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Technical note

Improvements of subgroup method based on fine group slowing-down calculation for resonance self-shielding treatment

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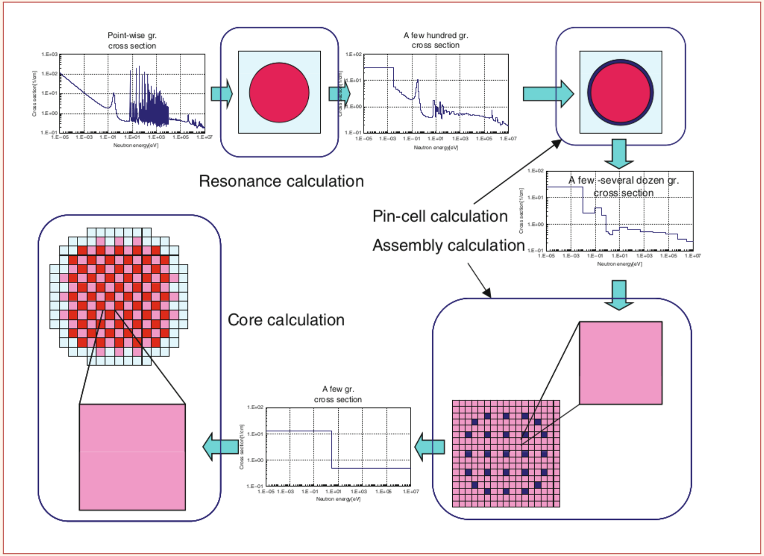

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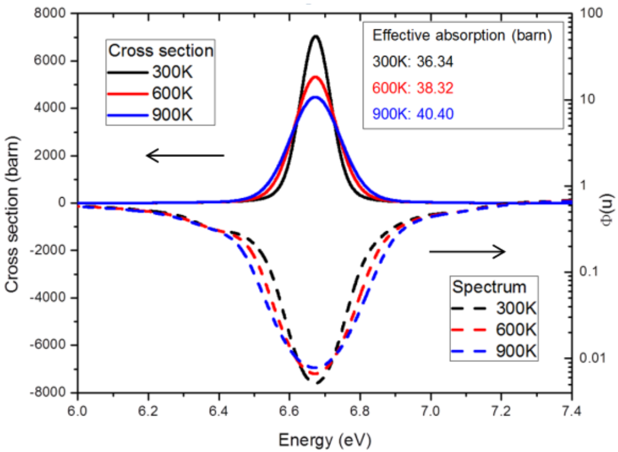
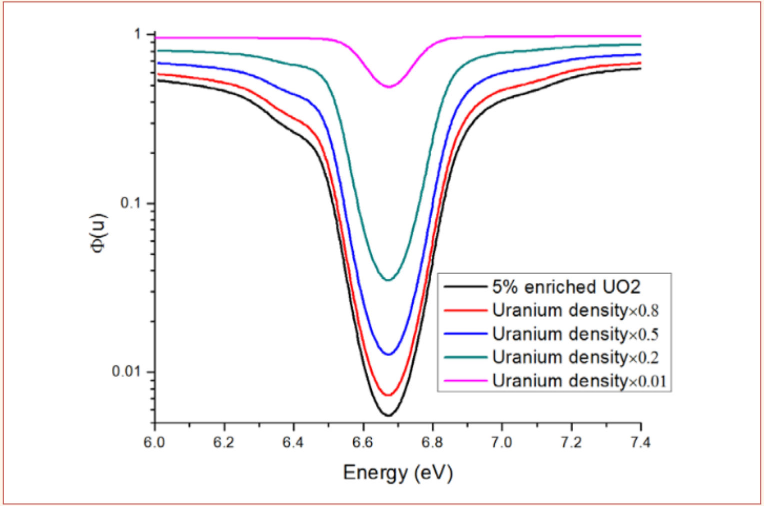
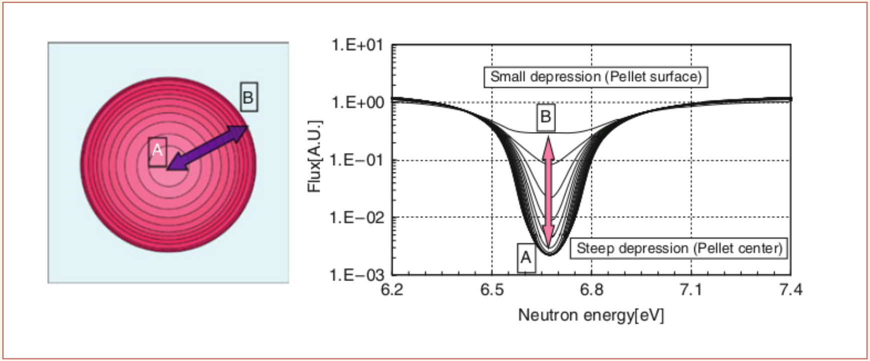
Energy Self-Shielding



Energy Self-Shielding



Spatial Self-Shielding



Self shielding factors:

- Fuel composition

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- Fuel to coolant ratio

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Traditional solution methods:

- Equivalence theory

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- Subgroup method

Traditional solution methods:

- 408 group structure: 56 fast, 289 resonance, 63 thermal

Fine-mesh Subgroup Method (FSM)

Proposal

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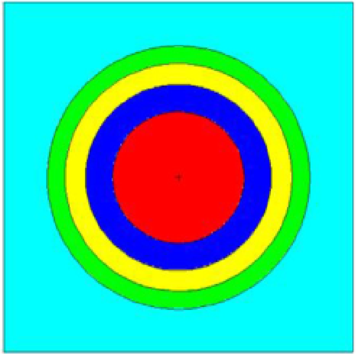
Proposal

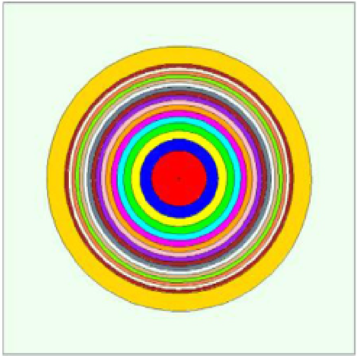
Traditional solution methods:

- 408 group structure: 56 fast, 289 resonance, 63 thermal
- Micro level interpolation optimization
- Condensed 47 group structure with 16 resonance groups
- Only down-scattering source for resonance groups

Single Cell Problems



(a) UO_2



(b) High burn-up UO_2

Typical UO_2 Pellet

U-238 Absorption

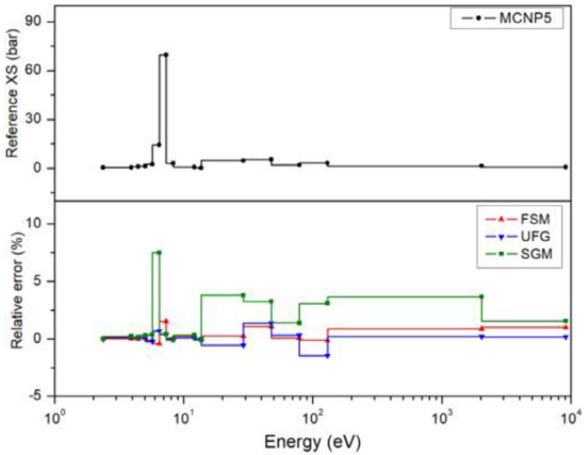


Fig. 3. Relative error of absorption cross section of U-238.

Typical UO_2 Pellet

U-235

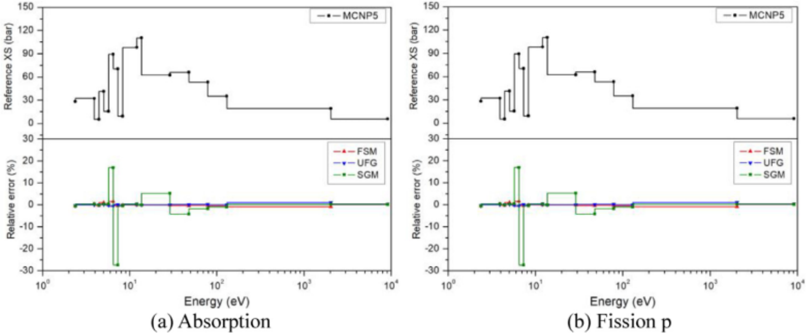


Fig. 4. Relative error of absorption cross section and fission production of U-235.

Typical UO_2 Pellet

Results

Table 2
Calculating cost and eigenvalue error of UO_2 pellet.

Method	Fixed source equation number	Time (s)	k_{eff} (pcm)	
MCNP	–	–	1.53226	–
FSM	1830	34.5	1.53272	46
UFG	204,000	1399.5	1.53208	−18
SGM	636	19.2	1.52675	−551

Burnup UO_2 Pellet

U-238

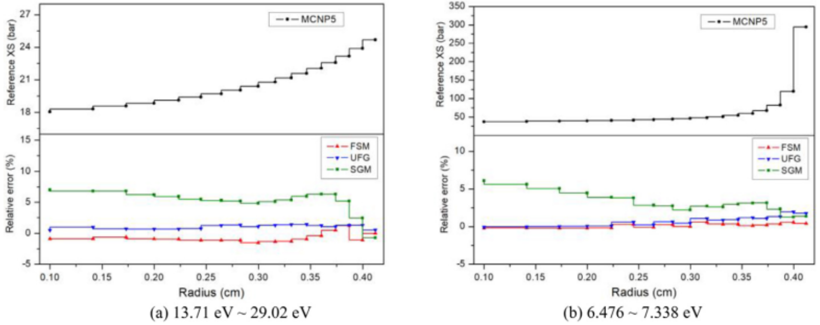


Fig. 5. Radial distribution of relative error of absorption cross section of U-238.

Burnup UO_2 Pellet

Pu-239

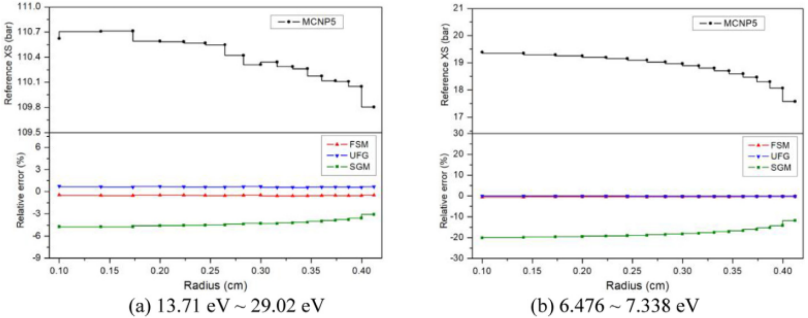


Fig. 6. Radial distribution of relative error of absorption cross section of Pu-239.

Burnup UO_2 Pellet

Pu-240

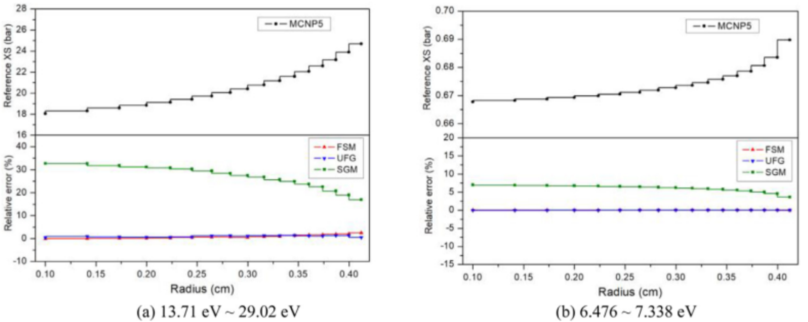


Fig. 7. Radial distribution of relative error of absorption cross section of Pu-240.

Burnup UO_2 Pellet

Results

Table 3
Calculating cost and eigenvalue error of burn-up UO_2 pellet.

Method	Fixed source equation number	Time (s)	k_{eff} (pcm)	
MCNP	–	–	1.18932	–
FSM	6900	835.1	1.18914	18
UFG	5,440,000	7269.2	1.18868	−64
SGM	6920	634.4	1.18347	−584

lattice Problems

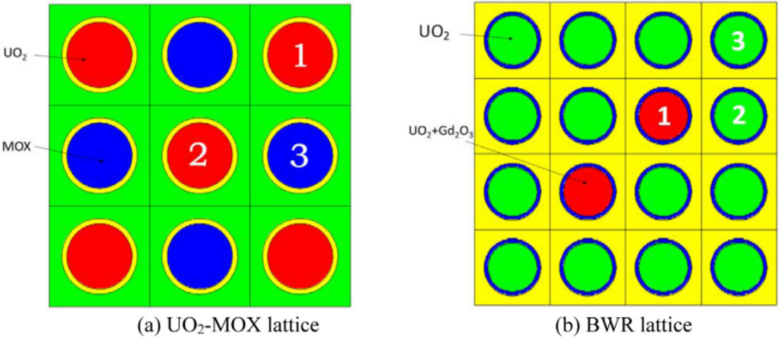


Fig. 8. UO$_2$-MOX lattice and BWR lattice with Gadoliniums.

UO_2-MOX Lattice

Pin 3 - MOX

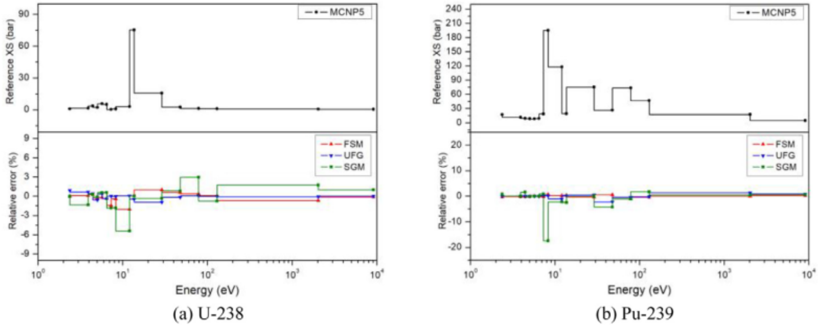


Fig. 9. Relative error of absorption cross section of U-238 and Pu-239 in No.3 MOX pin.

UO_2-MOX Lattice

Pin 1 - UO_2

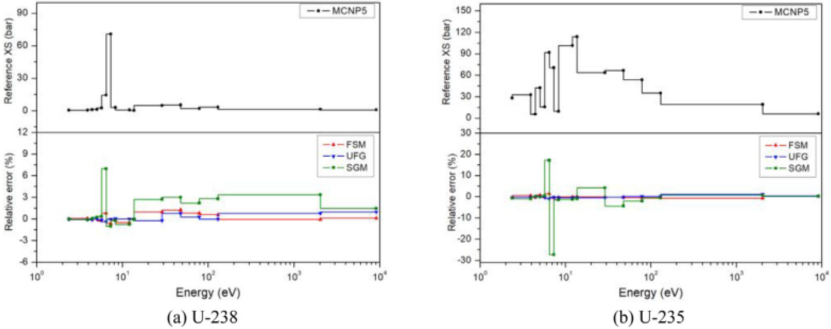


Fig. 10. Relative error of absorption cross section of U-238 and U-235 in No.1 UO_2 pin.

UO_2-MOX Lattice

Results

Table 4
Calculating cost and eigenvalue error of UO_2 – MOX lattice.

Method	Fixed source equation number	Time (s)	k_{eff} (pcm)	
MCNP		–	1.35551	–
FSM	155,088	911.5	1.35633	82
UFG	14,688,000	2357.2	1.35588	37
SGM	149,472	682.3	1.35053	–498

lattice Problems

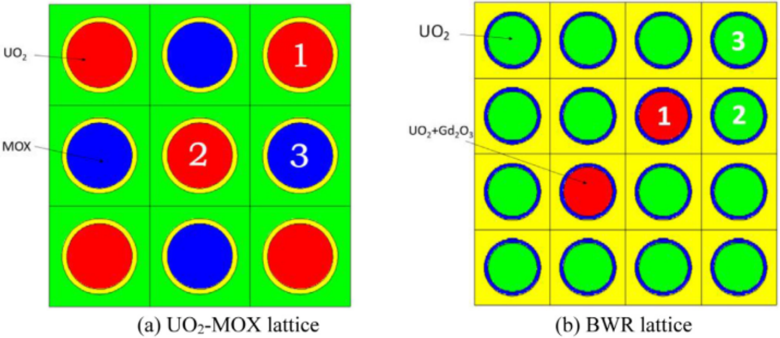


Fig. 8. UO_2-MOX lattice and BWR lattice with Gadoliniums.

BWR lattice with Gadolinium

Pin 1 - Gd

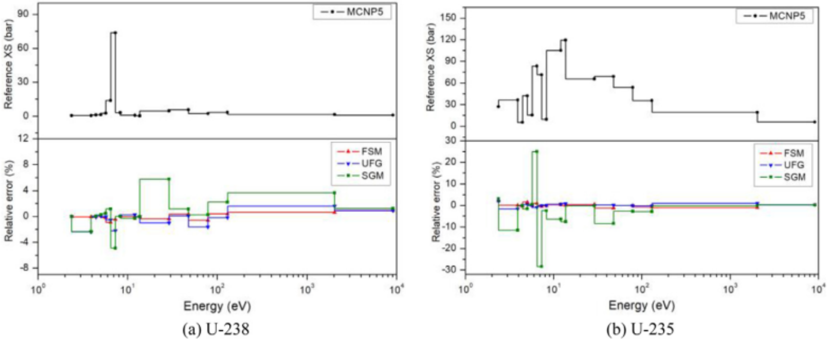


Fig. 11. Relative error of absorption cross section of U-238 and U-235 in No.1 Gd pin.

BWR lattice with Gadolinium
Pin 1 - Gd

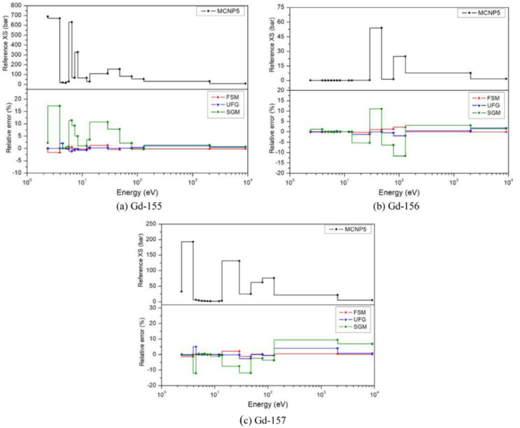


Fig. 12. Relative error of absorption cross section of Gd-155, Gd-156, and Gd-157 in No.1 Gd pin.

BWR lattice with Gadolinium

Results

Table 5
Calculating cost and eigenvalue error of BWR lattice with Gadoliniums.

Method	Fixed source equation number	Time (s)	k_{eff} (pcm)	
MCNP	–	–	1.22763	–
FSM	282,406	596.4	1.22914	151
UFG	284,920,000	9927	1.22867	104
SGM	241,344	382.3	1.22411	−402

Thoughts

- Only downscattering source term

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- How important is the speed up?

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- Only downscattering source term
- How important is the speed up?
- Micro optimization worth exploring

Thanks!
Questions?