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THESIS OUTLINE

Study on Burnup Performance of Small Pebble Bed Reactors with Accumulative Fuel Loading Scheme

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Pebble bed reactor (PBR) is one of the promising nuclear power plants in the future. There are three fueling strategies in PBR, and accumulative fuel loading scheme is the simplest fueling scheme. Therefore, PBR with accumulative fuel loading scheme was chosen in this study.

Chapter 1. Introduction

This chapter presented the background of PBR and the fuel management strategy of PBR. Moreover, it showed the motivation and the objectives of this study. The burnup performance of PBR with accumulative fuel loading scheme was simulated with several fuel materials such as UO_2, MOX, U-ROX, and Pu-ROX. The purpose of the study was to make clear the potential of several fuel materials in PBR with accumulative fuel loading scheme to achieve high burnup with long operation period.

Chapter 2. Burnup performance of UO_2 fuel in PBR with accumulative fuel loading scheme

This chapter presented UO_2 fuel in PBR with accumulative fuel loading scheme. MVP/MVP-BURN code is used to simulate the neutron transport and burnup analysis with JENLD-4.0 as nuclear data library. A new code based on Fortran Language was developed to treat accumulative fuel loading scheme in the calculation. The optimum fuel was 6-g HM/pebble with 20% of ^{235}U enrichment. The results showed that maximum and average discharge burnups were 223 GWd/t and 182 GWd/t, respectively. The operation period was 10.2 years, and maximum power density was 21 W/cm^3. However, high excess reactivity occurred at BOL condition. Two solutions were offered to overcome that situation: using the low ^{235}U enrichment at BOL condition and applying

BP material (B_4C and Gd_2O_3) at BOL condition. The results showed that initial excess reactivity could be reduced effectively but operation period becomes shorter and discharge burnup could be smaller. On the other hand, the results of operation period and discharge burnup using BP material was almost similar to UO_2 fuel without BP material. However, initial excess reactivity could not be suppressed as low as in a case of using low enriched uranium.

Chapter 3. Burnup performance of MOX fuel in PBR with accumulative fuel loading scheme

This chapter presented MOX as fuel material in PBR with accumulative fuel loading scheme. MOX fuel is used as one of the strategy of plutonium management to enhance the use of plutonium in a thermal reactor. In this study, plutonium from the spent fuel of PWR with 5 years of cooling time was introduced. Therefore, the MOX fuel consist of 30% plutonium (2.6 wt% ^{238}Pu, 55.5 wt% ^{239}Pu, 23.6 wt% ^{240}Pu, 12.0 wt% ^{241}Pu, and 6.3 wt% ^{242}Pu) and 70% depleted uranium. The optimum fuel composition was 5-g HM/pebble. The results showed that the operation period of 5 years was achieved with maximum discharge burnup of 172 GWd/t. The maximum power density was 9 W/cm^3 and located at the top of the reactor core. In MOX fuel, the initial excess reactivity was relatively lower compared to UO_2 fuel. Furthermore, BP material was not effective to reduce the initial excess reactivity. To confirm the safety regulation of the reactor especially at BOL condition due to the excess reactivity relatively larger compared to other regions throughout the operation period, therefore, control rod simulations were obtained in MOX fuel. At BOL condition, 36 control rods were needed to ensure the reactor became subcritical in all temperature conditions. In addition, negative reactivity coefficient was achieved in MOX fuel.

Chapter 4. Burnup performance of U-ROX fuel in PBR with accumulative fuel loading scheme

In Chapter 4, U-ROX fuel as a once-through concept was introduced in PBR with accumulative fuel loading scheme. Moreover, it was introduced to show the possibility to achieve high discharge burnup with long operation period due to the fissile density of U-ROX fuel is about three to five times lower than UO_2 fuel. U-ROX fuel consists of 81.75 mole % of YSZ solid solution and 18.25 mole % of UO_2 with 20% of ^{235}U enrichment. In this study, 5-g HM/pebble was obtained as optimum fuel composition. The results showed that maximum and average discharged burnup were 218 GWd/t and 178 GWd/t, respectively with 8.4 years of operation period. However, high excess reactivity occurred at BOL condition. The procedure to suppress the initial excess reactivity in UO_2 fuel was applied for U-ROX fuel. In this case, B_4C as BP material was adopted to suppress and to flatten the reactivity swing at BOL condition. Moreover, negative reactivity coefficient also achieved in all temperature condition throughout the operation period.

Chapter 5. Burnup performance of Pu-ROX fuel in PBR with accumulative fuel loading scheme

In this chapter, PuO_2 was diluted in ROX fuel instead of UO_2. Plutonium from the spent fuel of PWR with 5 years cooling time was applied in this study. The optimum fuel composition was 3-g HM/pebble. The results showed that operation period was 11.4 years with maximum and average discharge burnups were 550 GWd/t and 407 GWd/t, respectively. Initial excess reactivity was lower compared to U-ROX fuel. Therefore, it was difficult to reduce the excess reactivity using BP material. In this study, 16 control rods were needed to ensure the reactor became subcritical especially at BOL condition. Furthermore, the simulation of reactivity coefficient showed that negative temperature reactivity coefficient was achieved in all temperature conditions.

Chapter 6. Conclusions

In chapter 6, the results of the study were summarized and included with the conclusion of the thesis.