

ABSTRACT

Soepriatna, Nicholas H. Ph.D. Purdue University, May 2015. Development, Design, and Optimization of Thermal Simulated Moving Bed Concentrator Process. Major Professors: Phillip C. Wankat and Nien-Hwa Linda Wang.

Several configurations of thermal Simulated Moving Bed (SMB) concentrator are studied using both the Standing Wave Design (SWD) method and detailed Aspen Chromatography simulations. The studied configurations are four-zone thermal SMB, two-zone thermal SMB concentrator (TSMBC), and two-zone TSMBC Cascades. Design and optimization methods based on the SWD method are developed for these systems.

The SWD method is modified and expanded for thermal SMB systems. The SWD method directly determines the optimum operating parameters and does not require experimental or simulation trials. These parameters include the zone flowrates and port switching time that gives the minimum amount of desorbent use.

A novel operation scheme for four-zone thermal SMB called thermal SMB fractionator and concentrator (TSMB-FC) is developed for fructose/glucose and p-xylene/toluene separations. For very dilute feed and linear isotherms, TSMB-FC system can simultaneously separate binary mixtures with high purities and yield as well as produce pure solvent contained in the feed. In very dilute, linear p-xylene/toluene system at a feed concentration of 0.008 g/L, the extract and raffinate products are concentrated to

80 fold and 10 fold, respectively, with 99.99% purity, and recover more than 50% of the solvent used in the feed.

For higher feed concentrations and non-linear isotherms, the SWD method readily determines conditions that allow thermal SMB systems to concentrate products and produce pure solvent. In fructose/glucose, which has weakly temperature dependent adsorption, TSMB-FC increases product concentrations by 25% with 50% decrease in desorbent use. In p-xylene/toluene systems at 0.05 g/L, TSMB-FC increases product concentrations by 10 fold while recovering 80% of the solvent in the feed.

The two-zone TSMBC system is designed to concentrate a dilute solute while producing a pure solvent. The SWD methods determine the optimum zone flowrates and port switching time that give the minimum energy use. For very dilute water systems containing phenolic contaminants at concentrations less than 0.01 g/L, TSMBC is 80% more energy efficient than a single-stage evaporator, and has twice the productivity and orders of magnitude higher concentration compared to temperature swing adsorption (TSA). At higher feed concentrations, TSMBC and TSA have comparable product concentration and productivity performance

TSMBC cascades are developed to increase product concentration or to increase solvent purity. Operating cost is the major contributor for the cost of TSMBC systems. Product concentration can be increased by several folds by increasing the TSMBC temperature gradient and at lower cost, but the operations need to be performed with more caution. For specified product concentrations and production scale, TSMBC cascades reduce the cost of solvent purification by 80% compared to a single TSMBC.