Decay Heat Analysis of a TRU-fueled Deep Burn VHTR Core

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1. Introduction

The decay heat of radioactive isotopes is one of main concerns in designing a reactor core as well as designing a spent fuel repository. In particular, the effective removal of the decay heat during accidents such as high or low pressure conduction cooling events is a crucial factor which determines the main design parameters of a very high temperature gas cooled reactor (VHTR) core.

In our previous work[1,2], a sophisticated decay heat analysis procedure by using McCARD[3] code and ORIGEN-2[4] code was introduced and a decay heat analysis of PMR200, a uranium-fueled VHTR, core was demonstrated.

In this study, the decay heat of a TRU-fueled deep burn VHTR core was analyzed by using the McCARD/ORIGEN-2 procedure introduced in reference 1.

2. Methods and Results

2.1 Reference Core Design Parameter

A 600MW TRU-fueled deep burn VHTR (DB-MHR) core[5] was taken as the reference core in this study. Figure 1 shows the core configuration of the reference core. The annulus core is composed of five rings of fuel columns with inner and outer reflector.

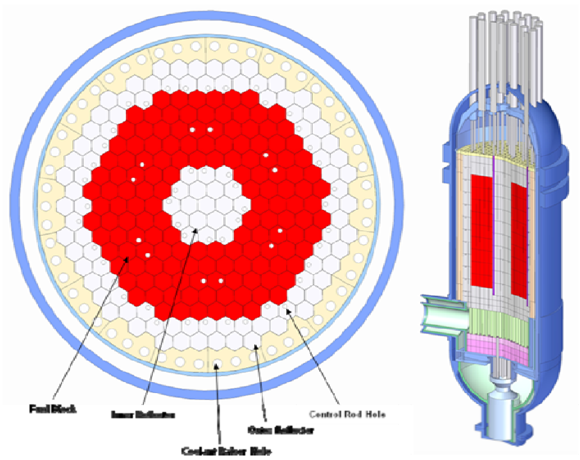

Figure 1. 600MW DB-MHR core configuration

Table 1 shows the major design parameters of the DB-MHR core. The core is composed of 144 fuel columns, each of which consists of 9 fuel blocks stacked axially. The fuel block geometry of the DB-MHR core is the same as that of the GT-MHR[6]. A packing fraction of 24% in fuel compacts was used for the whole core. The specific power density of the DB-MHR is about five times higher than that of PMR200 in reference 1 while the average volumetric power density of the DB-MHR is less than that of PMR200. The TRU fuel composition loaded in the DB-MHR core is listed in Table 2. A three batch axial fuel shuffling scheme adopted for the fuel reload of the DB-MHR core is illustrated in Figure 2.

Table 1. 600MW$_{th}$ DB-MHR core design parameters

Parameters	Values
Thermal Power (MWth)	600
No. of Fuel Columns	144
No. of Axial Layers	9
Active Core Height (cm)	792.9
Top/Bottom Refl. Thickness (cm)	120/120
Kernel Diameter (μm)	200
TRISO Vol. Fr. in Compacts (%)	24
Specific Power Density (W/g)	377.05
Average Power Density (W/cc)	4.66

Table 3. TRU Fuel Composition

Nuclides	Fraction (w/o)
^{237}Np	6.83
^{238}Pu	2.85
^{239}Pu	49.48
^{240}Pu	23.01
^{241}Pu	8.79
^{242}Pu	4.85
^{241}Am	2.80
^{242m}Am	0.02
^{243}Am	1.38

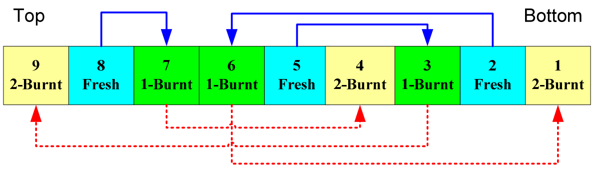

Figure. 2. Three batch axial-only shuffling scheme

2.2 Analysis Methods

Figure 3 shows the McCARD/ORIGEN-2 calculation procedure introduced in reference 1, in which the McCARD code performs Monte Carlo core depletion calculation and the ORIGEN-2 code performs decay cooling calculation after shutdown.

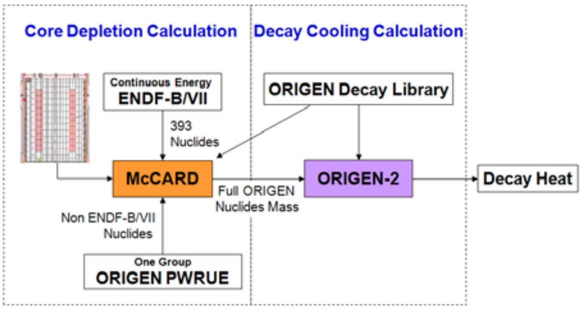

Figure 3 McCARD/ORIGEN-2 calculation procedure

2.3 Results and Discussions

Figure 4 shows the effective multiplication factor histories of each cycle during the McCARD depletion calculation for the DB-MHR core. The standard deviations of the effective multiplication factor of the core at each burnup steps are around 40pcm. The DB-MHR core reaches equilibrium after 10 cycles with an equilibrium cycle length of 495 days. The batch average discharge fuel burnup is 559.9GWd/tHM.

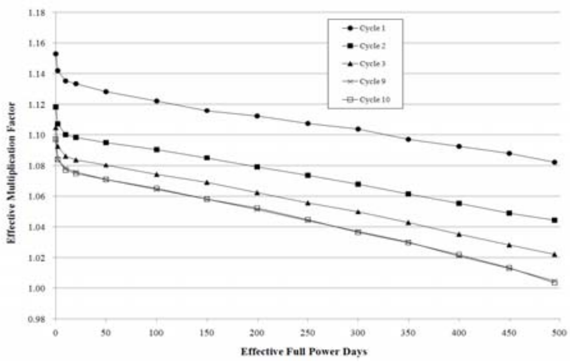

Figure. 4. k_{eff} of the DB-MHR core during depletion

Figure 5 compares the decay heat curves of the uranium-fueled PMR200 core and the TRU-fueled DB-MHR core at the end of the equilibrium cycle. The decay heat of the GT-MHR core provided by General Atomics(GA)[7] was also included in Figure 5 for comparison. The EOC decay heat of the PMR200 by McCARD/ORIGEN-2 procedure[1] is almost identical to that of the GT-MHR by GA. The decay heat fraction of the DB-MHR with TRU fuel is much higher than that of PMR200 with uranium fuel. The decay heats from the actinides are very different from each other due to the fuel composition difference while the decay heat by the fission products is very similar for the two cases. Figure 5 also shows that the major decay heat sources among the actinide nuclides are Np239 and Cm242 in the PMR200 case and the DB-MHR case, respectively. Due to much shorter half life of Np239 (2.36 days) than that of Cm242 (162.8 days), the decay heat from the actinides in the PMR200 case vanishes more rapidly than in the DB-MHR case. Much higher decay heat fraction in the TRU fueled core requires more attention for effective removal of the decay heat in designing the TRU fueled deep burn VHTR cores to ensure the safety of the deep burn core during the conduction cooling events.

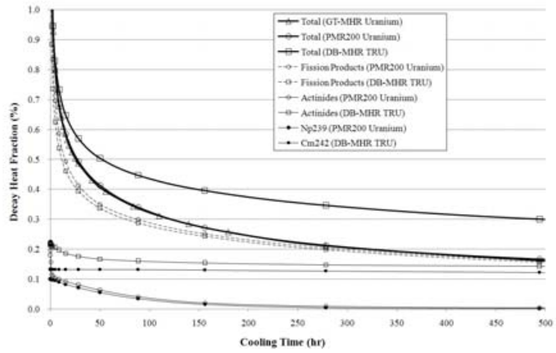

Figure 5. Decay curve comparison

3. Conclusions

The decay heat of a TRU fueled DB-MHR core was analyzed by using the decay heat calculation procedure introduced in reference 1 and the decay heat of the uranium fueled PMR200 core and that of the DB-MHR core was compared. The decay heat fraction of the TRU fueled DB-MHR core is much higher than that of the uranium fueled PMR200 core due to the fuel composition difference, which means that more attention for effective removal of the decay heat should be paid in designing the TRU fueled deep burn cores to ensure the safety of the deep burn core during the conduction cooling events.

ACKNOWLEDGEMENTS

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