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Overview of Benchmark Activity for Reactor Physics Study of LWR Next Generation Fuels

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1. Introduction

This paper summarizes the benchmark activity conducted by "the Working Party (WP) on Reactor Physics for LWR next generation fuels," which was organized in 1999 under the Research Committee on Reactor Physics by Japan Atomic Energy Research Institute (JAERI) as a joint activity with Atomic Energy Society of Japan (AESJ). The next generation fuels mean the ones aiming at further extended burn-up such as 70GWd/t over the current design.

To investigate the calculation accuracy of the nuclear characteristics of LWR next generation fuels, the WP has performed the following activities:

- Proposal of the benchmark problem,
- Collection of the benchmark problem solutions,
- Comparisons of the solutions and their analyses.

The paper describes each part briefly and gives some concluding remarks. The details can be found in the papers or the reports [1-7] published by the WP members, as well as on the WP website served by JAERI [8].

2. Proposal of the benchmark problem

The benchmark problems consist of UO_2 fuel and MOX fuel problems, each of which has a pin cell, PWR assembly and BWR assembly configurations. Since the next generation fuels in this benchmark problem aim at very high burn-up of about 70 GWd/t, some of the current design limitation (enrichment < 5wt%^{235}U, for example) for the current LWR fuels were neglected.

The brief benchmark calculation models are shown in Fig.1. The details of the benchmark problem specification can be found in Ref.[3,8].

3. Collection of the benchmark problem solutions

Proposed benchmark problems were solved by many organizations using various calculation codes and nuclear data libraries. A total of 19 sets of calculated results have been submitted by 13 organizations including KAERI with HELIOS code and ENDF/B-VI, as shown in Table 1.

All the digital data of the calculated results can be acquired on the WP website [8] with MS-Excel format, so that one can easily compare his/her own calculated results with the other ones.

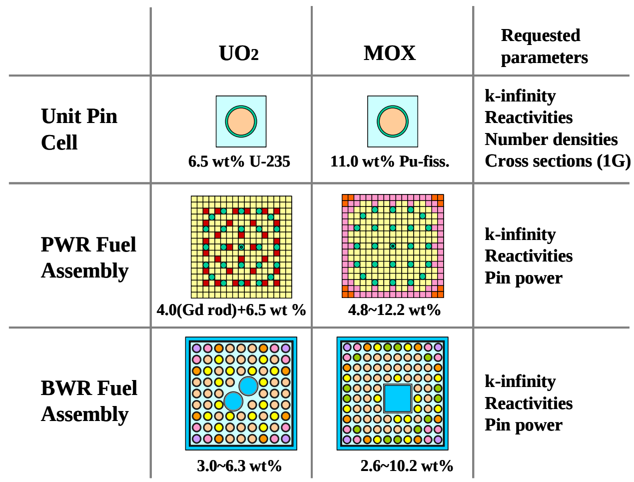

Figure 1. The brief benchmark calculation models

4. Comparisons of the solutions and their analyses

Obtained nuclear characteristics as a function of burn-up, such as k-infinity, temperature or void reactivity, nuclide number densities and pin power distributions, were compared with each other and some interesting results were observed [4-7].

In some case, the results given by the well-validated design codes did not agree with the ones given by the other majority. This means that a plenty of design experiences and the feedback from operating data of actual plants may sometimes make the design codes go towards different direction from others, which include theoretically reliable one like a continuous energy Monte Carlo code with the latest nuclear data library.

A continuous energy Monte Carlo code is normally believed to give the reference solution in terms of calculation method with a certain nuclear data library. But the reality is that the calculation results from different continuous energy Monte Carlo codes hardly match even if they use the same nuclear data library. In this study, two different codes, MVP-BURN and MCNP-BURN2, both of which use JENDL-3.2, finally gave almost the same results after detailed investigation. This is a meaningful result to obtain "realistic and useful" reference solution to calculation methods.

There were some cases in which large differences were found among calculation results and in those cases, the causes of the differences were investigated in detail.

Table 1. List of benchmark participants and their codes

Data Index	Organization	Code	Base Library	Pin Cell		PWR Assembly		BWR Assembly	
				UO2	MOX	UO2	MOX	UO2	MOX
MVP-BURN(J32)	JAERI	MVP-BURN	JENDL-3.2	x	x				
SRAC(J32)	JAERI	SRAC	JENDL-3.2	x	x		x		
SRAC(J33)	JAERI	SRAC	JENDL-3.3	x	x				
SRAC(F22)	JAERI	SRAC	JEF-2.2	x	x				
SRAC(B65)	JAERI	SRAC	ENDF/B-VI(R5)	x	x				
MVP-BURN(J32/KU)	KURRI	MVP-BURN	JENDL-3.2			x	x		
MVP-BURN(J32/OS)	Osaka Univ.	MVP-BURN	JENDL-3.2					x	x
CASMO(F22/TE)	TEPSYS	CASMO4	JEF-2.2	x	x			x	x
CASMO(B4/NF)	NFI	CASMO4	ENDF/B-IV,V	x	x	x	x		x
NULIF(B5)	NFI	NULIF	ENDF/B-V	x					
CASMO(B4/NU)	NUPEC	CASMO4	ENDF/B-IV,V					x	x
SHETRAN(B63)	SEPCO/YONE	SHETRAN	ENDF/B-VI(R3)	x	x	x	x		
TGBLA(B5)	GNF-J	TGBLA	ENDF/B-V	x	x			x	
VMONT(J32)	GNF-J	VMONT	JENDL-3.2	x	x			x	
MCNP-BURN2(J32)	Toshiba	MCNP-BURN2	JENDL-3.2	x	x			x	
FLEXBURN(J32)	CRIEPI	FLEXBURN	JENDL-3.2	x	x	x	x		
LWRWIMS(F22)	EPDC/KCC	LWRWIMS	JEF-2.2	x	x				
PHOENIX-P(B63)	MHI	PHOENIX-P	ENDF/B-VI(R3)	x	x	x	x		
HELIOS(B6/KA)	KAERI	HELIOS	ENDF/B-VI	x	x	x	x		x

Analyses of the post irradiation and critical experiments with the codes used in the benchmark were reviewed in the process of the investigations. Those studies have resulted in the proposal of future experiments to find the true solution, such as the critical experiment with high concentration Plutonium that has the isotopic ratio of discharged LWR fuel.

5. Concluding remarks

Based on the above mentioned all results, the present status of calculation accuracy for the LWR next generation fuels has been confirmed and future research topics were proposed.

Due to regulatory concern or commercial proprietary issue, it was difficult to compare calculation results of design codes directly with each other or with ones by open codes. But this time, it has become possible by setting up the problem with the near future design, not with the current one, and we have gained lots of variable information that includes some feedback to current LWR analysis.

Anyone can access the WP website [8] and obtain all the calculated results only by applying ID and password. The WP hopes that as many reactor physics researchers and engineers as possible would utilize the results of this benchmark activity to their own study or work.

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