Compensation for Fuel Losses in The Melt-Refining Process in Small CANDLE Reactor

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This paper is concerned with both the neutronic and thermal-hydraulic analysis for a small CANDLE reactor with the melt-refining process. Compensating for the fuel losses during the reprocessing is conducted in the refabricating fuel pins stage by feeding fresh fuel into the breeding region. The analysis results show that it is possible to design the small CANDLE reactor with the reprocessing meanwhile the core design is satisfied when subjected to the design constraints.
Keywords: small CANDLE reactor, melt-refining process, compensate for fuel losses, feeding fresh fuel into breeding region.

1. Introduction

The CANDLE reactor has been proposed with the numerous advantages, but the material integrity up to high burnup is an important issue of fast CANDLE reactor. In order to overcome this issue, the melt-refining process (MRP) is a promising solution. The purpose of this study is to investigate burnup performance of a small CANDLE reactor with MRP including compensating the fuel losses by feeding fresh fuel into breeding region.

2. CANDLE reactor with MRP

The reactor uses the U-10Zr as fresh fuel, LBE as coolant and ODS as cladding. The active core has a cylindrical geometry, radius of 130cm and height of 220cm, surrounded by a reflector of LBE with 50cm thickness. The reactor power is 300MWt. The fuel unit cell is hexagonal with clad inner radius and its thickness are 0.45cm and 0.06cm, respectively. Three cores are investigated as follows: (1) In the first core, with scenario of which 10 % of all actinides are not recovered during MRP, so-called “90% recovery efficiency”. (2) In the second core, with scenario of which 5% of all actinides are not recovered during MRP, defined as “95% recovery efficiency”. (3) In the third core, it is the same as in the second core except that the smear fuel density increases from 75% to 79% and the reflector thickness increases from 50cm to 100cm, named as “Modified core”. For the neutronic analyses, MRP with the cooling time intervals was performed using the SRAC-COREBN code, with the JENDL-4.0 nuclear data library and the in-house program. The thermal-hydraulic analyses were performed using COMSOL Multiphysics 5.2.

4. Analysis results

The CANDLE burnup strategy is achieved in all investigated cores. The k-eff is increased over the equilibrium cycle. The 95% recovery efficiency core is subcritical meanwhile the 90% recovery efficiency core is critical because of that the number of MRRs in the axial direction in the 95% recovery efficiency core is greater. The Modified core is critical due to the higher smear fuel density. The compensating for the fuel losses results in not only reducing fuel waste but also achieving deeper burnup at the core top in comparison with that of the reference core. The compensating for the fuel losses leads to the deformation of the power density distribution in the core, but the core satisfies the design constraints. By the compensating for the fuel losses the averaged fuel burnup of the core is decreased but it would be compensated by the safety operation.

5. Conclusions

The compensating for fuel the losses during MRP by feeding fuel into the breeding region is investigated with two bounding scenarios of which 5% and 10% of all actinides are not recovered during MRP are examined. The analysis results show that it is possible to design the small CANDLE reactor with MRP to overcome the issue of material integrity.