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Reactor core and actinide production evaluation based on different loading material of recyled spent nuclear fuel of LWR in FBR

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ARTICLE INFO

Article history:
Received 5 November 2015
Received in revised form
16 January 2016
Accepted 20 January 2016
Available online 14 February 2016

Keywords:
Fuel breeding
Excess reactivity
Spent nuclear fuel
FBR
LWR

ABSTRACT

Reactor core analysis is one of the important factor for evaluating reactor operation and safety concern as well as the evaluation on fuel breeding of nuclear fuel to show nuclear fuel sustainability. Actinide compositions including plutonium and minor actinides production are also evaluated for estimating the plutonium non-proliferation aspect as well as for nuclear fuel breeding aspect. Loaded initial fuels in fast breeder reactor (FBR) are based on the spent nuclear fuel (SNF) of light water reactor (LWR). Those SNF of LWR will vary depending on LWR operation such as fuel burnup levels as well as cooling time process after the reactors are shutdown. In order to optimize the analysis of FBR design, a large FBR type with core and blanket fuel arrangements as driver fuels and breeding fuel regions as well as adopted some specific fuel batches and cycle length systems were adopted as a basic analysis case. Some obtained results are showing that reactor core performance such as criticality and breeding ratio are depending on the loaded fuel composition as well as operating reactor operation. Less criticality condition and higher breeding ratio are obtained by longer cooling time process of loaded SNF LWR. In addition, higher burnup of loaded SNF LWR achieves less criticality condition, while fuel breeding ratio profile is obtained higher for higher burnup. Loaded fuel composition of U-TRU fuel gives higher breeding ratio and its breeding ratio become higher for longer cooling time of loaded fuels. Actinide element compositions become less at end of equilibrium cycle (EOEC) of FBR, except for plutonium (Pu) and curium (Cm) which obtains higher composition. It shows the utilization of trans-uranium fuel type such as U-TRU type gives a significant production of minor actinide which can be estimated to contribute for reducing the excess reactivity as well as to increase nuclear fuel breeding capability. Less criticality is effective to reduce the excess reactivity at beginning of cycle for safety concern and higher breeding profile is indicating that more fuel sustainability aspect of nuclear fuel is gained.

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http://dx.doi.org/10.1016/j.ijhydene.2016.01.102

Introduction

Energy becomes the most crucial problem for the next 50 years humanity of the world's top ten human problems that human should provide a sufficient energy supply to maintain the sustainable development in the world [1]. One of the challenges for providing secure nuclear energy supply is sustainability of nuclear fuel resources which can be maintained efficiently and by additional uranium resources from sea water, combination with thorium fuel resources as well as some fusion reactors, its sustainability of nuclear fuel will provide a similar profile with some other renewable energy resources as a sustainable energy source [2]. Used fuel or spent nuclear fuel from the reactors such as LWR will be the key issue which focuses on utilization of spent fuel as a recycling fuel resource and fuel breeding resource [3]. Nowadays, some minor actinides (MA) have been developed to be recycled for some purposes such as converted fuel for extending longer reactor operation, burning and transmutation of MA, fuel breeding of FBR as well as for proliferation resistance purposes [4–12]. Core performance of criticality and breeding capability of fast breeder reactor (FBR) as well as actinide compositions are evaluated based on different loaded initial fuels of spent nuclear fuel (SNF) of light water reactor (LWR) in the present study. Those loaded SNF LWR fuel compositions are varied and those are depending on LWR operation such as fuel burnup level as well as cooling time process after the reactors are shutdown.

Analysis and methods

Loaded fuel compositions as initial fuels to be loaded into the FBR cycle are coming from the spent nuclear fuel (SNF) composition from light water reactor (LWR) which are varied based on the LWR cycle design paramter such as burnup of 36 GWd/t up to 60 GWd/t with several cooling time process of 0–30 years. In this evaluation, it will be focused on the SNF LWR composition based on the several burnup values, cooling times and combination of transuranium fuel loading. Transuranic fuel types are used for this evaluation to be compared with conventional MOX fuel of FBR. ORIGEN Code is performed to evaluate fuel behaviors and fuel compositions of LWR from initial fresh fuel up to the end operation as well as during cooling time process after fuels are discharged [13]. FBR design of Japan Sodium Fast Reactor (JSFR) is adopted to be used for this evaluation with core and blanket fuel arrangements as driver fuels and breeding fuel regions as well as adopted some specific fuel batches and cycle length systems [14]. Several coupling codes were used for FBR design optimization which are based on SLAROM code, JOINT code and diffusion calculation of CITATION code as well as JENDL 3.2 revision as a nuclear data library [15–18]. Transuranium analysis is used to estimate the conversion process of MA into plutonium isotopes such as Np-237 or Am-241 convert to Pu-238 which can be expected to increase fuel breeding capability as well as protected plutonium production [10,11,19–28].

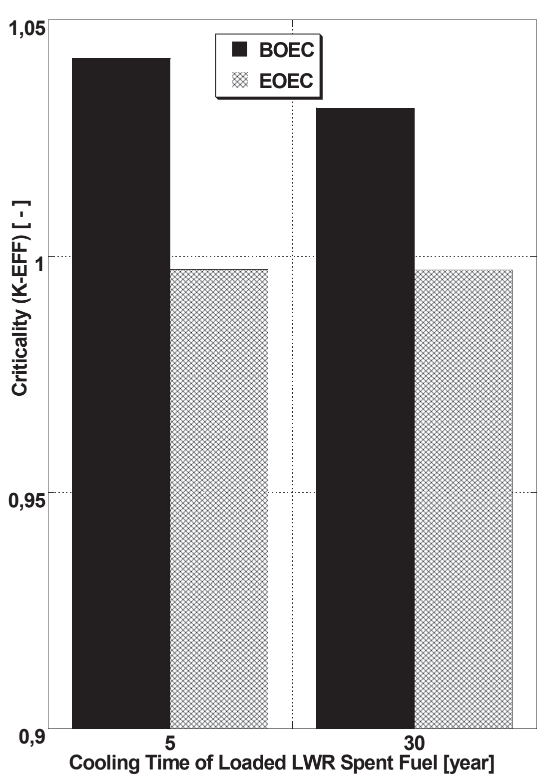

Fig. 1 – Criticality profile for different cooling time of loaded spent fuel.

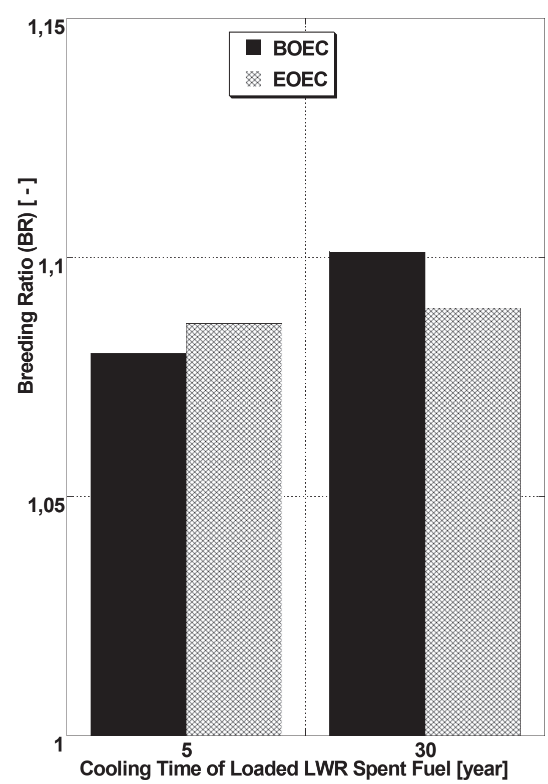

Fig. 2 – Breeding ratio for different cooling time of loaded spent fuel.