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A Comparative Depletion Analysis using the DeCART and McCARD Codes for LWR Fuel Assembly having UO_2-ThO_2 and FCM Pins

Ser Gi Hong[a*], Do-Yeon Kim[a], Hae Lee Hyun[a], Gonghoon Bae[a], and Ho Jin Park[b]
[a]*Department of Nuclear Engineering, Kyung Hee University*
1732 Deokyoungdaero, Giheung-gu, Yongin, Gyeonggi-do, 446-701
[b]*Korea Atomic Energy Research Institute, Daedeok-daero, Yuseong-gu, Daejon, Korea*
[*]*Corresponding author: sergihong@khu.ac.kr*

1. Introduction

This paper summarizes a comparative depletion analysis for new LWR fuel assembly using the DeCART[1] and McCARD[2] Monte Carlo codes to assess feasibility of the analysis using the DeCART code and multi-group cross section libraries. The fuel assembly has been devised to effectively transmute TRU (Transuranics) nuclides from LWR spent fuel by using FCM fuel pins in commercial LWR reactors[3]. For DeCART calculations, we generated new 190 group cross section libraries and the depletion analysis results using them were compared with those of McCARD calculations. The results show that the analysis using DeCART and 190 group cross section libraries give the reasonably accurate results of eigenvalues and pin power distributions over burnup.

2. Methods and Results

2.1 Reference Fuel Assembly Model

The reference fuel assembly has the same arrangement of fuel rods as the ABB/CE 16x16 type fuel assembly which has four large water holes for control rods and one central water hole for instrumentation.

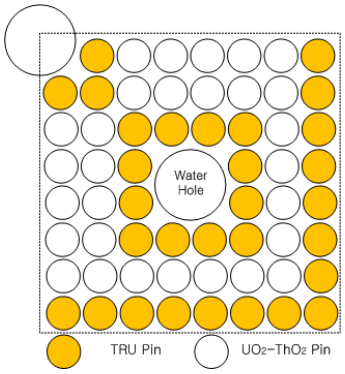

Fig. 1. Configuration of the reference fuel assembly

Fig. 1 shows the configuration of one quarter of the reference fuel assembly. As shown in Fig. 1, this fuel assembly contains 120 FCM fuel rods and 116 UO_2-ThO_2 fuel rods. Table I summarizes the main design parameters of the reference fuel assembly.

Table I : Specifications of reference fuel assembly

Items	*Values*
Rod outer diameter (mm)	9.72
Clad thickness (mm)	0.733
Pin pitch (mm)	1.2882
Fuel assembly pitch (cm)	20.879
FCM TRU pins	
Kernel diameter (μm)	
TRISO/BISO	600/500
Kernel compositions	
TRISO/BISO	$TRUO_2/Gd_2O_3$
Packing fractions	
TRISO/BISO	48%/2%
UO_2-ThO_2 pins	
Weight % of ThO_2	50%
Uranium enrichment (%)	16%

2.2 Description of Multi-group Cross Section Libraries

In the previous studies, we used the 47 group HELIOS library while we generated new 190 group cross section libraries by using the multi-group cross section generation system[4] developed by KAERI in this work. For generation of the resonance integrals of major resonance nuclides (^{232}Th, ^{235}U, ^{238}U), we used a cylindrical pin cell model having equivalent region-wise volumes (fuel, clad, and moderator) to the UO_2-ThO_2 pin cell described in Sec. 2.1. On the other hand, the resonance integrals for TRU nuclides were not newly generated because their background cross sections are relatively large due to their small contents both in UO_2-ThO_2 pin and FCM pin, and those of 190 group KARMA library (ENDF/B-VII.r0) were used in our library. Also, we made multiplicative corrections of the resonance integrals of ^{232}Th, ^{235}U, and ^{238}U such that the one group cross sections of them over the resonance energy range are the same as those estimated using McCARD.

2.3 Results of Depletion Analysis and Discussion

The depletion analysis over 1210 EFPD was done for the reference fuel assembly using DeCART and McCARD. Table II compares the relative discrepancies of k-inf at 0 EFPD between DeCART with several libraries and McCARD for UO_2-ThO_2 and FCM pins. In Table II, "XS190FCM01" and "XS190FCM02" represents the new cross section libraries generated

without the corrections of the resonance integrals and with the corrections, respectively.

Table II : Comparison of discrepancies in k_{inf}

Code and Library	*k-inf*	*Discrepancy (pcm)*
UO_2-ThO_2 pin		
McCARD	1.31725	
DeCART-XS190FCM01	1.31007	-416
DeCART-XS190FCM02	1.31432	-169
DeCART-HELSIOS190	1.30611	-647
FCM pin		
McCARD	1.04777	
DeCART-XS190FCM01	1.04927	136
DeCART-XS190FCM02	1.04928	137
DeCART-HELIOS190	1.04822	41

Table II shows that DeCART using the new library with RI (Resonance Integral) corrections gives very accurate k-inf both for UO_2-ThO_2 pin and FCM pin while the one with the new library without RI corrections gives ~416pcm discrepancy for UO_2-ThO_2 pin. Also, it is noted that DeCART using the HELIOS-190G library gives larger discrepancy for UO_2-ThO_2 pin than the others. Its relatively large discrepancy of HELIOS-190G may be caused from the fact that this library is based on ENDF/B-VI while the others are based on ENDF/B-VII.r0. For FCM pin, all the DeCART calculations gave very accurate agreements with McCARD. This is the reason why we didn't make corrections of RI for TRU nuclides. Fig. 2 compares the discrepancy of k-infs over depletion time between DeCART with several libraries and McCARD for the reference fuel assembly. Also, this figure shows the evolution of k-inf of McCARD. It is observed that there is large fluctuation of k-inf because the FCM pins contain BISO particles having G_2O_3 kernels.

In LIBGEN which assemblies the general multi-group cross sections, subgroup data, fission product yield, decay and burnup chains, and so on, the multi-group cross sections are interpolated by using a single background cross section for all the fission products and so it is an important parameter to determine the k-inf evolution.

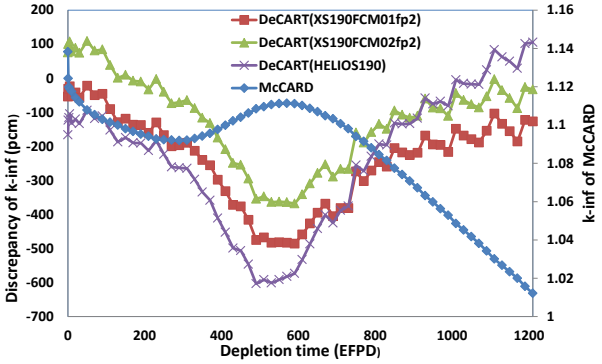

Fig.2. Comparison of discrepancies of k-inf versus time

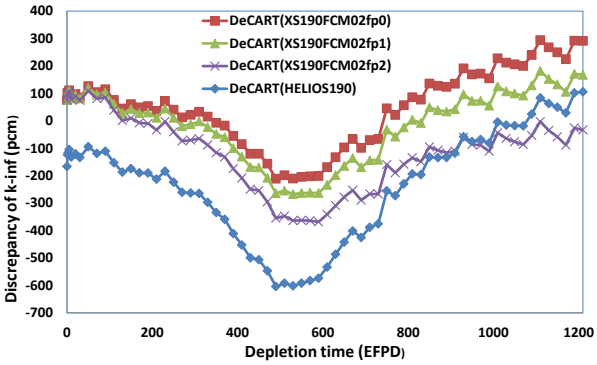

Fig.3. Effect of the FP background XS on k-inf

In this work, we considered the following three background cross sections of the fission products : 1) 12000barns (denoted by "fp0"), 2) 20000barns (denoted by "fp1"), 3) 50000barns (denoted by "fp2"). Fig. 2 shows that DeCART using our new library with RI corrections shows good agreement of k-inf with McCARD. DeCART-FCM01fp2, DeCART-FCM02fp2, and DeCART-HELIOS190 gave the discrepancies of 480pcm, 368pcm, and 604pcm, respectively. Fig. 3 shows the effect of the background cross section on the evolution of k-inf. This figure shows that DeCART-FCM02fp1 (RI correction and 20000barns of FP background cross section) gives the best result of minimum discrepancy of 268pcm.

Summary and Conclusions

In this paper, new 190 group cross section libraries for modeling using DeCART were generated and tested. From the depletion calculations, it is concluded that DeCART multi-group depletion calculations using new libraries for LWR fuel assemblies having FCM and UO_2-ThO_2 pins are reasonably accurate in comparison with McCARD Monte Carlo code.

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