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The Hydrogen Recombination Characteristics of a Grid-Type PAR during a Spray Operation

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1. Introduction

During a severe accident, hydrogen distribution in a containment building and characteristics of hydrogen depletion by PARs are differ depending on the thermal-hydraulic behaviors occurring in the containment. Various pressure control systems are installed in the containment building to prevent overpressure in severe accident conditions. Representative systems include a spray, a fan-cooler (RCFC: reactor containment fan-cooler), a filtered containment venting system (FCVS), and a passive containment cooling system (PCCS).

The containment pressure control system ensures the integrity of the containment building by maintaining the containment pressure lower than the design pressure in a severe accident condition. However, during operation of this pressure control system, the effectiveness of the hydrogen control system and the hydrogen safety in the containment building must be ensured.

This study intends to experimentally evaluate the hydrogen removal characteristics of a grid-type PAR when a spray is operating.

2. Test Facility

For the experimental simulation of hydrogen recombination characteristics of a PAR affected by a spray operation, the SPARC experimental facility [1] was used, which is equipped with a pressure vessel capable of controlling the wall temperature with a volume of 82 m^3. In order to measure gas species concentrations, 14 probes for hydrogen, oxygen and water vapor were installed.

3. Test Conditions

The purpose of this study is to evaluate the effect of a spray on hydrogen removal of PAR using a SPARC test facility. For the SPARC-SPRAY-PAR (SSP) experiment, SSP3 and SSP4 experiments were performed according to the time of spray initiation.

The SSP3 test is an experiment to simulate an accident in which the PAR operates as hydrogen is released after the spray is activated, and the SSP4 test is an experiment to simulate an accident in which the spray starts after the operation of the PAR is initiated by the hydrogen release.

The main spray nozzle rings of APR1400 are installed on the dome wall of the containment building, and the spray directions of the nozzles are designed to allow wetting all the area of the containment building. The PARs installed in the APR1400 containment building have chambers with a cap to protect catalytic bodies. However, the behaviors of the spray droplets are very irregular, and some droplets may move in a parabolic trajectory depending on the spray directions. As such behaviors of the spray droplets, the possibility that the droplets flow into a PAR chamber through the PAR exit is very high. In the SSP tests, the spray spreading angle and the arrangement of the PAR were designed so that a part of the water droplets could flow into the PAR chamber.

4. Results

Fig. 1 shows the spray flow rate, which was operated for 500 seconds at a flow rate of 957 g/s. The spray water is preheated to a temperature of 50 ºC in a spray water tank and then injected by a pump. After the spray stopped, hydrogen injection was carried out for about 1600 seconds (1890 s ~ 3490 s) at a mass flow rate of 0.2 g/s, and a total of 318 g of hydrogen was injected.

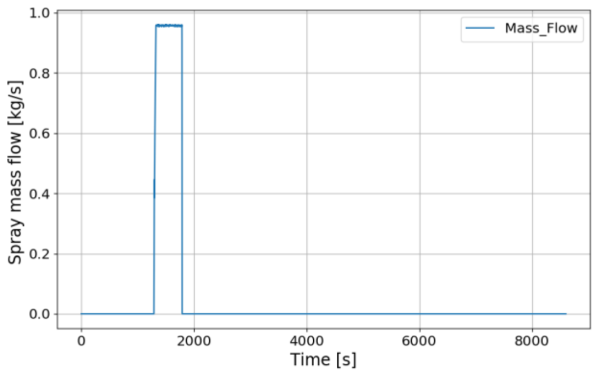

Fig. 1. Spray mass flow in SSP3 test.

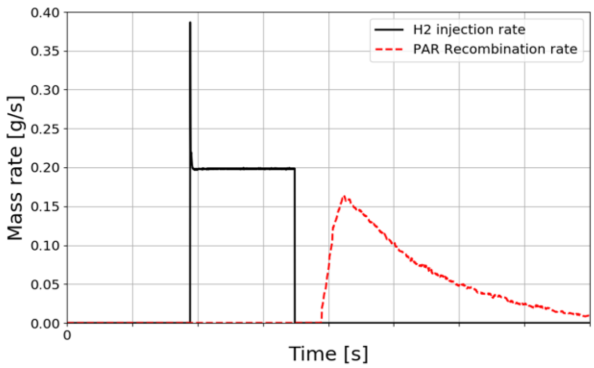

Fig. 2. Hydrogen injection and recombination rate along time in SSP3 test.

Fig. 2 is to compare the time periods of hydrogen injection and the PAR operation in the SSP3 test. 400 seconds after the end of hydrogen injection, hydrogen recombination of the PAR begins. This is 2000 seconds (33 minutes) after the start of hydrogen injection.

In SSP4 test, hydrogen was injected at 0.2 g/s from 1727 s to 4226 s (2500 s). The spray was initiated 1000s after start of the hydrogen injection.

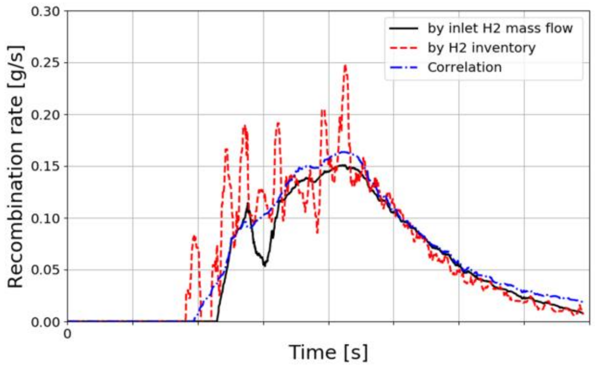

Fig. 3. Hydrogen recombination rate along time in SSP4 test

Fig. 3 compares the values obtained using a method by inlet hydrogen mass flow (method-1) and a method by hydrogen inventory in the test vessel (method-2) for the PAR hydrogen removal rate of the SSP4 test with the KNT KPAR40 correlation equation. In the case of SSP tests, a correction factor of 0.8 was multiplied to the recombination rate by method-1. Until 4500 seconds, the hydrogen removal rate shows a very irregular behavior, but after that, it shows a value very similar to the correlation equation.

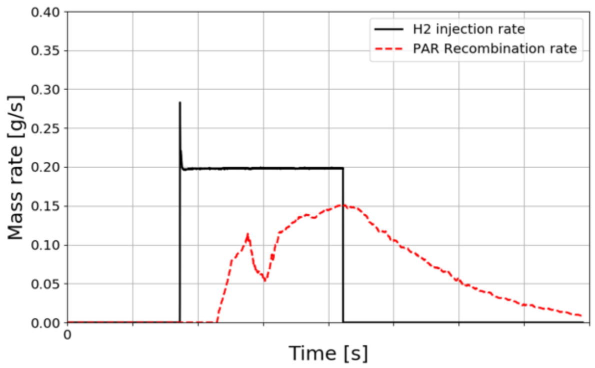

Fig. 4. Hydrogen injection and recombination rate (by method-1) along time in SSP4 test.

Fig. 4 is to compare the time period of hydrogen injection and the PAR operation in the SSP4 test. The hydrogen removal rate was obtained by method-1, and it can be confirmed that the PAR is operated a few minutes after hydrogen injection.

5. Conclusions

In this study, the hydrogen removal characteristics of a grid-type PAR was experimentally evaluated when a water spray was operated. It was found that a PAR start-up may be considerably delayed when the catalytic surface is wet by a spray operation before a hydrogen release. And it was also found that the hydrogen removal rate of PAR is hardly affected even though the droplets penetrates into the PAR chamber in the case that a spray is activated after PAR starts up.

ACKNOWLEDGMENTS

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[1] J. Kim, et al., Experimental Study on the Grid-type Passive Auto-Catalytic Recombiner for Hydrogen Mitigation in a Containment, KAERI/TR-9069/2021, 2021.