Design of the heaters and fins in a ZrCo hydride bed for a rapid delivery

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1. Introduction

In the DT gas storage and delivery system (SDS) for ITER, a large number of ZrCo hydride beds (~20) will be required if DT gas is supplied directly from the SDS to the tokamak gas injection systems (GIS) [1-3]. In the direct supply, DT gas supply during plasma operation will be carried out in the following manner: firstly DT gas in the ZrCo hydride bed is delivered rapidly to the DT supply header composed of gas reservoir and supply pump during plasma well time (1350s), and secondly, DT gas in the reservoir is supplied to the GIS during plasma burn time (450s) with constant D-T compositions (50%T-50%D and 90%T-10%D) and constant flow rates and constant supply pressure (0.12MPa) [2]. The design target of time average delivery rate has been expected to be 20Pam^3/s for ~23 min from the view point of reduction of required number of the SDS beds [2,3]. The delivery temperature of ZrCo hydride should be controlled to be ≤ 350℃ to minimize disproportionation reaction (ZrCoHx ⇔ $0.5ZrH_2$ + $0.5ZrCo_2$ + $0.5(x-1)H_2$; x represents a stoichiometry), which occurs at higher temperature and higher hydrogen pressure [4]. It is known that temperature of metal hydride such as ZrCo hydride and U hydride decreases rapidly during rapid delivery of hydrogen due to the endothermic reaction (ZrCo + $1/2T_2$ → ZrCoT + 80.495 kJ/mol(T_2), 1341kJ/SDS bed [5]). The heat consumption rate in the ZrCo hydride bed (SDS bed) is estimated to be ~720W. In this study, time transient temperature profiles of the SDS bed was investigated and design arrangement of heater and heat transfer fins for the rapid delivery was discussed. Heat analysis was performed by using Heating 7.3 program [6].

2. Heat transfer from heaters to ZrCo hydride

2.1 ZrCo hydride bed configuration

The SDS bed consists of a primary vessel containing ZrCo hydride and a secondary vessel. ZrCo powder of ~3.5kg placed in the primary vessel absorbs D-T at room temperature and desorbs D-T rapidly at 250-350℃ under a vacuum pumping. An inner heater (1.2kW) in the inner wall of primary vessel and an outer heater (3.8kW) on the outer wall of primary vessel are applied. Twenty six nickel or copper fins (1mm in thickness, 108mm in diameter; 2mm less than the inner diameter of primary vessel) are attached to the inner wall of the primary vessel with 10 mm pitch to increase the heat transfer from the heater to the ZrCo hydride. The secondary vessel consists of an inner wall, the outer wall and the space between two walls provide a guard vacuum layer for tritium confinement. Four thermal reflectors are placed between the outer wall of primary vessel and the inner wall of secondary vessel.

2.2 Temperature change of ZrCo hydride during a rapid delivery

Delivery operation of the SDS bed will be carried out in two-step heating to minimize disproportionation. In the first step, the ZrCo hydride bed is preheated at 250℃ for 1 hr in a closed state without vacuum pumping. In the second step, the hydride bed temperature is raised to 350℃ in 10 min under vacuum pumping to deliver DT gas from SDS bed to a DT gas reservoir. The two-step heating method was proposed to achieve a large time average delivery rate (~20Pam^3/s) for ~23 min [7].

Figure 1 shows the time transient of temperature profiles in the SDS bed heated only by the inner heater. Temperature of the ZrCo hydride in the primary vessel decreases substantially in the radial direction and temperature of the major fraction of ZrCo hydride is lower than 300℃ during rapid delivery.

Figure 2 shows the time transient temperature profiles in the SDS bed heated simultaneously by the inner and outer heaters. Temperature of middle section of the ZrCo hydride is slightly lower than that of the primary vessel wall temperature (350℃), however, major fraction of the ZrCo hydride is heated up to 310-350℃ during rapid delivery.

2.3 Comparison of nickel fins and copper fins for rapid delivery

Temperature change in the ZrCo hydride during rapid delivery in the 30 min is shown in Figure 3. Temperature rise in the middle of ZrCo hydride is faster in the case of copper fins than the case of nickel due to the large difference in the thermal conductivity of copper (401W/m/K) and nickel (90.7W/m/K). This fact indicates the SDS bed equipped with copper fins can overcome rapid temperature reduction caused by the endothermic reaction during rapid delivery.

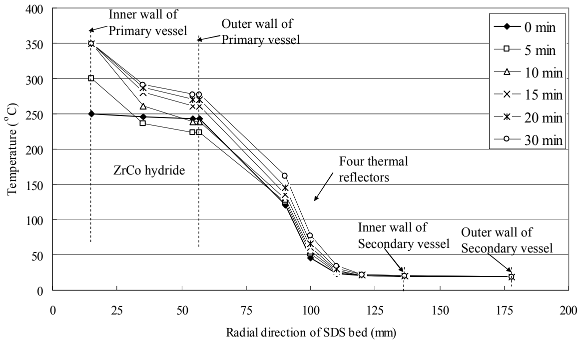

Figure 1. Temperature profiles in the SDS bed with inner heater during rapid delivery.

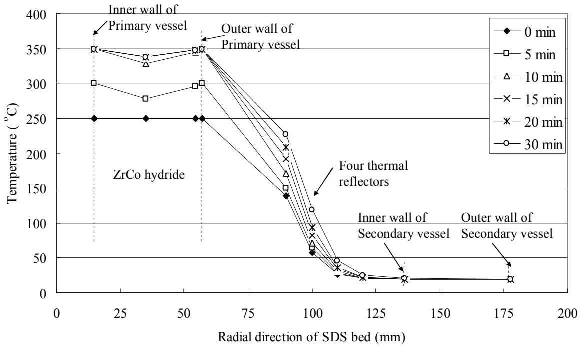

Figure 2. Temperature profiles in the SDS bed with inner and outer heaters during rapid delivery.

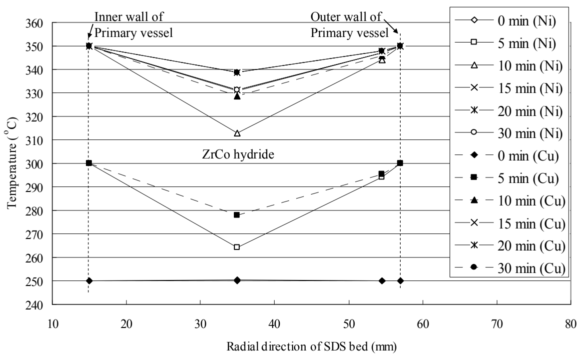

Figure 3. Comparison of effect of Ni fins and Cu fins during rapid delivery

3. Conclusion

Time transient temperature profiles of the ZrCo hydride bed was investigated to analyze the effect of the endothermic reaction (heat consumption rate ~720W/SDS bed) during rapid delivery of DT gas from the SDS bed. It was found that the rapid reduction of the ZrCo hydride temperature can be mitigated by applying inner and outer heaters to the SDS bed primary vessel, and by employing copper fins. Achievable time average delivery rate (target value: 20Pam^3/s per SDS bed) will be experimentally demonstrated in the R&D schedule developed for the ITER Korea SDS project.

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