ME – PhD Thesis Defence

Studies on Two-Stage Air-Cooled Silica gel + Water Adsorption Cooling System

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ABSTRACT

Adsorption cooling systems are evolving as promising complements to conventional vapor compression refrigeration (VCR) systems because of their ability to utilize low-grade heat sources such as industrial waste heat, solar, and shallow geothermal. Of all solid-vapor adsorbent + adsorbate working pairs available, silica gel + water system is widely used in adsorption chillers owing to its low regeneration temperatures (as low as 50°C). For a given working pair, an adsorption chiller's performance depends upon the system operating conditions, adsorber bed design, and the adsorbent particle size and shape. The aim of the current study is to experimentally investigate the influence of input parameters and the adsorbent particle size on the performance of an air-cooled silica gel + water adsorption cooling system.

The initial part of the studies focuses on the numerical modeling of the adsorber bed. As the adsorber bed is a critical component of an adsorption cooling system, its systematic design and analysis are essential for maximizing the system performance. With this objective, a 3D CFD model of the shell and tube-based adsorber heat exchanger is developed and analysed for the heat and mass transfer characteristics using COMSOL Multiphysics. The effect of critical depth on the vapor flow in the adsorber bed on its uptake capacity, the effect of particle diameter, and ambient temperature on the performance of the adsorption chiller is evaluated numerically. In order to understand the effect of operating parameters on the entire adsorption cooling system, a system simulation framework was developed to perform a steady-state simulation of the silica gel + water adsorption refrigeration system.

The latter part is dedicated to the experimental investigation of the performance of the adsorption cooling system in a two-bed mode both in single-stage and two-stage operations using silica gel of 0.8 mm radius as the adsorbent. For single-stage operation, the merit of employing unequal sorption duration was investigated. The performance in the two-stage operation was investigated by varying the source temperature, half-cycle time, and sink temperature. Also, unequal source temperature for the lower and upper stages on the chiller performance was elucidated. The effect of adsorbent size on the chiller performance was investigated through experimental studies in single-stage operation using silica gel particles of 0.23 mm equivalent radius. Based on these experiments, the adsorber bed design criterion for smaller adsorbent particles which are non-spherical and with non-uniform size distribution is recommended.

ABOUT THE SPEAKER

M. Reddy Madhuri is a Ph.D. student in the Department of Mechanical Engineering, IISc, Bangalore. She is working with Prof. Pradip Dutta in the Heat Transfer laboratory. She graduated with a Bachelor's degree in Mechanical Engineering from Sri Venkateswara University College of Engineering, Andhra Pradesh, and obtained her Master's degree in Aerospace Engineering from IIT MADRAS in 2014. Prior to joining IISc, she worked at GE Aviation. Her broad research interests include Adsorption, CO_2 capture, Thermal management, and Computational methods for heat and fluid flow.