cycle time optimization has been done for finned type adsorber employing activated carbon-ethanol pair with the developed CFD model. The cycle time is considered in the range of 600s to 1400s. The optimum cycle time was found 800 s and the corresponding evaluated SCP and COP were found to be 488 W/kg and 0.61, respectively.

Finally the performance investigation has been carried out for different fin specifications through CFD simulation. In this regard, five different domains were considered for activated carbon-ethanol pair for the cycle time 800s. In case-1, fin pitch is considered constant at 3.7 mm while fin height was varying 5, 10 and 15 mm. In case-2, fin height is 10 mm constant but fin pitch was varied 2, 3.7 and 5.5 mm. In both cases, fin thickness was constant 0.53mm. The optimum fin specifications are found almost 4 mm for fin pitch and 10 mm for fin height considering the five studied domains and the corresponding evaluated SCP and COP were 568 W/kg and 0.63, respectively.