Comparative Analysis of Single and Dual Irradiation Pass of Deep Burn High Temperature Reactor Scenario

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1. Introduction

A concept of a deep-burn (DB) of trans uranic (TRU) elements in a high temperature reactor (HTR) has been proposed [1] and studied with a single irradiation pass [2,3]. However, there is still a significant amount of TRU after burn in an HTR. Therefore, it is necessary to burn more TRU in a fast reactor (FR) with repeated reprocessing such as a pyro-process.

In this study, the fuel cycle calculations are performed and the results are compared for a single-pass DB-HHR scenario and a dual-pass sodium-cooled fast reactor (SFR) scenario.

For the analysis, front-end and back-end parameters are compared. The calculations were performed by the DANESS (Dynamic Analysis of Nuclear Energy System Strategies) [4], which is an integrated system dynamic fuel cycle analysis code.

2. Fuel Cycle Model

The 600 MWt DB-HTR core is an annular type with a small inner reflector volume for improving the neutron economy and achieving a higher fuel burnup. The active core consists of 5 fuel rings and comprises 9 axial layers, which results in 1296 fuel blocks in a core.

The SFR core rates 1500 MWt, and the core is a homogeneous annular type with a large central non-fuel region for reducing the conversion ratio so as to achieve high transmutation capability. The core height is short as 80 cm, and there are 300 fuel assemblies in the core.

In the single pass irradiation scenario with only DB-HTR, the PWR spent fuel (SF) is reprocessed and the DB-HTR SF is stored. However, in the dual pass of the irradiation cycle, both PWR SF and DB-HTR SF are reprocessed. The reprocessed PWR SF is fed into the DB-HTR, and the reprocessed DB-HTR SF is fed into the SFR. Also, the SFR SF is reprocessed and recycled in the SFR.

3. Fuel Cycle Analysis

3.1 Once-through Cycle and Front-end Parameters

The nuclear reactor capacity was 13.8 GWe in 2000. By the "National Energy Basic Plan" [5], it will increase to 27.3 GWe in 2030. After 2030, it is assumed that the nuclear capacity increases continuously and becomes ~70 GWe in 2100.

With the above operating scenario, the total SF will be ~116600 t in 2100, According to the SF inventory, the out-pile inventories of Pu, MA, and TRU are 1153 t, 95 t, and 1248 t, respectively, in 2100.

In the DB-HTR and HTR-SFR cycle, the capacity deployments of DB-HTR and SFR are adjusted to minimize the TRU stock pile, which is shown in Fig. 1.

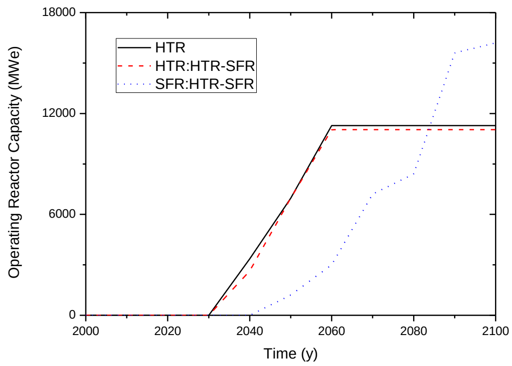

Fig. 1. Deployed HTR and SFR in single and dual passes

The accumulated natural uranium consumption is compared in Fig. 2. The uranium consumption decreases for both cases because a part of the uranium oxide (UOX) fuel is substituted by HTR or SFR fuel. For the single- and dual-pass recycling, the total uranium consumption decreases by ~13 and 23%, respectively, in 2100 compared with the OT case.

The amount of fuel enrichments in 2100 decreases by ~13 and 24% for single- and dual-pass irradiation, respectively, compared with OT cycle. The UOX fuel fabrication decrease 13 and 22%, respectively. In a single pass, the TRISO fuel fabrication becomes 926 t in 2100. Also the TRISO and SFR fuel fabrications in a dual pass reach 856 and 4130 t, respectively, in 2100.

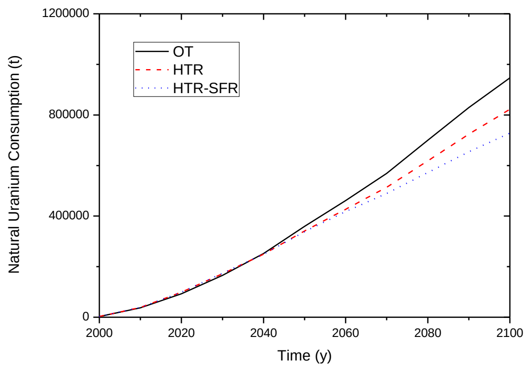

Fig. 2. Comparison of natural uranium consumption

3.2 Back-end Parameters

The accumulated PWR SF reprocessing amounts increase and become ~74000 t in 2100 for both scenarios. In the HTR-SFR scenario, the HTR and SFR SF reprocessing become ~130 t and 1300 t, respectively.

The total amount of SF inventories of both irradiation passes decreases by ~80% compared with the OT cycle. Also, the long-term stored SF inventories are reduced by ~80% (Fig. 3). This is because most of the PWR fuel is reprocessed to feed the HTR.

As shown in Fig. 4, the long-term stored plutonium inventories of both scenarios in 2100 are 646 t and 72 t, respectively, which are reduced by 40 and 93%, respectively, compared with the OT cycle. The MA inventory in the DB-HTR scenario increases because the MA is assumed to be not used in the DB-HTR scenario. However, the long-term stored MA inventory in the HTR-SFR case reduces by ~93%. Consequently, the total long-term stored TRU inventories of a single- and dual-irradiation pass in 2100 are reduced by 26% and 93%, respectively, compared to that of the OT (Fig. 5).

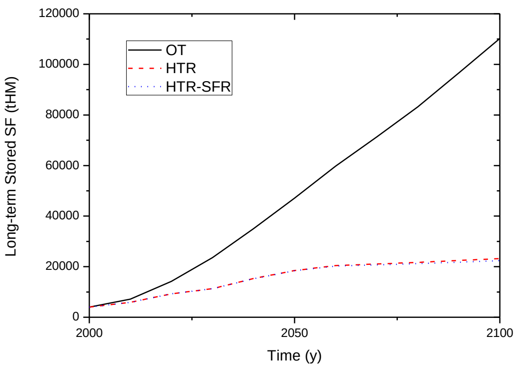

Fig.3. Comparison of the long-term stored SF.

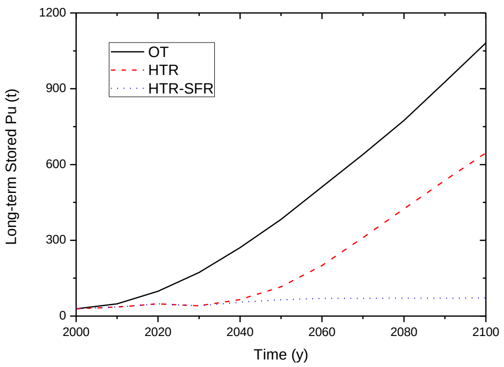

Fig. 4 Comparison of long-term stored Pu inventory

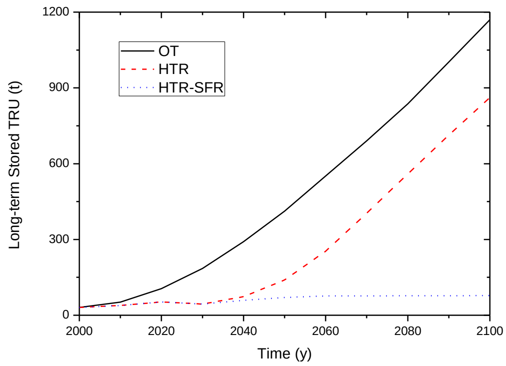

Fig. 5. Comparison of long-term stored TRU inventory

4. Summary

From the results, it is known that the DB-HTR and SFR scenarios are more effective in reducing the long-term stored SF and TRU inventories. The dual pass irradiation scenario can reduce the long-term stored SF and TRU inventories by more than 90%.

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