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Dynamic Analysis of Deep Burn High Temperature Reactor Scenario

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1. Introduction

Recently, a deep-burn of trans uranic (TRU) element in the high temperature reactor (HTR) has been studied [1,2]. The concept is proposed by General Atomics, in which a graphite-moderated modular helium reactor (MHR) is used to obtain ultra high burnup [3]. For the deep-burn (DB) concept, ceramic-coated particle fuels (TRISO) are used and deep-burning (typically 50~65%) of TRUs from Light water reactors (LWRs) are feasible in a single irradiation campaign without repeated reprocessing.

In this study, a DB-HHR scenario with once-through (OT) cycle is considered for an efficient transmutation of the TRUs from LWRs. In this scenario, the fuel cycle is not closed: the only LWR spent fuel (SF) is reprocessed and the DB-HTR SF is stored.

For analysis, front-end and back-end parameters are compared with those of the OT cycle. The calculations were performed by the DANESS (Dynamic Analysis of Nuclear Energy System Strategies) [4], which is an integrated system dynamic code for the analysis of today's and future nuclear energy system. The dynamic analysis has been used for Generation-IV reactor system study, and for several fuel cycle analyses [5,6].

2. DB-HTR Core Model

The DB-HTR core has been modified from the original GT-MHR [3] of GA design. As the GT-MHR, the DB-HTR core is also annular type. However, the inner reflector volume is much smaller in the DB-HTR for improved neutron economy and higher fuel burnup. The active core consists of 5 fuel rings. The DB-HTR core is comprised of 9 axial layers, which results in the number of fuel blocks of 1296 in a core. Two types of fuel composition are considered, the first is 0.2%UO_2 + 99.8% (NpO_2+$PuO_{1.8}$) + SiC kernel getter [0.2% UO_2 mixed TRU] and the second is 30% UO_2 + 70% (NpO_2+$PuO_{1.8}$) + SiC kernel getter [30% UO_2 mixed TRU].

3. Fuel Cycle Analysis

3.1 Once-Through Cycle

In 2000 there were 4 CANDU reactors and 12 PWRs, and the total reactor capacity was 13.8 GWe. From the "National Energy Basic Plan"[7], the nuclear capacity in 2018 will increase to 27.3 GWe with 29 operating reactors. After 2018, it is assumed that the nuclear capacity increases continuously and becomes ~70 GWe in 2100.

Fig. 1 shows the share of capacity of each reactor needed to meet the energy demand. When all the CANDU reactors are shutdown, the electricity generation is dominated by the PWR after 2050. Also, it is shown that all the existing PWR shut downs by 2070 and consequently APWR is dominant after 2070. The number of operating APWR will be 51 in 2100. As shown in Fig. 2, the PWR SF inventory continuously increases with time and becomes ~98100 t in 2100, while the CANDU SF remains constant value at ~18500 t after 2050, which is because the CANDU reactors are not operated after 2050. Consequently, 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.

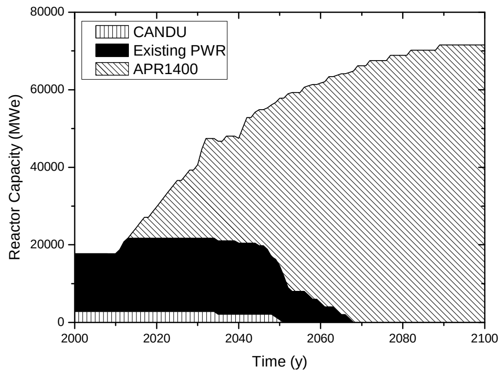

Fig. 1. Operating reactor capacity

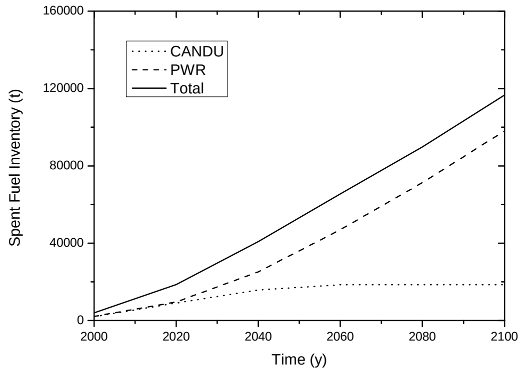

Fig. 2. Spent fuel inventory from each reactor

3.2 DB-HTR Cycle

The capacity deployments of DB-HTR are adjusted to minimize the TRU stock pile. The accumulated natural uranium consumption is compared in Fig. 3.

The uranium consumption decreases for both fuel cases because a part of the uranium oxide (UOX) fuel is substituted by HTR fuel. For both fuel types, the total uranium usage decrease by ~12 and 14% for fuel 1 and 2, respectively in 2100 compared with OT case.

The amount of fuel enrichments in 2100 decrease by ~12, and 14% for fuels 1 and 2, respectively compared with OT cycle. The UOX fuel fabrication decrease 11 and 14% for fuel 1 and 2, respectively. The TRISO fuel fabrications become 924 and 1350 t for fuel 1 and 2, respectively.

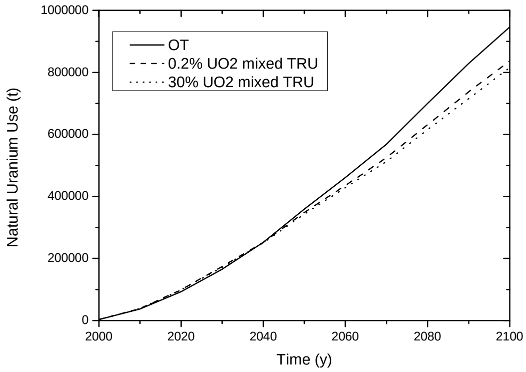

Fig. 3. Comparison of natural uranium consumption

Fig. 4 compares the total amount of SF between OT and HTR cycles. It can be seen that the HTR cycle reduces the total amount of SF by ~80% for both fuel types. This is because that almost of the PWR fuel is reprocessed to feed the HTR.

The accumulated PWR SF reprocessing amount increases and becomes ~37000 t in 2100 for both fuel types. The HTR scenario reduces the out-pile plutonium inventory. The out-pile plutonium inventories of both fuel type in 2100 are 424 t and 450 t, respectively. The reduction rate of the MA inventory is lower than the plutonium inventory because the MA is assumed to be not used in this HTR cycle. The resultant out-pile TRU inventories of each fuel type in 2100 are 525 t and 570 t, respectively, which are reduced by 58% and 54%, respectively, compared to that of the OT. (Fig. 5)

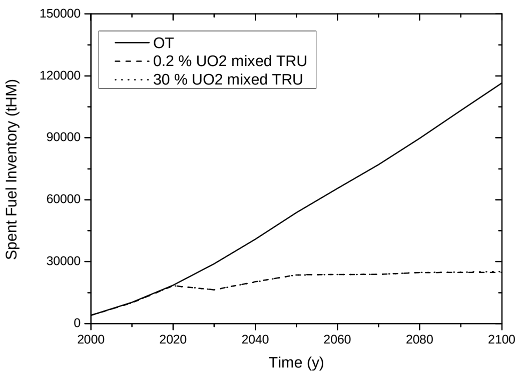

Fig. 4. Comparison of the SF inventory

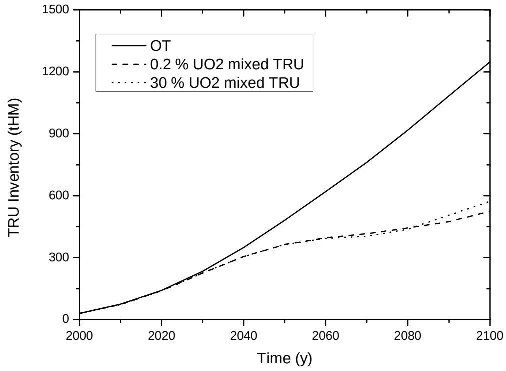

Fig. 5. Comparison of the TRU out-pile inventory

4. Summary

From the results, tt is known that the DB-HTR scenario can effectively reduce the SF and out-pile TRU inventories. The remaining TRU in SF can be reduced more by introducing of FR burner. Therefore, the synergistic scenario study with FR is recommended in future.

REFERENCES

[1] A. Baxter, C. Rodriguez, and F. Venneri, "The Application of Gas-Cooled Reactor Technologies to the Transmutation of Nuclear Waste," Progress in Nuclear Energy, **38**, p.81, 2001.

[2] C. Rodriguez et al., "Deep-Burn: making nuclear waste transmutation practical," Nuclear Engineering and Design, **222**, 299, 2003.

[3] Potter and A. Shenoy, "Gas Turbine-Modular Helium Reactor (GTMHR) Conceptual Design Description Report," GA Report 910720, Revision 1, General Atomics, July 1996.

[4] L. V. D. Durpel, A. Yacout, D. Wade, and H. Khalil, "DANESS-Dynamic Analysis of Nuclear Energy System Strategies," Global 2003, New Orleans, November 16-20, 2003.

[5] US-Department of Energy, "A Technology Roadmap for Generation IV Nuclear Energy Systems," GIF-002-00, 2002.

[6] C. J. Jeong, H. Choi, "Dynamic Modeling and Analysis of Alternative Fuel Cycle Scenarios in Korea," Nuclear Engineering and Technology, **39 (1)**, pp85-94, 2007.

[7] "National Energy Basic," Ministry of Knowledge and Economy, 2008.