§4. Water Vapor Adsorption by Honeycomb-Type Zeolites for Tritium Removal System

Tanaka, M., Uda, T.

Tritium is a radioactive hydrogen isotope that decays to ^{3}He by emitting a beta particle with a half-life of 12.33 years. The maximum and average energies of the beta particle emitted from tritium are 18.6 keV and 5.69 keV, respectively. Moreover, tritium has a high coefficient of diffusion, allowing it to diffuse through metals, and thus, escape containment. Tritium that leaks out should be rapidly removed from the atmosphere. The most widely used atmospheric tritium removal technique is oxidation to water by catalytic oxidation reactors, followed by adsorption. This conventional tritium removal system has been used in tritium handling facilities worldwide and found to have adequate performance. However, tritium removal systems used for safety management in fusion power plants must achieve large processing volumes and throughputs and have large pressure drops. The pressure drop in the system determines the load on the pumping system. To reduce the pressure drop, a tritium removal system using a honeycomb-type material has been proposed. Advantages of the use of honeycomb-type materials compared with conventional pellet-type materials include a lower pressure drop, easier maintenance, and a more uniform flow. In previous studies, we investigated the oxidation performance of a honeycomb-type catalyst for H_2 and CH_4 in air.[1)] The results revealed that the honeycomb-type material produced a lower pressure drop than a pellet-type material and had nearly the same oxidation performance as a conventional pellet-type catalyst. However, for the tritium removal system, the adsorption process after catalytic oxidation must also employ a honeycomb shape. In the present study, we evaluated the effect of the cell density and zeolite content of the honeycomb-type adsorbents on the water vapor adsorption properties from the viewpoint of practical use.

The honeycomb-type zeolite was prepared by Nagamine Manufacturing Co. Ltd. The specifications of the zeolite samples are summarized in Table 1. The honeycomb adsorbents were prepared by mixing zeolite and a clay binder in specific ratios. The test samples were 20 mm in diameter and 30 mm in length. The cells in the honeycomb were square shaped. The test sample was then heated to about 350 °C for 3 h to desorb the residual water under dry N_2 gas flow before each experiment. The adsorption properties were evaluated based on the breakthrough method using a flow-type fixed-bed apparatus under various temperatures. Wet N_2 gas was introduced into the test sample at a constant flow rate. The adsorption capacity of the adsorbents was estimated to integrate the area between the normalized concentration $c/c_0 = 1$, which is the ratio of the outlet and the inlet water vapor concentration and the breakthrough curve over the entire period.

The adsorption capacity of the honeycomb-type adsorbent was proportional to its zeolite content. These findings indicate that increasing the zeolite content is an effective method of improving the adsorption capacity of the honeycomb-type adsorbent. However, the honeycomb-type adsorbent that contained 80% zeolite was inferior to the adsorbent that contained 50% zeolite with respect to the precision of molding due to the slight distortion of its cross-sectional shape. The primary cause of this distortion may be compatibility with the binder material and that between the binder and zeolite content. Optimization of the binder material and the molding conditions should be investigated in a future study to enable the solidification of the honeycomb-type zeolite.

The adsorption properties of the honeycomb-type adsorbent samples (except for the sample containing 80% zeolite) are summarized in Table 2. The adsorption capacities of the honeycomb-type adsorbents that contained 50% zeolite were almost the same, despite the zeolite type and cell densities. However, H-4A-200-50 had a larger adsorption capacity per unit volume than H-4A-300-50 because the honeycomb-type zeolite with 200 cells per square inch (CPSI) has thicker walls and higher dry weight than that with 300 CPSI. Therefore, based on their precision of molding and apparent adsorption capacities, H-4A-200-50 and H-5A-200-50 are considered to be suitable for use in a tritium removal system of a fusion power plant.

1) Uda, T., et al., Fusion Engineering and Design, **83**, (2008), 1715.

Table 1. The specifications of adsorbent samples

Shape	Types of zeolite	Cell density [CPSI]*	Content of zeolite	Notation
Pellet	MS-4A	-	-	P-4A
Honeycomb	MS-4A	300	50%	H-4A-300-50
Honeycomb	MS-4A	200	50%	H-4A-200-50
Honeycomb	MS-5A	200	50%	H-5A-200-50
Honeycomb	MS-5A	200	80%	H-5A-200-80

*CPSI: Cells per Square Inch

Table 2. Comparison of the specifications of adsorbent and the adsorption properties

Adsorbent	H-4A-200-50	H-4A-300-50	H-5A-200-50	P-4A
Volume [cm^3]	9.4			
Dry weight [g]	5.62	4.72	5.87	7.88
Adsorption weight [g] 305K, 1.2 kPa-H_2O	0.46	0.38	0.46	1.41
Adsorption capacity [g/g]	0.082	0.081	0.078	0.18
Apparent adsorption weight [g/cm^3]	0.049	0.041	0.048	0.15