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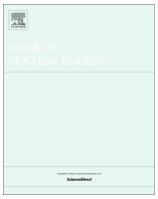

Technical note

End effect analysis with various axial burnup distributions in high density spent fuel storage racks

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ABSTRACT

End effect of spent fuel comes from the difference between uniform and actual axial burnup distributions of fuel assemblies. It is significant to control the criticality safety in spent fuel storage and transportation. This work is focused on estimation of end effect in the spent fuel of light water reactor for the spent fuel storage rack region-II. High and low burnups of corresponding different uranium enrichments are taken into consideration to analyze the end effect with different axial burnup distributions such as uniform, MOC and EOC profiles. Two types of fuel assemblies such as CE type and Westinghouse type are considered. The whole calculations have been carried out by using the SCALE6 code including ORIGEN-S and KENO-Va.

1. Introduction

In order to store efficiently spent fuel assemblies on-site, the more compact and the higher density fuel rack design has been carried out. Usually, a spent fuel storage rack consists of two types, region I and region II. Region I is designed for storage of new fuels before they are loaded in reactor and spent fuels after they are just withdrawn from reactor. Region II is for storage of spent fuels after they are stored for some period in region I. Configurations of region I and region II with CE type fuel assemblies are depicted in Figs. 1 and 2, respectively. Fig. 3 shows the region II storage rack loaded with Westinghouse type fuel assemblies, too. The cell pitch of region-II rack is optimized to maintain the sub-criticality by using fixed neutron absorber. To acquire the operation permission, the criticality analysis should be carried out and provide enough margin including bias and uncertainties. The NRC guide such as NUREG-0800 provides detailed description of fresh and spent fuel storage and handling (USNRC, 2007).

In the case of spent fuel storage in spent fuel storage rack region II, burnup credit concept is widely accepted. It accommodates the reactivity decrease due to burnup of spent fuel which is regarded as a certain credit. Thus, the concept of burnup credit is widely accepted in the storage of spent fuels to provide additional accommodation margin. For example, no burnup credit case of region I fuel rack, the pitch size is larger than that of region II fuel lack. And additional neutron absorber plates are installed to maintain sub-criticality. However, the burnup should be estimated accurately to provide the reliable reduced reactivity of spent fuels. In addition, it is important to calculate accurately the axial variation in burnup of spent fuel. To be simplicity, a uniform axial burnup distribution is used including additional bias. When assuming a flat distribution of axial burnup, the center region is the most reactive because leakages increase at the bottom and top regions. In a real case, the center region is not such a high active because the high power in the center causes the more burnt fuel. And the lower burnup and increased leakage move toward the ends of the fuel assembly. Thus, there exists the reactivity difference between the uniform and the real axial burnup, which is defined as end effects (Wagner and DeHart, 1999).

When the burnup is below around 25 GWD/MTU, the peak of fission density happens around the center region of fuel. The uniform axial burnup is generally more reactive and conservative in this case because the amount of burnup decrease in center region is greater than the one of burnup increase in both end regions. However, as burnup increases, the spatial burnup peak shifted from the center to the ends. On the contrary to the low burnup case, the uniform distribution is less reactive due to inverse

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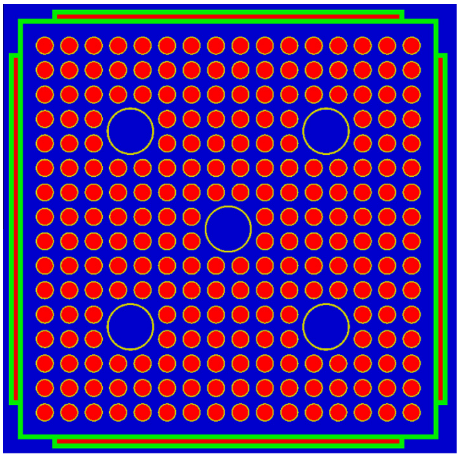

Fig. 1. Configuration of region-I storage rack with a CE type fuel assembly.

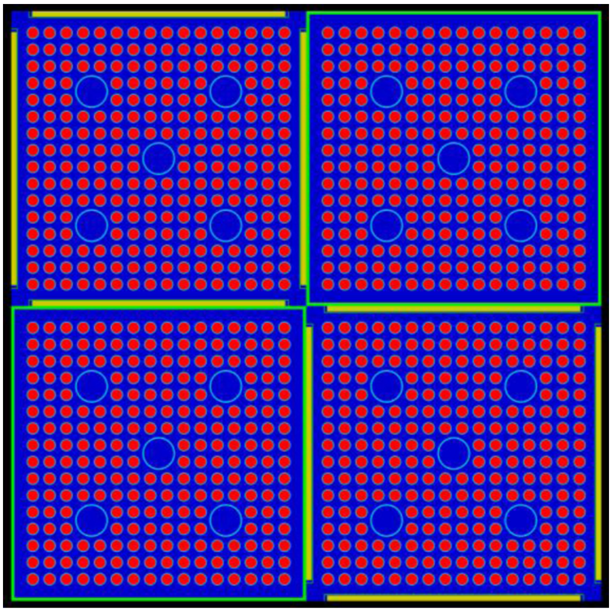

Fig. 2. Configuration of region-II storage rack with a CE type fuel assembly.

behavior of reactivity effect. Thus it is required marginal bias when assuming a uniform distribution for high burnup case. Turner suggested a 1%Δk/10 GWD/MTU for end effect and it is accepted to apply high burnup case with a uniform distribution approximation (Turner, 1988).

Our main concern is to verify the recommendations for low and high burnt fuel storage including the axial burnup distribution effect. New tools and new models are taken into consideration in this paper and new storage models are also applied for the CE and Westinghouse type of fuel assemblies. Especially several axial burnup models are tested and are quantified effect of reactivity changes. In this study, in order to investigate end effects and to confirm the previous recommendation, low and high burnup states are chosen with three different axial power profiles including a uniform axial power distribution.

In Section 2, the isotopic distribution of various burnup states. Analysis results and discussion are provided in Section 3. And finally, the conclusion is provided in Section 4.

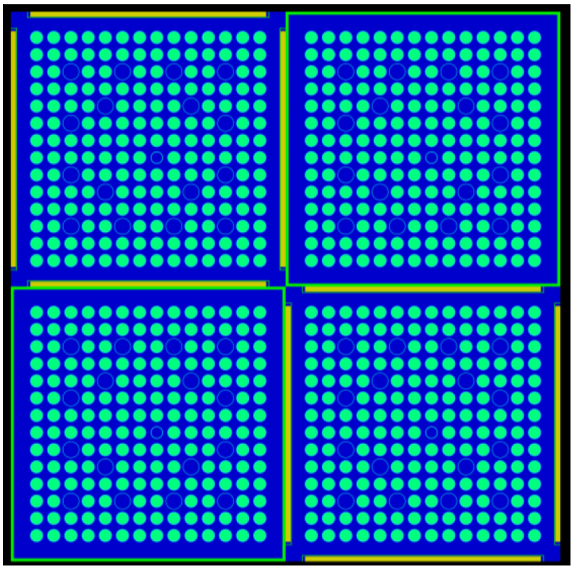

Fig. 3. Configuration of region-II storage rack with a Westinghouse type fuel assembly.

2. Burnup dependent isotopic distribution

In order to obtain reactivity difference for axial burnup dependent isotopic distribution, the following three steps of calculation procedures are required such as determination of axial burnup distribution, calculation of burnup dependent isotopic inventories for various fuel assemblies, and criticality calculation with different axial burnups. Fig. 4 depicts the calculation procedure including analysis code systems.

As the first step, a typical axial power distribution is obtained from the analysis from a typical PWR through the analysis of the AFEN-TH code system.(Cho et al., 1998). The AFEN-TH code is an analytic nodal expansion method for whole core calculation including macroscopic depletion and thermal hydraulic feedback. The core is Hanbit unit 3 cycle 1 and the fuel type is CE16X16. The burnable absorber is 4 wt% Gd. The number of fuel assembly in the core is 177. Fig. 5 shows the axial power distribution for BOC (begin of cycle), MOC (middle of cycle), and EOC (end of cycle) states.

The chosen fuel assemblies are is a CE16X16 type and a Westinghouse type. The specification of fuel assembly is provided in Table 1. The low burnup case is 25 GWD/MTU and its initial

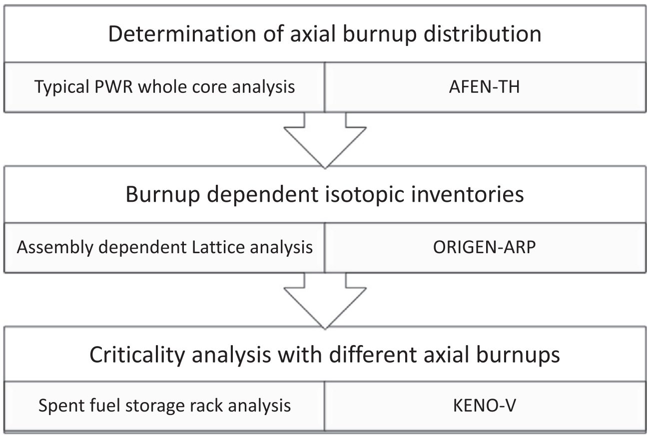

Fig. 4. Criticality analysis procedure with axial burnup distribution.