A Small LWR Core Design Using ThO_2-UO_2 and Fully Ceramic Micro-encapsulated Fuels for TRU burning

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1. Introduction

In this paper, the new 308MWt LWR core using new fuel assembly designs is designed to efficiently destroy TRU (transuranics) nuclide without degradation of safety aspects by using ThO_2-UO_2 fuel pins and FCM (Fully Ceramic Micro-encapsulated) fuel pins containing TRU fuel particles[1, 2, 3]. Thorium oxide fuel has been known as fertile, meaning it produces a fissile isotope, which can contribute to the extension of the fuel cycle length. Additionally, the use of thorium fuel offers proliferation resistance because it produces much smaller amount of TRU nuclides than the uranium fuel in commercial reactors. All calculations were performed by using DeCART (Deterministic Core Analysis based on Ray Tracing) and MASTER (Multi-purpose Analyzer for static and Transient Effects of Reactors) code[4, 5]. The results show that new core has the TRU destruction rates of ~21% per 1400EFPD (Effective Full Power Day).

2. Methods and Results

The fuel assembly depletion calculations were performed with the DeCART code which is a whole core neutron transport code capable of 3D core depletion analysis and developed by Korea Atomic Energy Research Institute (KAERI). As the multi-group cross section library, the karma library was used in this study. The numbers of energy groups for neutron and gamma are 47 and 18, respectively.

In this study, the reference fuel assembly is the ABB/CE 16x16 type fuel assembly which has four water holes for control rods and one central water hole for instrumentation. In this study, some of UO_2 pins are replaced with FCM pins to destroy TRU nuclides from LWR spent fuel. A TRU FCM pin consists of the typical cladding and the matrix in which the TRISO particle fuels containing a central TRU kernel are distributed. Also, we used BISO particles containing a central BP (burnable poison) kernel. We considered four different fuel assembly types having different kernel composition and each fuel assembly type has axial cutbacks of 21.5cm height both in bottom and top of the FCM fuel rods to optimizing of axial power distribution, separately. Exceptionally, in the type B fuel assemblies, the FCM fuel rods have axial cutbacks of 40cm in top but 21.5cm in bottom. Fig. 1 shows how the UO_2-ThO_2 pins and FCM TRU pins are arranged in 1/4 fuel assembly. The new assemblies of A and B types apply to the left side configuration which have separated enrichment uranium fuel pins, while C and D types have the arrangement of fuel pins shown in the right side configuration in Fig. 1. Table I summarizes the composition of the fuel pins and main design parameters. In the case of cut back, they are designed by just removing of BISO from A, B, C and D types, respectively.

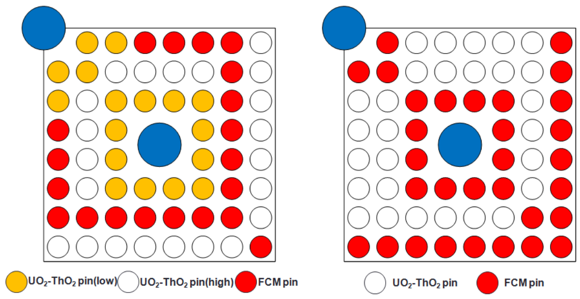

Fig. 1 Configuration of the new fuel assembly (1/4)

Table I Composition of fuel pins for the new assemblies

Item	A	B	C	D
FCM TRU pin				
Kernel diameter	600μm			
Matrix	SiC			
Packing fraction (TRISO/BISO)	44/ 4.0	45/ 3.5	47/ 1.5+1.5	48/ 1.0
BP material	Gd_2O_3	Gd_2O_3	Gd_2O_3, Er_2O_3	Gd_2O_3
UO_2-ThO_2 pin				
Uranium enrichment	11% 8.5%	12.5% 10%	16%	17%
Wt% of ThO_2	50 wt%			

In this study, thermal power and active fuel height of the new core are 308 MWt and 210cm, respectively. And the new core uses one-batch refueling fuel management scheme. Fig. 2 shows the radial loading pattern of core. On the outside of core, the assemblies with the highest enrichment were used to achieve the power flattening. Fig. 3 shows the critical boron concentration (CBC) for critical state of the new core over 1400EFPD. The CBC evolution for the new core shows a big fluctuation. This is due to the fact that gadolinium havs high absorption cross section and so it burns out rapidly.

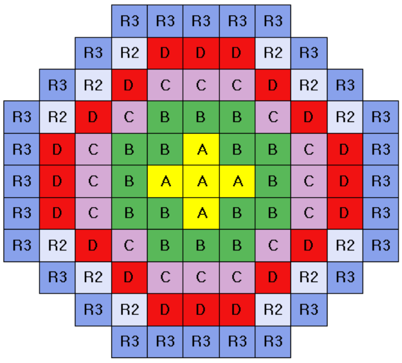

Fig. 2 Radial configuration of the new core

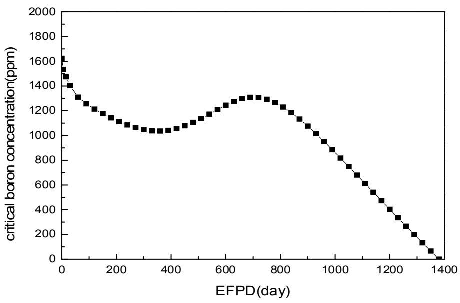

Fig. 3 Critical boron concentration for the new core

Fig. 4 shows axially integrated radial peaking factor (F_r) and three dimensional power peaking factor (F_q) for the new core. The values of peaking factor occur in B and C types. In the early cycles, peaking factor occurs in the assemblies of C type because A and B assemblies have high fraction of BISO. After almost all gadolinium are burned out, the location where maximum power peaking occur peaking factor moves to the assemblies of B type.

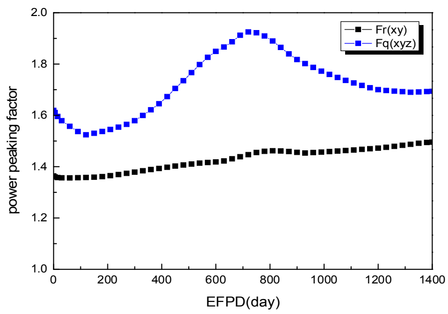

Fig. 4 power peaking factor for the new core

Fig. 5 shows the moderator temperature coefficients (MTC) for the new core. They are compared with those of the typical LWR having no thorium fuels and FCM TRU pins (YGN unit 3 cycle 1). In the first half of cycle, the change of MTC for the new core is very small compared with the typical LWR core and hereafter MTCs both at HFP and HZP become more negative. Over the whole cycle length, our core has more negative MTC than the YGN unit 3 cycle 1 core.

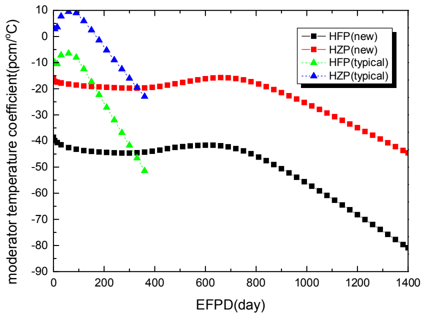

Fig. 5 Comparison of MTC for the new core and typical LWR core

Although the mass inventories of TRU are not shown here, they are 670.906 kg and 528.796 kg in BOC and EOC. The destruction rate of TRU is 21.18%. TRU net destruction is caused by the fact that the amount of TRU destruction in FCM pins is much larger than the production of TRU in UO_2-ThO_2 pins

3. Conclusions

We designed the new core having UO_2-ThO_2 pins and TRU FCM pins to effectively destroy TRU nuclides from LWR spent fuel. The results of the analyses show that the new core has the TRU destruction rates of ~21% per 1400EFPD (Effective Full Power Day) without degradation of MTC.

Acknowledgement

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