§3. Experimental Study on Optimization of Pressure Swing Adsorption Process for Hydrogen Isotope Separation

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We have been developing a hydrogen isotope separation process by pressure swing adsorption (PSA) method using synthetic zeolites, aiming at applying it to an environmental tritium safety system such as of removal of tritium from LHD exhaust gases during deuterium experiments or of volume reduction of tritiated-hydrogen waste gas storage by extraction/release of tritium-purified hydrogen volume. The experimental and analytical results obtained till now have convinced us of this PSA process available for practical use. In the last two years, we could verify experimentally that our PSA process realizes hydrogen isotope separation and enrichment. As the next step, we have started the study on optimization of the PSA process, in this fiscal year.

On Improvement of Mass Transfer in Zeolite Packed-Bed

Influence of the longitudinal dispersion in packed-beds with spherical zeolite particles on the over-all mass transfer volumetric residence $1/K_F a_v$ could be analyzed. The mass transfer resistance in this experimental process operation is explained with the following relation:

$$\frac{1}{K_F a_{vB}} = \frac{1}{k_F a_{vB}} + \frac{\varepsilon_B D_L}{u^2}\left(1+\frac{\varepsilon_B}{\beta\gamma}\right)^2 + \frac{r_0^{\ 2}}{15(1-\varepsilon_B)D_{P,eff}} + \frac{x_0^{\ 2}}{15\beta\gamma D_{c,eff}} \quad (1)$$

where on the right side the first term is the partial volumetric resistance in the boundary-film on particle surfaces, and the second term indicates the resistance corresponding to the effect of the longitudinal dispersion. The third and fourth terms are of the mass transfer within particles: the former is the resistance in macro-porous media and the latter is that in micro-porous media identical to the crystalline diffusion resistance in zeolite crystals.

The last two terms are independent of the superficial gas velocity u in a packed-bed column. The first and second terms are affected by the velocity. The experimental overall resistance exhibits the dependence on superficial velocity. This dependency results almost in the second term because the first term is negligibly small under the experimental conditions. The corresponding resistance of the second term is inversely proportional to the square of superficial velocity when the dispersion coefficient D_L is constant. This would appear in the turbulent flow region where the dispersion behaves stably. In the laminar flow region where the back-mixing occurs, the dispersion coefficient is proportional to the velocity. Accordingly, the corresponding resistance in this region would be inversely proportional to the velocity. These dependencies are endorsed in the experimental results as shown in Fig. 1.

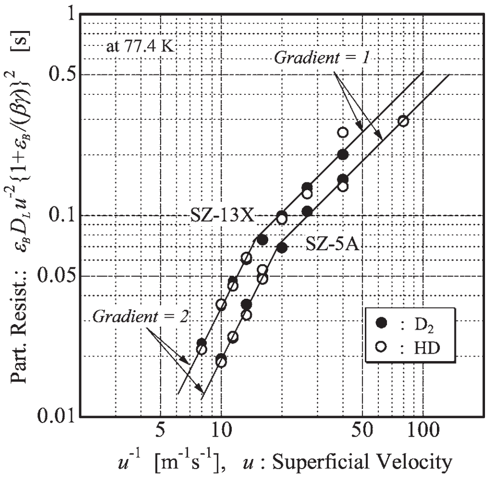

Fig. 1. Dependence of mass-transfer volumetric resistance on superficial velocity.

Verification of PSA Process under Successive Operation

For the purpose of examining the effective pressure and period in evacuation process, we carried out experiments of successive operation of the PSA process system using a SZ-5A or 13X packed-bed, one batch of 4 cycles and that of 10 cycles. The experimental results show the mass balances consistent to the analytical estimation based on the static and kinetic adsorption characteristics of hydrogen isotopes onto the zeolites at the liquid-nitrogen temperature 77.4 K.

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