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# Article / Book Information

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**Summary**

Purpose of this study was to find the procedure to improve the effective utilization of nuclear fuel by improving the burnup performance in the start-up phase of OTTO cycle PBR. The understanding and analysis of the start-up phase in OTTO cycle PBR, besides the equilibrium analysis, is important to improve the heavy metal utilization of the core and to assure the safety characteristic of the OTTO cycle PBR since the start-up phase of the core.

To perform the analysis of the PBR, a computer code system named Monte Carlo burnup analysis code for PBR (MCPBR) has been developed. MCPBR applies the Monte Carlo method for a more accurate analysis of the complex characteristic of PBR. MCPBR is able to perform fuel management analysis in the start-up and equilibrium condition. Code to code comparison already performed with VSOP and PEBBED. Results of the MCPBR for $k_{eff}$ and discharge nuclide density are acceptable. Differences in the results can be attributed mainly to the different of nuclear data library as shown by different results of using JENDL-4.0 and JENDL-3.3 in MCPBR. Beside the difference in neutron transport and burnup calculation method, and also the core material composition modeling. Ability of MCPBR to model the void cavity at the top of

the PBR core also already confirmed.

In the start-up phase of the PBR, the $k_{eff}$, neutron flux, and nuclide densities of the core keep changing until an equilibrium condition is achieved in which all parameters become constant. There are many possible schemes for the initial loading of the OTTO PBR, but the most simple and efficient is to restrict the initial loading to single fuel enrichment and additional graphite pebble ball. In this case, there are two different schemes for the initial loading in the start-up of PBR involving single enrichment pebble fuel and dummy graphite balls, the mixed and top-bottom scheme. In the mixed scheme, the fuel pebble balls and graphite pebble balls are initially mixed homogeneously in the core at a certain ratio. Meanwhile in the top-bottom scheme, the fuel pebble balls are initially located in the top part of the core and the graphite pebble balls in the bottom part of the core. After the initial loading, in both schemes, only fuel pebble balls are inserted into the top part of the core. For both schemes, the fuel pebble ratio (*fpr*) parameter was introduced which represented the ratio of fuel pebble balls to all pebble balls in the core.

Study on the optimum procedure for start-up of small 10MWt OTTO cycle PBR has been performed. Optimized core for higher burnup was able to achieve 69.4MWd/kg-HM using 20% enrichment fuel with 2.1gHM/pebble. Start-up analysis of this core concludes that the top-bottom scheme is the optimum start-up scheme. From further analysis with different moderation level designs based on different HM/pebble parameter, 8g and 20g HM/pebble, it can be concluded that the moderation level of the core is the main determinant to decide the optimum start-up scheme. For small 10MWt OTTO cycle PBR with 8g and 20g HM/pebble design, which was less moderated design, mix scheme was the optimum start-up scheme.

Study on the optimum procedure for start-up of typical modular reactor of 200MWt OTTO cycle PBR has been performed. Core design with optimum burnup can be achieved with 5.6g HM-loading and enrichment is 20wt% with burnup value 187.4 MWd/kg-HM. For this target equilibrium design a top-bottom scheme is the optimum start-up fuel management scheme. To satisfy the maximum power density limitation, increasing the HM/pebble and axial fuel speed (*v*) strategies was applied. For higher HM/pebble, the optimum design to satisfy the maximum power density was achieved with 17g HM/pebble and 20wt% enrichment. However, using this option the burnup value was drop to 61.7 MWd/kg-HM. For this design, a mix scheme was the optimum start-up fuel management scheme. For higher axial fuel speed, the optimum design to satisfy the maximum power density was achieved with v=0.7cm/day with burnup value 133.8 MWd/kg-HM. For this design, v=0.7cm/day and 5.6g HM/pebble, a top-bottom scheme was the optimum start-up fuel management scheme.

In general, for the development of OTTO cycle PBR for any core size and power, the tool and procedure to analyze and determine the optimum start-up scheme which was developed in this study can be utilized. Based on this study which includes the small 10 MWt OTTO cycle PBR and the typical 200MWt modular OTTO cycle PBR, it can be conclude that the moderation level of the design is the main determinant to choose the optimum start-up scheme. A top-bottom start-up scheme is the optimum start-up scheme for over moderated core design, while the mix start-up scheme is optimum for the less moderated core design.  Using the optimum start-up scheme for each core design the utilization of nuclear fuel can be improved.