Feasibility of rotational shuffling Breed-and-Burn fast reactor with nitride fuel and sodium coolant

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Abstract

This study aims to make clear the possibility of designing a small Breed-and-Burn (B&B) reactor with nitride fuel and sodium coolant when rotational shuffling is adopted. Serpent 2.1.0 Monte Carlo simulation code is used for burnup calculation with shuffling program. It is found that rotational shuffling B&B fast reactor can reach equilibrium conditions with natural uranium fuel.

Keywords: Rotational Fuel shuffling Breed-and-Burn fast reactor (RFBB), nitride fuel, and sodium coolant.

1. Introduction

Breed-and-Burn (B&B) reactor can be fueled with natural uranium or depleted uranium only, once initial criticality is established. B&B reactor is based on breeding fissile material and fission of it in-situ in a once-through fuel cycle. For achieving criticality and better neutron economy, Rotational Fuel shuffling Breed-and-Burn fast reactor (RFBB)[1] was proposed in which high-reactivity fuels are located continuously in high neutron importance regions during reactor operation. The purpose of the study was to make the clear possibility of designing a small RFBB with nitride fuel and sodium coolant.

2. Analyses

The analyses were performed on a reactor with power of 450MWt and 168 natural uranium fuel assemblies separated into 6 symmetry regions as shown in figure 1a. Rotational shuffling was performed from every region from assembly position ID 1 to 28 as shown in figure 1b. After constructing the core, burnup analysis was performed for evaluation of fuel cycle length of fuel shuffling. Shuffling is repeated until burnup reaches equilibrium. Next, the change in the effective multiplication factor at the equilibrium state is examined, if the effective multiplication factor seems to change during one fuel cycle length, a different cycle length is adjusted. After that, reactor characteristics were obtained for the core. If results satisfy the design goals, heat removal analysis on the hottest channel is performed to check the fuel temperature profile.

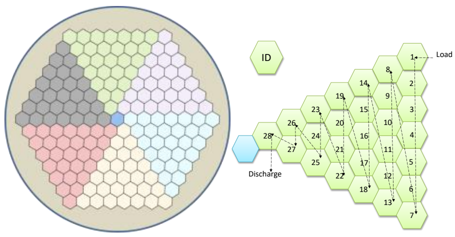

Figure 1. A) Whole core layout and B) fuel shuffling pattern and position ID in one-sixth core.

3. Results

An equilibrium state was obtained after 56 shuffling steps. The detailed burnup of the equilibrium state in 860-day cycle length was analyzed. The average discharge burnup was 187MWd/kg-HM. The change in power distribution between the beginning of the fuel cycle in the equilibrium condition (BOEC) and the end of the fuel cycle (EOEC) was small enough. The maximum fuel temperature was lower than the operational limit and the cladding material temperature was lower than its melting temperature.

4. Conclusion

It is found that RFBB with nitride fuel and sodium coolant could be in normal operation and reach high burnup. At that high burnup level, nitride fuel operational limit of temperature and cladding material damage was within its safety limit. In the future, further analysis will be performed including the more detailed geometries and conditions.

References

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