Preliminary hydrogen cryo-sorption and desorption test using molecular sieve bed

Mu-Young Ahn[a]*, Soon Chang Park[a], Seok-Kwon Son[a], Seungyon Cho[a], Yi-Hyun Park[a], Youngmin Lee[a]

[a] Korea Institute of Fusion Energy, Daejeon, Republic of Korea
**Corresponding author: myahn74@kfe.re.kr*

1. Introduction

To effectively recover tritium produced from breeding blankets in a fusion reactor, several processes have been suggested. Among them, cryogenic adsorption, or cryo-sorption, is regarded as a candidate process due to its high hydrogen adsorption performance in low hydrogen and high helium concentration environment as envisaged in purge gas for breeding blankets [1]. The authors have shown that cryo-sorption performance with a large-scale molecular sieve having 50.7 kg of Molecular Sieve 5A (MS5A) inside of it is consistent and well comparable to that of small-scale experiments [2]. In this study, adsorption and desorption behavior is investigated using the same molecular sieve bed applying two cycles of full adsorption and three days desorption in between. In particular, operability of the large bed is explored with focus on transition between adsorption and desorption.

2. Experimental description

Fig. 1. Layout of PGLoop [2]

Fig. 1 shows the PGLoop facility in which the Cryogenic Molecular Sieve Bed (CMSB) module is installed. Firstly, the set-up is evacuated and the CMSB is cooled by liquid nitrogen down to 77 K. Then, helium purge gas containing small fraction of hydrogen flows to the CMSB where hydrogen is selectively adsorbed in the bed. If the bed is fully adsorbed, the liquid nitrogen is evacuated and carrier gas recovers desorbed hydrogen from the bed as temperature of the bed increases. Then, the bed is cooled down again for the next adsorption. The first desorption is targeted to three days; two and a half days for regeneration and a half day for preparation of the next adsorption; while in the second the bed is regenerated until full desorption is achieved. A schematic diagram for the experiments and the experimental scenario are described in Fig. 2 and Fig. 3, respectively.

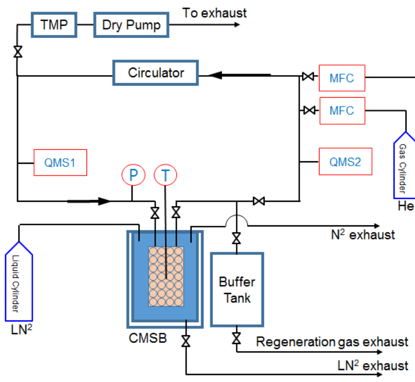

Fig. 2. Schematic diagram for experiments [2]

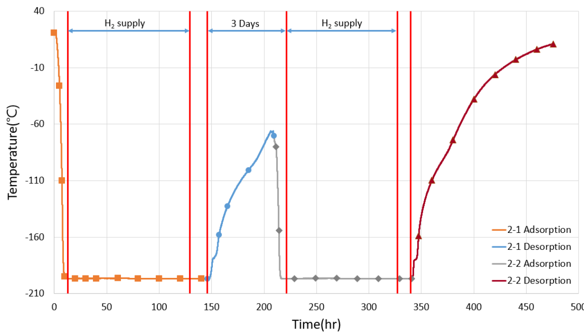

Fig. 3. Two cycles of adsorption and desorption

3. Experimental results

The same condition for two full adsorptions was chosen from the previous study to confirm repeatability of adsorption performance, however two different flow rates with helium sweep gas were considered, Exp.2-1; 20 Standard Liter Per Minute (SLPM) for the first regeneration and Exp.2-2; 40 SLPM for the second one, to investigate impact of flow rates on desorption. Table 1 lists the experimental conditions for the full adsorption and Fig. 4 shows their results, where Exp.2-1 and 2-2 denotes the present results while the other the previous result for comparison. It is confirmed again that adsorption performance is consistent compared to literature values as well as the previous study [2].

Table 1. Summary of adsorption conditions

No.	Total pressure (kPa)	H_2 partial pressure (Pa)	Flowrate (SLPM)	H_2 adsorbed (standard liter)
1-1	120	103	70	382
2-1	120	103	70	379
2-2	120	103	70	379

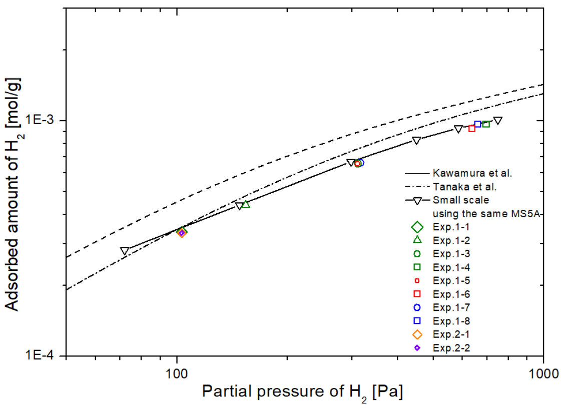

Fig. 4. Adsorption isotherm for hydrogen at 77K

Temperature behavior of the cryogenic bed during the two regeneration is shown in Fig. 5. As the flow rate of Exp.2-2 is higher than that of Exp.2-1, temperature increase of Exp.2-2 is steeper compared to Exp.2-1. Fig. 6 illustrates amount of desorbed hydrogen in terms of pressure measured in the buffer tank. The desorbed hydrogen amount becomes saturated when temperature of the bed approaches around -10 ºC as can be seen in Exp.2-2. Regarding the case of Exp.2-1, temperature of the bed was around -66 ºC at maximum after regeneration of two and a half days, thus the bed was not fully desorbed. Nevertheless, most of adsorbed hydrogen was desorbed as seen in Fig. 6.

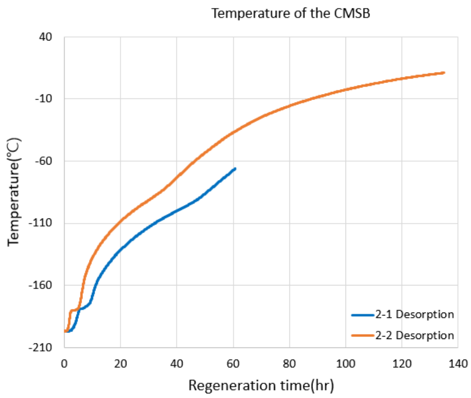

Fig. 5. Temperature of the bed during desorption

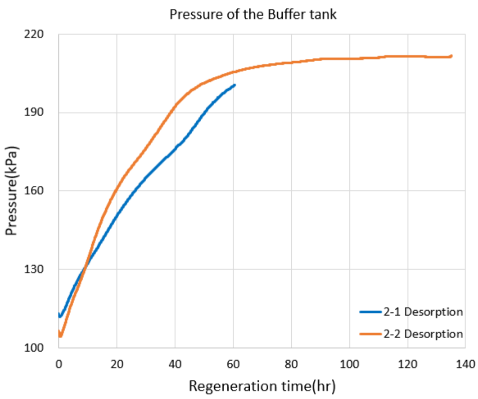

Fig. 6. Pressure of the buffer tank indicating amount of desorbed hydrogen

4. Conclusions

Preliminary test was conducted using the CMSB module of PGLoop facility for two cycles of hydrogen adsorption and desorption. Cryo-sorption performance of the large-scale bed was confirmed again that size effect of beds on hydrogen adsorption is small with the current CMSB design. Desorption performance was studied applying two different flow rates for regeneration of the bed. While desorption efficiency is higher when the higher sweep gas flow rate was applied, the both cases show reasonable performance. However, the experimental results suggest that regeneration time to reach acceptable desorption level which is dictated by operational requirements of a blanket tritium circuit may require more than two and a half days. Further study will be performed to establish operational requirements and scenarios for transition between adsorption and desorption.

Acknowledgments

This work was supported by the R&D Program through the Korea Institute of Fusion Energy (KFE) and funded by the Ministry of Science and ICT of the Republic of Korea (KFE-IN2103).

REFERENCES

[1] R. S. Willms, D. J. Taylor, M. Enoeda, K. Okuno, Practical-scale tests of cryogenic molecular sieve for separating low-concentration hydrogen isotopes from helium, Fusion Engineering and Design, Vol.28, p. 386, 1995.
[2] S. C. Park, S.-K. Son, M.-Y. Ahn, A. Ying, S. Cho, Y.-H Park, Y. Lee, Hydrogen adsorption performance for large-scale cryogenic molecular sieve bed, Fusion Engineering and Design, Vol.146, p. 1863, 2019.