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Comparative Study on Incineration Effect of HLW Isotopes in Fast Reactors

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1. Introduction

The crucial concern of nuclear energy is associated with the problem of particular nuclide in spent fuel that has high radioactivity and long half-life. Especially, TRU and LLFP(Long-Lived Fission Product) have high radioactivity and long half-life. Research on transmutation reactors development and reduction of long half-life and amount of highly radioactive nuclides using nuclear incineration and transmutation technologies, has been ongoing. In the case of liquid metal reactor of SFR and LFR, transmutation by nuclear fission is getting larger than that by reaction of neutron absorption found in other nuclear reactors. In turn, accumulation of MAs with long half-lives and high mass number at SFR and LFR is less than that of other thermal reactors whereas the extinction rate of MA is getting higher. However, research related to comparison of MA incineration rates among fast reactors, for instance, SFR and LFR, has not almost been performed in somewhat more detail before.

In this study, the comparative analysis was conducted to investigate the variations of MA and LLFP in terms of burnup rate at SFR and LFR which are fast reactor candidates for GEN-IV. It covers the comparisons of resources recycling, nuclides transmutation, radioactivity, and decay heat of spent fuel of SFR and LFR than those of PWR. Since calculation of ORIGEN code is not capable to handle complex geometry of entire core yet it has ability only to deal with simplified point-depletion, calculation results may have limitations with regard to completely confidence. Consequently, the research herein can provide useful data concerning high-level radioactive waste which is used for fast reactors in addition to understanding of nuclide characteristics generated by these reactors

2. Calculation Tools

2-1 ORIGEN2.1

The isotope depletion code ORIGEN2.1[1] has been used to estimate nuclear waste transmutation rates as well as composition and toxicity of radioactive materials. For calculating the burnup, decay and processing of radioactive materials, ORIGEN2.1 uses a matrix exponential method and one-group cross-sections generated by neutron transport simulation programs.

3. Selection of Reference Plants

Three reference plants under consideration are the following:

3-1 PWR

Korean Commercial PWR with thermal power of 2815 MWth was chosen. It has 3,000 MWD/MTU burnup rate and used UO2 fuel type with 3.2 w/o fuel enrichment [2]

3-2 LFR-PEACER

PEACER-300 with total thermal power of 850 MWth was selected to represent LFR type. It has 3 refueling batch, and is loaded with (U,TRU)Zr fuel type with enrichment of 14.8/17.0/19.2 (inner/middle/outer) [3]

3-3 SFR-KALIMER

As SFR type, KALIMER with total thermal power of 392.2 MWth was considered. Its breeding Ratio is 1.05 and loaded fuel type is U-Pu-10% Zr. [4]

4. Calculation Results

4-1 Perspectives on Resources Recycling

Based on calculation results for resource recycling, LFR is the most efficient to achieve optimal resource recycling. It was found that the amount of Pu-239 at PWR slightly increased due to depletion time. The LFR was observed to convert more efficiently from U238 and Pu240 into Pu239 and Pu241 when compared to PWR and SFR. However, the conversion rate of SFR was still much higher than that of PWR.

4-2 Variation of TRU and LLFP Amount

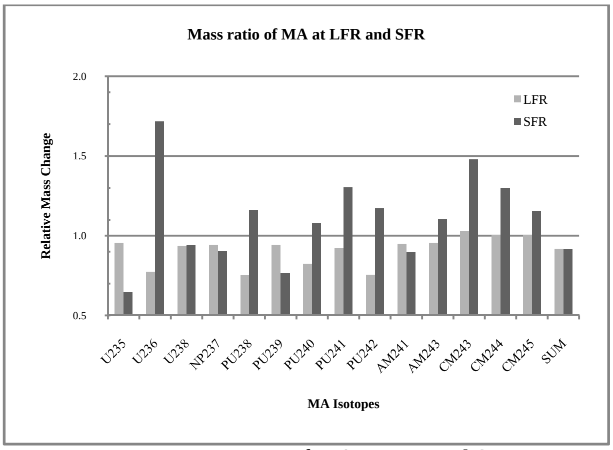

Figure 1. Mass ratio of MA at LFR and SFR

The initial loading amount of each element is assumed as 1 for both LFR and SFR. The Fig. 1 represents comparison of change in mass of MA isotopes. In this analysis, some MAs which have very small mass in reactors have been ignored due to small mass initial loading amount. As shown in Fig. 1, about MA of 1/3 was reduced in the SFR. The mass of most MAs at LFR reduced more than those of SFR. However, overall sums of MA at both LFR and SFR, was found to be almost equivalent.

	PWR		SFR		LFR	
	MOC	**EOC**	**MOC**	**EOC**	**MOC**	**EOC**
TC 99	4.34E-02	8.11E-02	1.07E-01	1.99E-01	1.00E-01	1.89E-01
SN126	1.32E-03	2.96E-03	6.83E-03	1.30E-02	5.97E-03	1.15E-02
SE 79	3.24E-04	6.24E-04	6.64E-04	1.27E-03	6.11E-04	1.18E-03
ZR 93	4.13E-02	7.59E-02	6.81E-02	1.29E-01	6.12E-02	1.17E-01
CS135	1.59E-02	3.21E-02	1.84E-01	3.49E-01	1.72E-01	3.30E-01
PD107	8.18E-03	2.42E-02	5.89E-02	1.10E-01	6.34E-02	1.19E-01
I129	8.98E-03	1.90E-02	3.41E-02	6.38E-02	3.12E-02	5.92E-02

Table 1. Percent change in the mass ratio of LLFP to fuel (%)

In investigation of variation of LLFP, seven kinds of fission products were selected for comparison under the consideration of high radioactivity and long half-lives. As described in Table I, the percentage change in the mass ratio of LLFP to fuel for seven elements increased distinctively. Among these seven LLFP isotopes, the percentage change of Cs-135 increased the most. In comparison of SFR with LRF, less percentage change in mass ratio of LLFP to fuel was found at LFR. It can say that LFR was beneficial for waste management and reduction of waste products.

4-3 Comparison the amount of waste generated

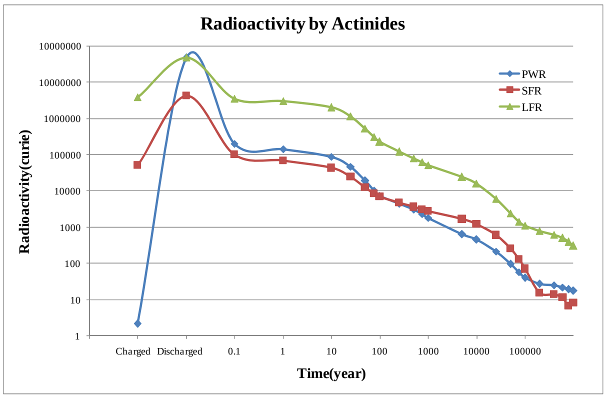

Figure 2. Radioactivity by Actinides

The actinide in spent fuel has larger radioactivity when compared to fission product. Each reference reactor has respectively different initial amount of MA. As illustrated in Fig. 2, only radioactivity of LFR was lower than initial radioactivity level after about 1 month though the initial amount of spent fuel loaded in LFR was the largest. It was found that radioactivity went down at faster rate than SFR. In other words, LFR could burn down long half-life nuclides more than SFR.

5. Conclusions

Basically, SFR and LFR that are designed to consume MA bring about enough breeding.

In the comparison of SFR with LFR, LFR is more efficient in the scope of resource recycling than capability of SFR. LFR can burn down many kinds of MA when compared to SFR though these two reactors burnt down almost same amount of MA.

Nonetheless, LFR generated less ratio of LLFP and burnt more LLMA than SFR. Additionally, the radioactivity in spent fuel radioactivity at LFR went down at faster rate than that of SFR. High radioactivity and decay heat bring about inconvenience to maintain spent fuel. Consequently, it can lead to less proliferation resistance.

As a result, LFR had a capability to burn down MA than SFR. When considered generation of LLFP and scope of resources recycling, LFR became more favorable. For optimal transmutation reactor, it is regarded as the most important function to burn down completely MA and to reduce disposal of spent fuel. From the judgment of calculation results, it implied that LFR is more beneficial for transmutation, waste management and radioactivity concerns.

REFERENCES

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