Effect of Gd_2O_3 to a fission number in the first pulse of a postulated nuclear excursion

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Effect of initially-loaded amount of burnable poison (BP) on consequences of postulated criticality events in a BWR spent fuel pool (SFP) has been investigated. Calculations of fission numbers per volume showed that a UO_2 fuel model without BP did not cause a conservative result while such model is generally used in criticality safety design.

Keywords: burnable poison, temperature coefficient, fission number, Nordheim-Fuchs model.

1. Introduction

A spent fuel pool (SFP) of a nuclear power plant consists of fuels with different burnup conditions. In criticality safety design of a BWR SFP, the UO_2 fuel model without burnable poison (BP) that envelops the highest neutron multiplication of an actual fuel during its life is generally used. It may lead, however, not conservative results in consequence analysis of criticality events because BP could cause weaker temperature reactivity feedback and increase fission yield.

2. Calculation Method

SRAC[1] code and JENDL-3.3[2] were used for the neutronic calculations. A pin cell model of fuel was introduced and the UO_2 and UO_2-Gd_2O_3 compositions were considered. Enrichment of ^{235}U was 4 wt% and amount of gadolinium was varied 0.01-0.04 wt%, which maintained infinite multiplication factors > 1. Cell burnup calculations were conducted to obtain atomic number densities in each burnup step. Thereafter temperature coefficient reactivity (α) was calculated for each step. The Nordheim-Fuchs (N-F) model that is based on the one-point kinetics as shown in equation (1), where only prompt neutron population is considered, was introduced to estimate magnitude of the first peak in a criticality event. The N-F model also supposes sufficiently large and instantaneous reactivity insertion. In this study, an initial reactivity of 2$ was assumed. Energy production was calculated using equation (2), which was converted into a fission number.

$$\frac{dn}{dt} = \frac{\rho - \beta}{l} n \qquad (1)$$

$$E = \frac{2(\rho_0 - \beta)}{\alpha K} \qquad (2)$$

ρ_0 initial excess reactivity ($)
β delayed neutron fraction
α temperature coefficient ($^1/_K$)
K reciprocal heat capacity ($^K/_J$)

3. Results

The result showed that, in the early period of burnup, the nominal α values of UO_2-Gd_2O_3 fuel was larger than those of UO_2 fuel. In contrast, those of UO_2-Gd_2O_3 became smaller in high burnup. Therefore, fission numbers per volume of UO_2-Gd_2O_3 fuel were slightly higher than those of UO_2 fuel in high burnup condition as presented in Fig. 1 and Table 1.

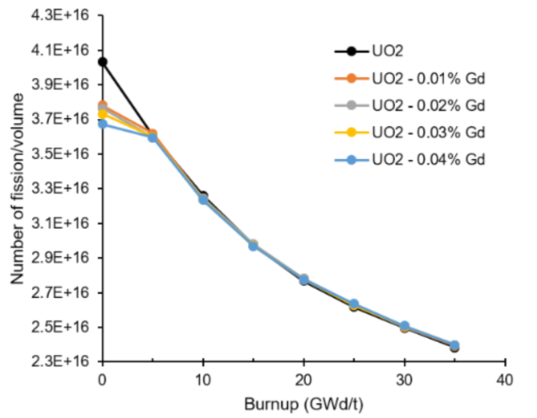

Fig. 1. Number of fission per volume of UO_2 and UO_2-Gd_2O_3

4. Conclusion

It was shown that BP has an effect that reduces temperature feedback reactivity and increases fission yield in a postulated criticality accident with high burnup fuels. Following the result, it should be clarified how the initially-loaded BP affects the feedback in the high burnup condition where BP burns out. Further study is also necessary by considering the realistic condition of SFPs. In that case, such effect of BP should be taken into account in the consequence analysis of criticality events for the best or even conservative estimation.

Table 1. Difference of fission numbers between UO_2 and UO_2- 0.04%Gd through burnup

BU (GWd/t)	0	5	10	15	20	25	30	35
Δ # of fissions	-8.91%	-0.28%	-0.81%	-0.24%	0.27%	0.65%	0.50%	0.61%

References

[1] Okumura, K,. Kugo, T., Kaneko, K. & Tsuchihashi, K. SRAC2006: A Comprehensive Neutronics Calculation Code System. Japan Atomic Energy Agency, Japan (2007).

[2] K. Shibata, et al. Japanese Evaluated Nuclear Data Library Version 3 Revision-3: JENDL-3.3, "J. Nucl. Sci. Technol. 39, 1125 (2002).