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Simplified Small Pebble Bed Reactor and the Use of Natural Uranium

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Nowadays, natural uranium resources are decreasing rapidly because of its utilization as nuclear fuel; therefore, innovative concepts are needed to use it more efficiently. A fast reactor is a good option for efficient natural uranium use, but the slow developments of this type of reactor forces us to look at other available options immediately. However, almost all commercial reactors operating today are the thermal reactor type, which is considered a proven technology due to its operation history, and many studies and experiments have been conducted on this reactor type. Moreover, high-temperature gas reactors have more advantages than the conventional water-moderated thermal reactors. The thermal efficiency of these reactors is higher than that of light water reactors, and their high output temperature can be utilized for other industrial purposes such as hydrogen production as well as for district heating. Pebble bed reactors (PBR) offer even further advantages including the efficient use of natural uranium, which can be seen from the facts that PBR has small excess reactivity during reactor operation and that the moderator material (graphite) has a small absorption cross section. In addition, a small PBR is the most promising reactor system to adopt inherent and passive safety features: namely, the coating of fuel particles, which limits the release of radioactive material into the environment, and the use large amount of graphite, which make high heat capacity of the core, as a moderator and reflector. Currently, these safety features have become a very important issue in avoiding severe nuclear accidents due to active system failure such as failure of the cooling pump system.

However, the high cost and complexity of pebble bed reactors, especially the unloading machinery, forces us to think about innovations for this reactor design that would be simpler both in term of design and operation and at the same time optimize the use of uranium resources by increasing the burnup value. In our study, we introduce and analyze an innovative design for a pebble bed reactor that could be constructed and operated at a lower cost, have easier

construction and maintenance processes, and increase efficiency of uranium use in the reactor system. Namely, we simplify the pebble bed reactor by removing the unloading devices from the system. For such kind of system, a suitable fuel-loading scheme is the Peu a Peu fuel loading scheme.

The purposes of our study were to design a simplified pebble bed reactor by removing the unloading devices from the system and then to optimize the peu à peu fuel loading scheme in the reactor system by performing optimization in term of reactor configuration and fuel composition, such as uranium enrichment and packing fraction of coated fuel particle inside the pebble ball; so that the system could achieve good burnup characteristics.

Moreover, to improve the burnup characteristics of this reactor design while at the same time using natural uranium more effectively, we also considered the use of thorium. Thorium-based fuel is gaining interest for many researchers in the nuclear industry as an alternative to the existing uranium-plutonium-based fuel. The abundance of thorium resources worldwide, which is several times larger than the uranium resources, could be expected to significantly extend the role of nuclear power as one of the world's energy resources. Many studies have been performed to examine the use of thorium as a nuclear fuel, but additional time and effort are needed to make its use on the industrial scale possible. In the meantime, using natural thorium with existing technology, for example, as a fertile material mixed with existing uranium dioxide fuel, is one way to extend the nuclear horizon by reducing the level of natural uranium utilization while waiting for the thorium technology to become more mature.

In our study, we trying to optimize the burnup characteristics of a small simplified PBR by introducing thorium into the fuel configuration as a fertile material. We also performed optimization of the thorium fraction in the UO_2 fuel, of uranium enrichment and of the packing fraction of coated fuel particles inside the pebble ball, so that the system could achieve better burnup characteristics and use scarce uranium resources more efficiently.

As the results, calculation and optimization for several small simplified PBR designs have been performed using both uranium fuel and mixed thorium-uranium fuel. These reactor designs have 110 MWt power and could achieved high burnup value compared to that of conventional PBRs. In terms of the use of natural uranium, from this study, it was confirmed

that these design could decrease the use of natural uranium for every electric power generated per year as around 33%.

Regarding the RPD (Reactor Physics Division) Award 2011, I am very happy and feel honored to received such kind of acknowledgement from the nuclear society in Japan. Thus, I would like to express my special appreciation to the Reactor Physics Division of AESJ. I hope someday, I could share the experiences interacting with AESJ to the nuclear community in my country. In addition to that, I want to express my deep gratitude to Obara-sensei as my academic advisor in Tokyo Institute of Technology for all his efforts all this time, and also for members of the Obara-lab. I hope that this kind of award could increases motivation of the students who learns reactor physics, including me, to work harder and do many good researches in the future and make many contributions to the peoples and society. Even though that right now nuclear industry facing a great challenge due to a certain nuclear accident, however I hope and I believe that the condition will be recovered and nuclear industries and it related field will be raise again, soon. Because I believed that the peacefully use of nuclear energy have very important roles for human life in the world, including Japan and also for a developing country like my country, Indonesia, which is hoping to introduce nuclear energy as one of the energy source in the near future. Hopefully.

Thank you,

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