Summary of doctoral dissertation: "Modeling of volatile organic compounds recovery in cyclic pressure thermal swing adsorption PTSA on multilayer adsorption bed" by Tomasz Aleksandrzak

The theoretical and experimental research and simulation of cyclic pressure thermal swing adsorption (PTSA) dynamic are presented. This process was carried out in an adsorption column containing a two-layer adsorbent bed. In this process, volatile organic compounds (VOCs) were removed and recovered from the dry air stream. The full cyclic PTSA process consists of four successive stages: VOCs adsorption, adsorbent bed heating, adsorbent bed regeneration (VOCs desorption), and adsorption bed cooling. The work focused mainly on the two important from technical aspects stages, namely VOCs adsorption and adsorbent bed regeneration.

The dissertation is divided into three main parts. In the first one, a review of the literature concerning of adsorbents and multilayer adsorption beds, models of single- and multicomponent adsorption equilibrium, and cyclic adsorption processes were presented. Special attention was turn into the mathematical models of the PTSA process appearing in the subject literature. The measurement of one-component adsorption isotherms and PTSA process dynamics are presented in next part. In the part three the mathematical model of the cyclic PTSA process and the computer simulation results validation on the basis of the experimental results were presented.

Adsorption equilibrium experimental studies concern single-component isotherms of toluene, propan-2-ol, and water on three commercially available adsorbents: RD-03 silica gel, Sorbonorit 4 activated carbon, and HiSiv 3000 zeolite were presented. The isotherms were measured at various temperatures: 20, 40, 60, 75, 100, 120, and 140°C. Constants of the adsorption isotherms of: Langmuir, Toth, Langmuir-Freudlich and Dubinin-Astachov models were fitted to experimental data using nonlinear regression analysis.

The main part of the experimental research concerns measurements of the PTSA process dynamics on a quarter technical scale. Twelve PTSA cycles were performed on a bed consisted of two layers. The first layer was Sorbonorit 4 activated carbon, and the second one was HiSiv 3000 zeolite. Toluene was adsorbed in the first four cycles, propan-2-ol was adsorbed on the next four cycles, and in the last four cycles were performed for a mixture of toluene and propan-2-ol. In the adsorption step (first stage of the cycle) all VOCs components were adsorbed at pressures in the adsorption column appearing in two levels of variability: 3,5 and, 5 bar.

In the second stage (adsorption bed heating) the bed was heated by means of silicone oil flows in a column jacket. The temperatures appears on two levels variability: 110 and 130°C. During the next process stage (adsorbent bed regeneration), the adsorbent bed was purged with a small stream of inert gas (air) to facilitate the elimination of VOC from the adsorbent particles. A high concentrated VOCs gas was directed to the condenser, where VOCs were condensed. The temperature of the cooling liquid in the condenser was -20°C. The amount of condensate was measured to determinate the VOC recovery efficiency.

The paper presents a comprehensive mathematical model of non-equilibrium, non-isothermal and non-adiabatic cyclic PTSA process with multilayer bed, taking into account mass and heat axial dispersion. The resistance of heat transfer between the gas phase and adsorbent particles was also taken into account. Mathematical model equations were solved using a numerical method of lines (NMOL). The validation of the computer simulation results of PTSA process dynamic was performed on the basis of experimental results obtained. Fairly good agreement of the simulation results with the experimental ones was achieved.

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