A Neutronic Evaluation of Fuel Assemblies using Metallic Microcell UO_2-Cr(or Mo) Pellets

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1. Introduction

Since the accident at the Fukushima Daiichi Nuclear Power Plant, international research programs have taken the lead in developing accident tolerant fuel (ATF). ATF is defined as an improved fuel form that exhibits enhanced material response, when compared to traditional UO_2 fuel assembly, while maintain or exceeding fuel performance during normal operations, operational transients, and beyond design-basis accidents (BDBA) conditions [1].

ATF concept design studied in this work is Cr (or Mo) metallic microcell fuel which has been suggested in Korea Atomic Energy Research Institute. This metallic microcell fuel is expected to provide enhanced thermal conductivity and high fission product retention in metal cells [2, 3]. Cr(or Mo) materials, on the other hand, have a negative effect on cycle length due to it is high neutron absorption.

In this study, the neutron characteristics of Cr(or Mo) metallic microcell fuel assembly were analyzed using STREAM code [4]. In particular, the effect of cycle length was noted in the fuel assembly neutronic performances.

2. Methods and Results

2.1 Computational Methods & Assembly Design

The STREAM code was used for ATF assembly calculations. STREAM code is a 2D lattice code that solves neutron transport equation by the method of characteristics (MOC). The reference assembly of Case A is PLUS7 16x16 type which has four large water hole for control rods and one central water hole for instrumentation.

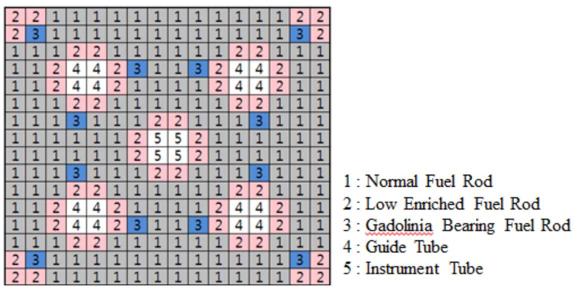

Fig. 1. Configuration of the reference fuel assembly

Fig. 1 shows the configuration of the reference fuel assembly. As shown in Fig.1, reference fuel assembly contains 172 metallic microcell normal UO_2 rods, 52 metallic microcell zoning UO_2 rods and 12 Gd_2O_3 burnable absorber rods.

The fuel assembly performances are summarized in Table I. six fuel assemblies of three cases are considered. Case A is reference PLUS7 fuel assembly, Case B types are metallic microcell UO_2-5vol% Cr fuel assembly and Case C types are metallic microcell UO_2-3,5vol% Mo fuel assembly.

Fig. 2 shows the capture cross sections of ^{238}U, ^{95}Mo and ^{52}Cr versus neutron energy. Cr(or Mo) metallic microcell fuel assemblies have penalty of cycle length. ^{95}Mo(15.8% natural abundance) has a high capture cross section. ^{52}Cr has most abundant isotopes in natural Chromium and it has lower capture cross section than ^{95}Mo.

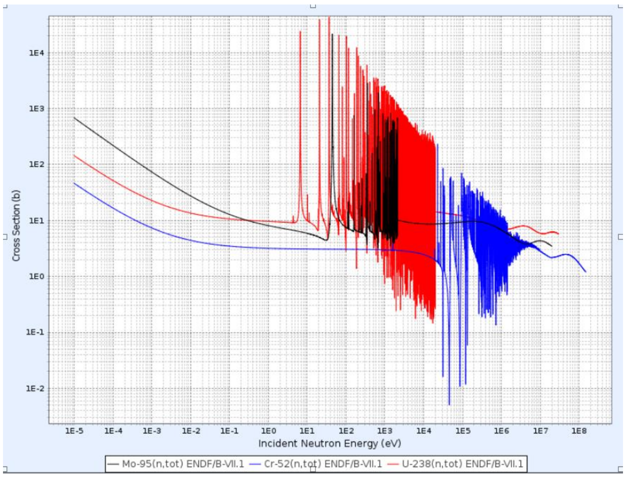

Fig. 2. Comparison of capture cross section of ^{238}U, ^{95}Mo and ^{52}Cr

2.2 Results and Analysis

As shown in Table I, The cycle length of Case A is 880 Effective Full Power Days (EFPDs). Case B which include Cr metallic micro cell is decreased by 50 EFPDs in comparison with Case A. also, cycle length of Case C is decreased by 90 EFPDs. There are two reasons of decreased EFPDs. First, lower amount of initial heavy metal. Second, Cr and Mo has high neutron absorption. Especially, ^{95}Mo is a strong neutron absorber.

As shown in Fig. 3, Case B-1 using 4.90/4.30 wt% enrichment and Case C-1 which includes UO_2-3vol%

Table I: Comparison of the Performances of fuel assembly

	Case A (Ref.)	Case B	Case B-1	Case C	Case C-1	Case C-2
Fuel Assembly Type	PLUS7	PLUS7	PLUS7	PLUS7	PLUS7	PLUS7
Fuel pellet	UO2	UO_2-Cr (5 Vol%)	UO_2-Cr (5 Vol%)	UO_2-Mo (5 Vol%)	UO_2-Mo (3 Vol%)	UO_2-Mo (3 Vol%) (depleted in Mo-95)
U enrichment (normal/zoning, wt%)	4.60/4.10	4.60/4.10	4.80/4.30	4.60/4.10	4.85/4.35	4.70/4.20
EFPD (days)	880	830	878	790	879	877
MTC (BOC/EOC, pcm /℃)	-19.69/-31.10	-18.37/-27.66	-18.58/-28.62	-22.33/-32.11	-21.53/-32.93	-20.08/-31.18

Mo and 4.85/4.35 wt% enrichment have a cycle length similar to Case A. The comparison of Case C-1 and Case C-2 having similar cycle length shows that Case C-2 which depleted in ^{95}Mo is decreased by 0.15 wt% enrichment. Because of ^{95}Mo that has high capture cross section strongly affects cycle length on the fuel assembly performances.

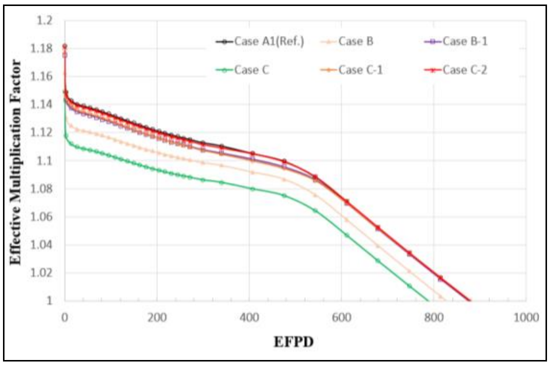

Fig. 3. Effective multiplication factor vs. EFPDs

Fig. 4 Shows the moderator temperature coefficients (MTC) for fuel assembly calculations. Case B which include Cr metallic microcell has less negative MTC than Case A. Also, Case C which include Mo metallic microcell has more negative MTC than Case A. This fact may be resulted from Cr(or Mo) materials have smaller capture cross section than ^{238}U.

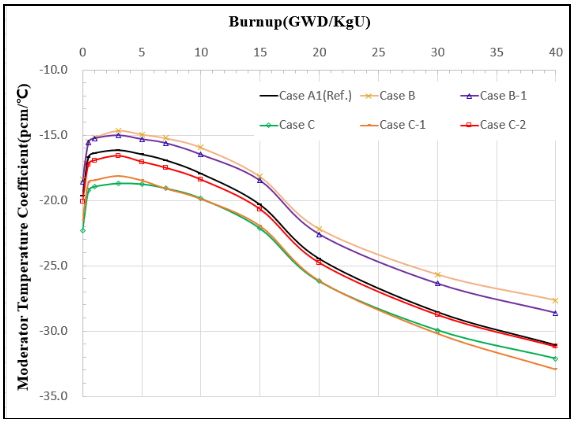

Fig. 4. Comparison of moderator temperature coefficients for all case

3. Conclusions

In this work, a neutronic analysis of six cases fuel assembly using ATF which include Cr(or Mo) metallic microcell was performed. Various cases changing both enrichment and Mo vol% were analyzed in similar to cycle length of reference UO_2 assembly. The results showed that Cr, Mo and Mo(depleted in ^{95}Mo) metallic microcell have increased fuel enrichment by 0.2, 0.25 and 0.1 wt% in comparison with reference UO_2 assembly, respectively. In particular, enrichment of all cases had not exceed current license limit of 5wt%.

The core calculation was not considered in the ATF neutronics analysis. The analysis of core using Cr(or Mo) metallic microcell will be performed in the following studies.

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