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Hydriding and Dehydriding Tests of a ZrCo Bed

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1. Introduction

A storage and delivery system (SDS), which is to provide infrastructures and many functional requirements, is to store and supply the D-T gases in metal hydride beds needed for a plasma operation. The hydride beds require the performance of a rapid recovery and delivery of D-T fuel gases, and an accurate measurement of the in-bed tritium inventory [1]. It has been considered that D-T gases stored in the ZrCo hydride beds should be supplied rapidly to the tokomak through a gas injection system (GIS). The role of the SDS is to meet the following requirements of a fuel supply; constant D-T compositions, constant flow rates and a constant pressure. Also, a rapid cooling of the SDS beds is eventually required for a rapid recovery of the D-T gases for a successive pulse plasma operation [2, 3]. In this study, we present hydriding and dehydriding tests of the first designed SDS bed related to an international thermo-nuclear experimental reactor (ITER) to use a non-nuclear material ZrCo for the storage and delivery of tritium.

2. Bed Structure and Thermocouple Points

Fig. 1 shows the structure of the ZrCo bed and thermocouple (K type, WATLOW) points. The SDS bed containing about 1250 g of ZrCo can store 70 g of tritium as a chemical form of $ZrCoT_{2.8}$. This bed consists of a cylindrical filter (pore size: 0.5 μm) and heaters for a simulation of the tritium decay heat. Two heaters (Watlow cable heater, outer-heater: 1.8 kW, inner heater: 1.5 kW) were installed on the outer surface of the primary vessel and the inner surface of the cylindrical filter. ZrCo powder (< 1 mm diameter.) is loaded into the 8 mm gap between the primary vessel (5 mm thickness) and the filter cylinder. Six thermal reflectors (material: 316 L) are installed between the primary and secondary vessel to minimize the heat loss from the vessel to the secondary vessel. The space between the two vessels was maintained as a high vacuum [4].

3. Bed Experimental Results

3.1 Experimental Conditions

Table 1 summarizes the dehydriding test conditions of the first ZrCo bed. The first hydriding test was performed at 100 °C. After a hydriding, the first SDS bed was heated from room temperature to 340 °C for 10 minutes. Then, a dehydriding process was done for 1 hour.

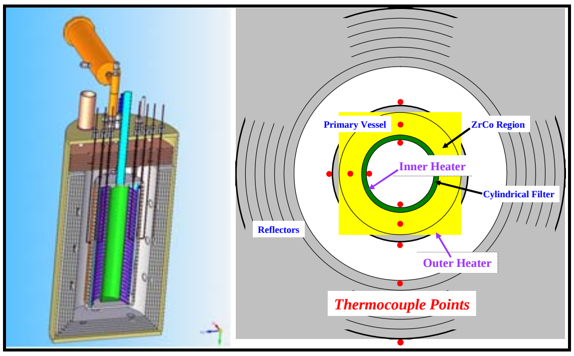

Fig. 1. Vertical Cross-section view of the ZrCo bed and thermocouple points

Table 1: Experimental Conditions

Time [min]	Temperature of inner heater and outer heater [°C]
10	Room Temperature → 340
60	340
5	340 → 400
30	400
10	400 → 500
60	500

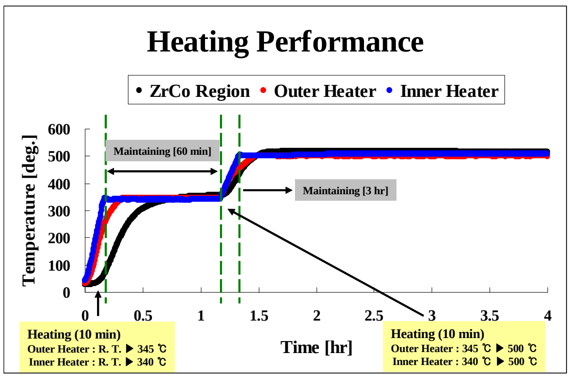

Fig. 2. History of the ZrCo region temperature according to the operating inner/outer heater

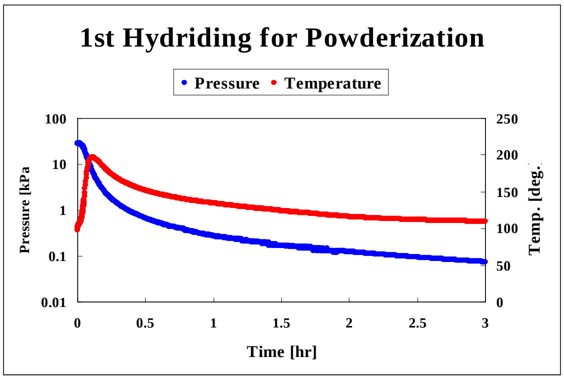

Fig. 3. Change of hydrogen pressure and temperature during hydriding for powderization at room temperature.

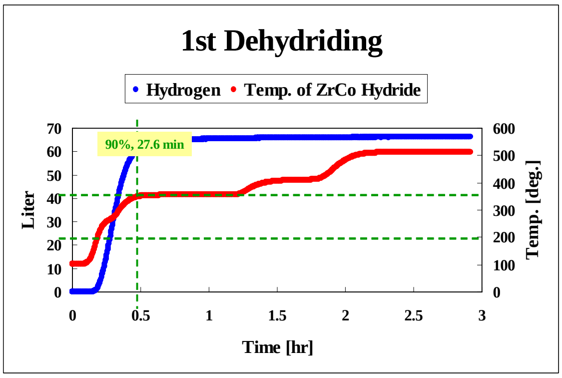

Fig. 4. Change of amount of hydrogen pressure and temperature during dehydriding.

3.2 Heat Performance

Degree of the heat transfer from the two heaters (inner/outer) to the ZrCo hydride was estimated by the temperature history, as shown Fig. 2. Inner and outer heaters were preheated from room temperature to 340 °C and 345 °C for 10 minutes and maintained at each temperature for 1 hour. Then, heated to 500 °C for 10 minutes and kept them. The temperature of the ZrCo hydride was slowly increased to the set temperature after about 30 minutes. It was considered that a fast heat transfer to the ZrCo hydride from the heaters was not clearly observed.

3.3 Hydriding and Dehydriding

Fig 3 shows the change of the hydrogen pressure in the loading tank and the temperature of the ZrCo powder packed layer during the hydriding for a powderization. The loading tank pressure dropped exponentially and 90% and 99% of hydrogen was absorbed in 11.2 and 59.5 minutes respectively. Temperature of the ZrCo hydride sharply increased from 100 °C to ~200 °C in ~6 minutes during the first recovery, then decreased gradually. This temperature rise was generated by the exothermic reaction heat [5].

Fig. 4 shows the history of the amount of hydrogen collected in the loading tank, temperature of the ZrCo hydride in the first delivery on the first ZrCo SDS bed. Dehydriding was started at 200 °C for the temperature of the ZrCo hydride. 90% of hydrogen was supplied in 27.6 minutes at 3.6 Pa·m^3/sec of the delivery rate. And the temperature of the ZrCo hydride was below about 356 °C during a delivery. Finally, the amount of the absorbed hydrogen was about 0.45% larger than the amount of the delivered hydrogen.

4. Conclusions

Hydriding and dehydriding tests of the first designed SDS bed related ITER based on a non-nuclear material ZrCo was performed in this study. High performance of the ZrCo bed for a rapid delivery and rapid recovery was not attained by this first bed model. But it can be possible through repeated experiments. And we are expecting that the thermo physical characteristics can be estimated by additional experiments (hydrogen retention, in-bed calorimetry, etc.).

Acknowledgements

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