MELCOR Analysis of Fission Product Adsorption on Graphite Dust in the Gas Cooled System

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1. Introduction

A high temperature gas-cooled reactor (HTGR), one of the generation-IV (GEN-IV) reactors, uses a graphite as a moderator inside reactor core. The graphite block is good component with high heat capacity, but it has dust issue. There are various dust generation mechanisms, friction, erosion, corrosion, foreign material, abrasion, and so on[1][2]. Korea Atomic Energy Research Institute (KAERI) has been developing the prismatic HTGR. The abrasion mechanism due to pebble moving might be excluded. However, there are still other possibilities for the dust generation like erosion or flow induced vibration.

The graphite dust may circulate in the primary loop independently with regard to the fission products (FP). However, based on the AVR (German Association Experimental Reactor Ltd.) experiences[3], ~50 GBq of Cs-137 were deposited onto the 1kg graphite dust [1.54E-5kg/1 kg dust]and I-131 on dust surface was about 3.5GBq/kg[1.06E-6 kg/1kg dust]. The studies of R. Moormann et al.[4] showed <0.1GBq of Ag-110m, 1GBq of I-131 and 200GBq of Cs-137 on graphite by best-estimation for the 200MW plant. Therefore, it is necessary to predict the transport phenomena both dust and FP. On the current study, the fission product sorption on the graphite dust was investigated using MELCOR code.

2. Modeling of Aerosol Behavior

Fig. 1 shows the MLECOR CVH model to simulate fission product and dust transportation for the VHTR350 which is a concept of KAERI. The active core has more complex geometry, but it is simplified to consider only coolant path.

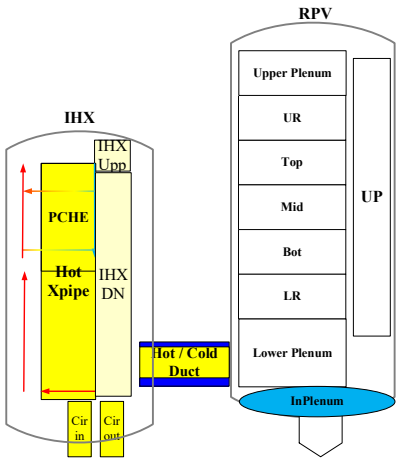

Fig. 1. MELCOR CVH model of VHTR350

The operating pressure is 7.0 MPa. The coolant inlet/outlet temperatures are set as 490/950 ℃. The fission product release rates into the primary loop were calculated by the COPA[5] code. The release rate of the Cs-137 and Ag-110m are written in Table I for each region in Fig. 1(Top, Mid, Bot). At the top region, the amount of the release rate is very small. The release model of COPA uses Arrhenius diffusion model. The inlet temperature is relatively low compared to the middle and bottom regions. Therefore, it is not sufficient to drive diffusion phenomena.

TABLE I

FP release rate[kg/s]

	Cs-137	Ag-110m
Top	7.3849E-112	3.2055E-95
Mid	1.59154E-16	2.45722E-14
Bot	2.83501E-13	4.72675E-13

For the graphite dust generation, there are only past data on the prismatic HTGR. Based on Peach Bottom, FSV, and HTTR[1], the dust in gas is about 3mg/m^3 and the dust on the surface is about 5g/m^2. With the assumption of the 280 m^3 volume and the 1.3E5 m^2 area for the VHTR350 concept, the total amount of the dust may be 650kg during normal operation in the primary loop. The total amount of the Cs-137 and Ag-110m in the primary loop during 40 years operation would be 3.578E-4kg and 6.272E-4 kg, respectively. Under these conditions, the Cs-137 and Ag-110m on the 1kg graphite dust surface would be maximum 5.505E-7 and 9.650E-7 kg which are less than those of the AVR results. It can be thought that the all the fission product might be deposited on the graphite surface conservatively. But, the MELCOR class transfer model is applied to predict fission product sorption on the graphite surface in the current research. Currently, the exact fission product sorption on the dust surface model is not implemented in the MELCOR. Also, there is little literature research on the sorption mechanism from the fission product to the graphite dust. Instead, the class transfer model was developed to simulate rapid chemical reaction like A+B → C+D.

Fig. 2 shows the change in the mass for the Cs-137 and the graphite dust with 4.079E-4 m/s of sorption coefficient from the Cs-137 to the dust. The transfer rate was simply excluded from Stempniewicz and Goede[6]. The sorption was occurred in the lower temperature region mainly. The amount of the mass change in the dust

does not come out due to the higher order of the dust mass. By the calculation, the Cs-137 on the dust surface was 4.742E-7 kg/1 kg.

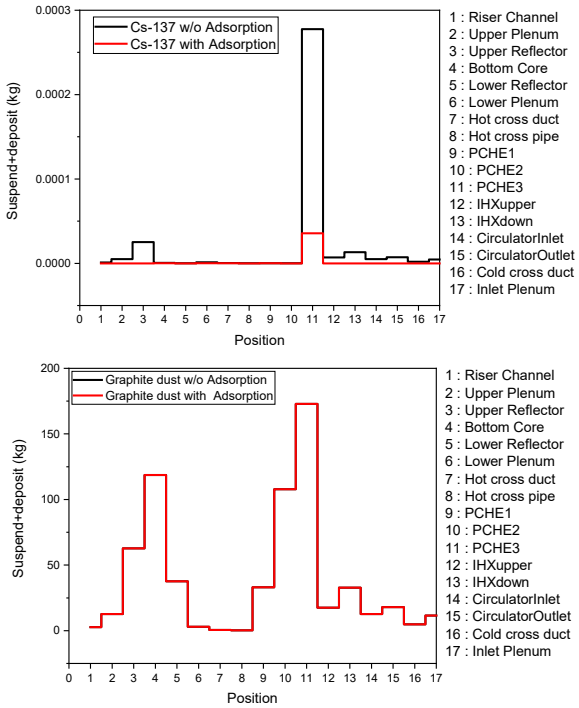

Fig. 2. Mass change in Cs-137 and graphite dust

Fig. 3 shows the change in the mass for the Ag-110m and the graphite dust with 4.079E-4 m/s of sorption coefficient from the Ag-110m to the dust. In the case of Ag-110m, the fission product sorption on to the graphite surface was 9.621E-7 kg/1 kg.

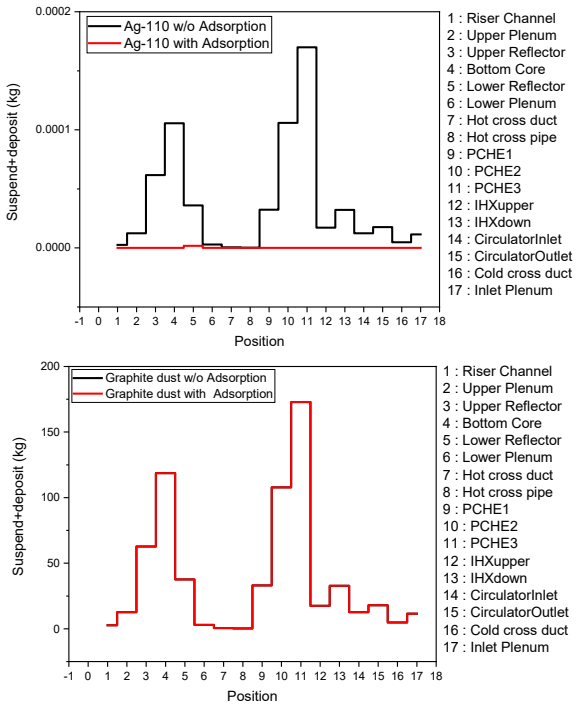

Fig. 3. Mass change in Ag-110m and graphite dust

The data on the sorption rate from the fission product to the graphite dust are not still well defined [6]. FP sorption with different coefficient were also conducted. TABLE II shows the FP sorption rate depending on the sorption coefficient. The first row represents the conservative value when the all released FPs are adsorbed on the graphite dust. The release rate of the fission product is much lower than the sorption rate[6]. Therefore, it is thought that the sorption phenomena were activated very quickly under the specific point in TABLE II. MELCOR module is needed to be investigated more in-depth in future.

TABLE II

FP sorption rate [kg / 1 kg]

Sorption coefficient	Cs-137	Ag-110m
Conservative	5.392E-7	9.650E-7
4.079E-4 [m/s]	4.742E-7	9.621E-7
4.079E-8 [m/s]	4.742E-7	9.621E-7
4.079E-14 [m/s]	1.959E-10	3.417E-10

4. Conclusions

In this paper, the fission product sorption on the graphite dust were studied. Because there is little research on the fission product sorption to the graphite dust, the simple class reaction approach in the MELCOR model was applied. The adsorbed fission products on the graphite surface were lower than the results of the AVR experiment. In the future studies, the class reaction model will be investigated more intensively.

Acknowledgements

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