

Fundamental Studies on Adsorption of Water Vapor by Silica Gel

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ABSTRACT

Adsorption is surface phenomenon governed by thermodynamic variables such as pressure and temperature. During the adsorption process, molecules of a substance termed as adsorbate, usually in gas or liquid phase accumulate at the surface of another liquid or solid substrate known as adsorbent. Accumulation of adsorbate at the surface of adsorbent reduces the pressure and concentration of adsorbate. This swing in pressure and temperature due to adsorption finds numerous engineering applications such as Vapor Adsorption Refrigeration systems, drying and extraction units etc. Amongst the many adsorbent-adsorbate pairs, silica gel-water pair is widely used for waste heat or solar heat driven adsorption cooling systems. To evaluate performance of a silica gel-water adsorption cooling system, knowledge of adsorption equilibrium and kinetics governing the uptake of adsorbate is needed. Among the various models available in literature, adsorption equilibria characteristics of silica gel-water pair is best predicted by Tóth's adsorption isotherms, with the kinetics of adsorption being described by Linear Driving Force (LDF) and Langmuir models. Both LDF and Langmuir models are semi empirical with equilibrium constants obtained using bulk experimental measurements.

The thesis explores applicability of bulk adsorption models for a single silica gel particle. The first part of the research provides an overview of bulk experimental uptake measurements using a strain gauge sensor that records the change in weight of adsorbent during adsorption in diffusive and convective environments. Measurements are recorded for a range of Reynolds numbers varying from 0-75 (based on particle diameter). These measurements are complimented by non-intrusive optical diagnostics techniques such as shadowgraph, TDLAS and PIV. Non-invasive measurements provide fundamental insights into the adsorption kinetics in addition to corroborating the efficacy of bulk uptake measurements. TDLAS is used to measure concentration gradients of water vapor in radial and azimuthal directions, while shadowgraphs provide the growth of the adsorbate layer around the silica gel particle. Micro-PIV provides information about the flow inside the water drop evaporating in the vicinity of the silica gel particle. This information is used to obtain evaporation rate for the water droplet. Subsequently, a multi-physics model using Langmuir kinetics is developed and solved using COMSOL to compute uptake kinetics and diffusion rates. It is found that the CFD results reasonably predict the experimental data for very low Reynolds number (0-1) flows, but substantially deviate for higher Reynolds numbers. These findings suggest the LDF model derived using bulk uptake measurements may not be ideal for predicting the kinetics of sparsely populated silica gel adsorption beds.

ABOUT THE SPEAKER

Gitesh Chaudhari is a MSc Research Student in the department of Mechanical engineering at IISc Bangalore, working Prof. Pramod Kumar. He completed his undergraduate in Mechanical Engineering from College of Engineering, Pune.

