Benchmark of ENDF/B-VII.1 and JENDL-4.0 on Reflector Effects

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Summary of Benchmark

Criticality C/E values by Monte Carlo calculation

<table>
<thead>
<tr>
<th>Exp.Core</th>
<th>JENDL-4.0</th>
<th>ENDF/B-7.1</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jezebel-239</td>
<td>0.9985</td>
<td>1.0001</td>
<td>(PMF001) Ultra-small, Pu, Bare, Pu240: 4.5at%</td>
</tr>
<tr>
<td>Jezebel-240</td>
<td>0.9985</td>
<td>1.0001</td>
<td>(PMF002) Ultra-small, Pu, Bare, Pu240: 20at%</td>
</tr>
<tr>
<td>Flattop-Pu</td>
<td>0.9986</td>
<td>1.0009</td>
<td>(PMF006) Ultra-small, Pu, Nat. U reflector, Pu240: 4.8wt%</td>
</tr>
<tr>
<td>Godiva</td>
<td>0.9977</td>
<td>1.0005</td>
<td>(HMF001) Ultra-small, Uranium, Bare, U235: 94wt%</td>
</tr>
<tr>
<td>Flattop-235</td>
<td>0.9978</td>
<td>1.0033</td>
<td>(HMF028) Ultra-small, Uranium, Nat. U reflector, U235: 93wt%</td>
</tr>
<tr>
<td>FCA X-1</td>
<td>1.0017</td>
<td>0.9979</td>
<td>Small, Pu+Enriched. Uranium, Dep. U blanket, Pu:28wt%, U235:12wt%</td>
</tr>
<tr>
<td>FCA X-2</td>
<td>1.0025</td>
<td>0.9953</td>
<td>Small, Pu+Enriched. Uranium, SS reflector, Pu:28wt%, U235:12wt%</td>
</tr>
<tr>
<td>JOYO Mk-1</td>
<td>0.9990</td>
<td>0.9965</td>
<td>Small, Pu+Enriched. Uranium, Dep. UO2 blanket, Pu:17wt%, U235:23wt%</td>
</tr>
<tr>
<td>JOYO Mk-2</td>
<td>1.0036</td>
<td>0.9977</td>
<td>Small, Pu+Enriched. Uranium, SS reflector, Pu:28wt%, U235:12wt%</td>
</tr>
<tr>
<td>ZPPR-9</td>
<td>1.0020</td>
<td>0.9977</td>
<td>Large, Pu, Depleted U. blanket, Pu:13wt%</td>
</tr>
</tbody>
</table>

Criticality C/E values by Monte Carlo calculation

±0.2%Δk
(≜Exp.error)
Method of Sensitivity Analysis

■ Cross-section sensitivity:

\[ S_{m,x,g} = \frac{dR / R}{d\sigma_{m,x,g} / \sigma_{m,x,g}} \]

where,

- \( R \): core parameter,
- \( m \): nuclide,
- \( x \): reaction type,
- \( g \): energy group number.

■ Contribution of each cross-section

\[
\frac{R_{ENDF} - R_{JENDL}}{R_{JENDL}} = \sum_{m,x} \sum_{g} \left[ S_{m,x,g} \times \frac{\sigma_{m,x,g,ENDF} - \sigma_{m,x,g,JENDL}}{\sigma_{m,x,g,JENDL}} \right]
\]
Reflector Effect: (Bare -> Nat. U)

Godiva

Ultra-small, Uranium, U235: 94wt% , Bare

(HMF001)

Flattop-235

Ultra-small, Uranium, U235: 93wt% , Nat. U reflector

(HMF028)
Reflector Effect: (Bare -> Nat. U)

Isotope- and reaction-wise contribution to the keff C/E difference between ENDF-7.1 and JENDL-4.0

=> The cancellation among inelastic, capture (+) and mu-ave., elastic (-) of U-235 seems to make the reflector effect by ENDF-7.1 worse than JENDL-4.0 by 300pcm.
ENDF/B-7.1 vs. JENDL-4.0: U-235 Fission, Capture, Elastic Scattering, and Mu Average
Reflector Effect: (Dep. U blanket -> SS reflector)

FCA

Small core, Pu + Enriched. Uranium, Pu:28wt%, U235:12wt%

FCA X-1: Dep. U blanket
FCA X-2: SS reflector
Reflector Effect: (Dep.U blanket -> SS reflector)

FCA X-1,2

keff C/Es of FCA X-1 and X-2

Isotope- and reaction-wise contribution to the keff C/E difference between ENDF-7.1 and JENDL-4.0

=> The replacement reactivity from U-238 blanket to SS reflector seems better evaluated by JENDL-4.0 than by ENDF-7.1 by 300pcm. This difference is caused by the negative reactivity from mu-ave. of Cr-52 and Na, and elastic of Fe-57, Ni-60, Al.
ENDF/B-7.1 vs. JENDL-4.0: Structure material

Na-23 Elastic scattering

Na-23 elastic

Na-23 mu-ave.

Cr-52 Mu average

Cr-52 mu-ave.

Fe-57 Elastic scattering

Fe-57 elastic
Reflector Effect: (Dep. UO$_2$ blanket -> SS reflector)

JOYO

Small core, Pu + Enriched. Uranium

JOYO Mk-I: Pu = 17wt%, U$_{235}$ = 23wt%, Nat. U blanket

JOYO Mk-II: Pu = 28wt%, U$_{235}$ = 12wt%, SS reflector
The replacement reactivity from U-238 blanket to SS reflector resulted in the positive change of keff for JENDL-4.0, which is larger than that of ENDF-7.1. This difference is caused by the negative reactivity from mu-ave. of Cr-52 and Na, and elastic of Fe-57, Ni-60, Fe-56. However, we cannot judge which library is favorable, since the fuel compositions of the two cores are quite different, unlike the FCA case.
Concluding Remarks

1. From Los Alamos data, JENDL-4.0 seems better than ENDF-7.1 about the summation of reflector reactivity effect from inelastic, capture (+) and mu-ave., elastic (-) of U-235.

   → Note that we cannot find which library is better for individual reaction from this benchmark.

2. From FCA data, the replacement reactivity from U-238 blanket to SS reflector seems better evaluated by JENDL-4.0 than by ENDF-7.1, which is caused by the negative reactivity from mu-ave. of Cr-52 and Na, and elastic of Fe-57, Ni-60, Al.

   → JOYO data shows similar trends for reflector effects, but we cannot guess which library is favorable from JOYO, because of the influence from core fuel compositions.