Estimation of the Equivalent Slab Length for a Fuel Block of a Prismatic High Temperature Gas-cooled Reactor

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1. Introduction

It is essential for the safe design and operation of a prismatic high temperature gas-cooled reactor (HTGR) to quantitatively evaluate a fission product release (FPR) into a coolant. A fuel block in the prismatic HTGR contains many compacts and coolant holes in it. The shape of a fuel block is too complicated to be directly used in the analysis of the FPR. The simple slab which is equivalent to the fuel block has been devised and used to calculate the FPR. This study obtained the equivalent slab length according to coolant temperature and power density rate in a compact through thermal analyses. Fractional releases are calculated and compared in both cases of fixed and variable equivalent slab.

2. Modeling for Fission Product Transport

A symmetrical element in a block of a prismatic HTGR looks like Fig. 1. It consists of a fuel compact, a gap between the compact and graphite, graphite, and a coolant hole. The fuel compact is a graphite cylinder containing many coated fuel particles. Fission products are generated in the coated fuel particles in a compact. They transport through the compact, the gap and the graphite, and finally they are released into the helium coolant. For a simple calculation, the symmetrical element is approximated by a one-dimensional slab as shown in Fig. 2 [1,2].

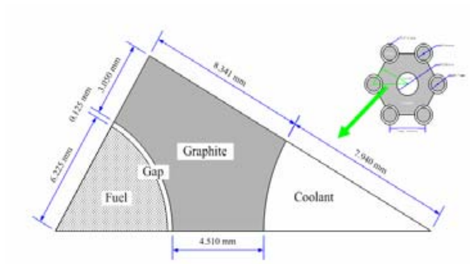

Fig. 1. A symmetrical element of a prismatic reactor core.

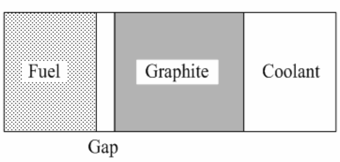

Fig. 2. One-dimensional slab model for a symmetrical element of a fuel block in a prismatic reactor core.

The equivalent slab must have the same diffusive resistance as the symmetrical element. The equivalent slab length is adjusted through a thermal analysis since the diffusive resistance in the symmetrical element is difficult to be examined. The equivalent slab length is adjusted so that the temperatures on the surfaces facing a gap and coolant in the equivalent slab are the same as those on the surfaces facing a gap and coolant in the symmetrical element.

3. Estimation of Equivalent Slab Lengths and Fractional Releases

The data relating to a prismatic HTGR, a coated fuel particle and a compact is given by a reference [3]. For the HTGR, the heat generation rate per volume of a compact is 4.024×10^7 to 4.024×10^8 W/m^3 when the power generation in a coated particle is 50 to 500 mW. It was assumed that coolant temperature was 500 to 1600 ^{o}C.

For thermal analyses, the power generation in a coated particle of 50, 100, 200, 300, 400, 500 mW and the coolant temperature of 500, 700, 900, 1200, 1600 ^{o}C are selected. The temperatures on the surfaces facing a gap and a coolant hole were calculated for totally 30 cases. The temperature in the symmetry element was calculated with ABAQUS [4] and the temperature in the equivalent slab with COPA-TEMBL [5]. The calculated equivalent slab lengths are presented in Fig. 3. They increase with coolant temperature and power. According to Fig. 3, the equivalent slab length is 5.7 to 9.2 mm, which is 4.510 mm in the symmetrical element. Fig. 4 shows fractional releases of Cs-137 into coolant when the coolant temperature is 950 ^{o}C. The difference in the two fractional releases is a little bit significant in the intermediate range of a fluence. The difference, however, disappears in the higher range of a fluence.

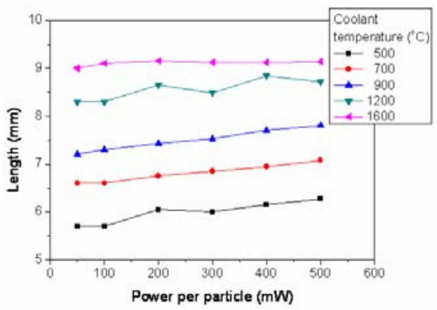

Fig. 3. Variation of equivalent slab length with coolant temperature.

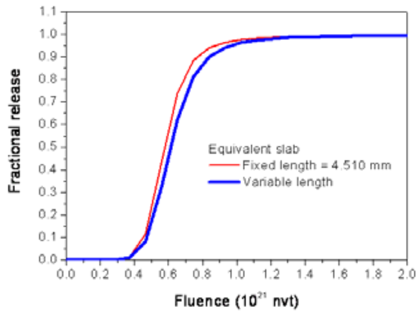

Fig. 4. Fractional release of Cs-137 into coolant (coolant temperature = 950 ^oC).

4. Conclusion

The lengths of a slab which is equivalent to the symmetrical element in a fuel block of a prismatic HTGR have been calculated according to a variation of the coolant temperature and power density rate. They are 5 to 9 mm of which the minimum length is 4.510 mm. The calculation of the fractional release for Cs-137 showed the fractional release was not greatly dependent on the equivalent slab length within the present results of the equivalent slab length. The procedure for calculating the equivalent slab length according to a variation of the coolant temperature and power density rate in a compact is inserted into COPA-FPREL, which is a computer program for estimating the FPR in a HTGR.

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