Benchmark Calculations for Graphite-Moderated Reactors Using Different Evaluated Nuclear Data

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1. Introduction

The R&D projects for the Very High Temperature Reactor (VHTR) are being carried out in connection with a hydrogen production as an alternative energy to fossil fuels. Also the innovative Gas-Cooled Fast Reactor (GFR) concepts are being actively considered in the Generation IV program. The VHTR and GFR contain relatively large quantities of graphite and/or silicon when compared to the existing LWR and HWR.

In this study, several graphite-moderated reactors were selected to perform the MCNP4C criticality benchmark calculations. The isotopic contributions to the k_{eff} have been estimated by substituting the JENDL-3.3 and JEFF-3.0 data for the ENDF/B-VI.8-based calculations. The impact of the different thermal scattering law data of graphite has also been investigated for the criticality calculations.

2. Benchmark Problems

Several graphite-moderated reactors were selected for the criticality benchmark calculations. The reactors employed are; core 5 (reference state #3) of the HTR-PROTEUS within the framework of an International Atomic Energy Agency (IAEA) co-ordinated research program (CRP) [1] and 8 critical benchmarks taken from the International Criticality Safety Benchmark Evaluation Project (ICSBEP): critical configuration 1 of the ZEUS experiments, the 8F/2 assembly of the ZEBRA zero-power fast reactor, the HUG (Homogeneous-Uranium-Graphite) experiment of the HECTOR zero-power reactor, 3 critical configurations (2, 4 and 6) of the RBMK graphite reactor and 2 critical configurations (1 and 11) of the ROVER critical experiments loaded with Westinghouse type NRX-A3 and -A4 fuel elements [2].

The ZEUS, ZEBRA and HUG are the “Intermediate” (0.625 eV ≤ Energy ≤ 100 keV) systems and the others are the “Thermal” (Energy < 0.625 eV) systems, as classified by the energy of the majority of neutrons causing a fission. Figure 1 shows the neutron spectra of the benchmark problems. For the RBMK, ROVER and HTR-PROTEUS, the neutron spectra are similar to the typical thermal spectra of a PWR, while a hardening of the spectra is apparent in the epithermal and fast regions.

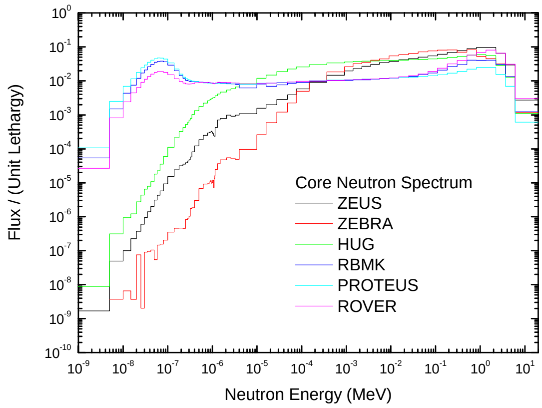

Figure 1. Neutron spectra of benchmark problems

3. Benchmark Calculations and Results

The MCNP4C libraries based on the ENDF/B-VI.8, JENDL-3.3 and JEFF-3.0 have been generated through a NJOY99.90 code [3] processing. The benchmark calculation results for the MCNP libraries have been compared with the experimental values, as shown in Figure 2.

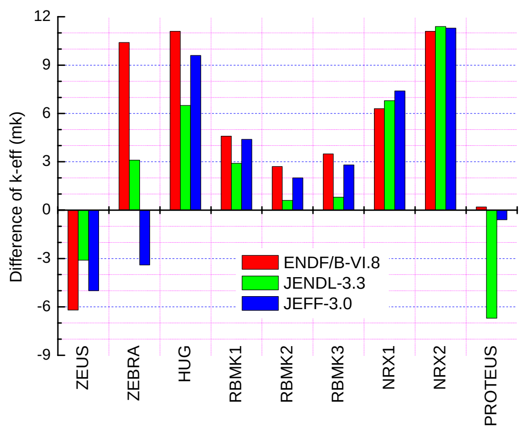

Figure 2. Comparisons of calculated k_{eff} with experiments

The ENDF/B-VI.8 results generally agree well with the JEFF-3.0 results except for the ZEBRA, in which the capture/fission reactions of ^{238}U are predominant. The JENDL-3.3 results tend to decrease for the k_{eff} except for the ZEUS and ROVER when compared with the other libraries. Especially for ZEUS, a relatively large increase of k_{eff} was observed due to the large amounts of Cu used as a reflector material. The ^{235}U data of JENDL-3.3 results in a decrease of k_{eff} for the ZEUS and HUG.

For the RBMKs and HTR-PROTEUS, the JENDL-3.3 results have a tendency to decrease for the k_{eff}, which is caused by the increasing capture reaction rate of graphite. Figure 3 shows the impact of the different thermal scattering law data of graphite for the criticality calculations. The calculated k_{eff} by the TMCCS library from the MCNP4C code package shows small discrepancies within 2 mk when compared with those by the libraries processed with the thermal evaluations for the ENDF/B-VI.3 and JEFF-3.0, respectively.

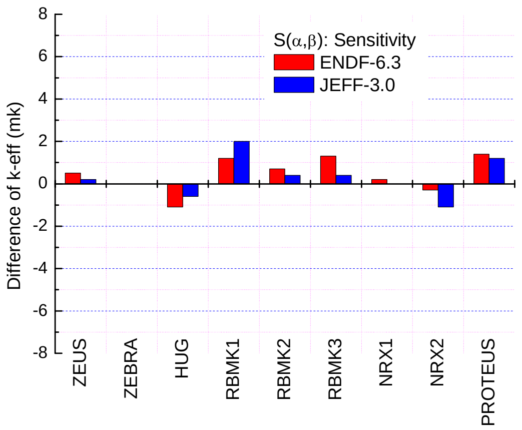

Figure 3. Impact of different thermal scattering law data of graphite

ACKNOWLEDGEMENT

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