On the use of SERPENT code for few-group XS generation for Sodium Fast Reactors

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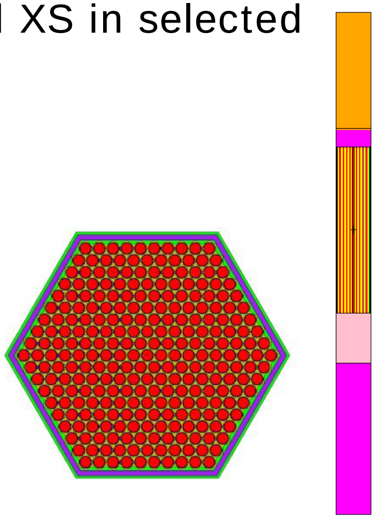
CONTENTS:

1. INTRODUCTION

- Fast Reactors are important→ 3/6 Gen-IV systems are FR.
- In UPM, we are working on the application of our nodal diffusion code ANDES to Sodium Fast Reactors.
- ANDES requires a set of nodal parameters that should be calculated with a transport code.
- According to this purpose, we assessed SERPENT and ERANOS codes.
- Some prior advantages of SERPENT (to justify its employment):
  - – continuous energy (useful to evaluate the impact of energy group structures)
  - – few-group constants generation is possible in principle and most of the required parameters are provided by default
  - – simplicity and transparency (not a black box)
  - –code under continuous development → more flexibility

SERPENT

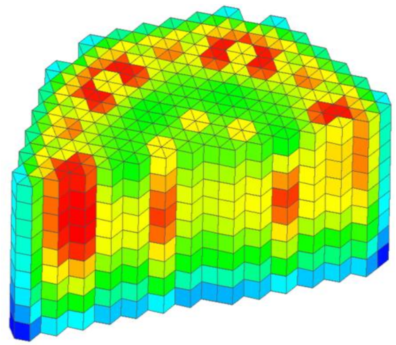
- 3D heterogeneous ESFR model
  - 225 inner FA / 228 outer FA
  - 24 CSD / 9 DSD (Control & Shutdown Devices)
  - 3 rings of reflector
- Universes definition
- Few-group homogeneized XS in selected universes →B1



core *Fuel Assembly*

ANDES

- 3D nodal homogeneous model



2. COMPARISON WITH ERANOS

2. Comparison with ERANOS

	ERANOS (ECCO)	SERPENT
Experience	Reference code for FR	Currently undergoing
Code type	Deterministic	Monte Carlo
Energy distribution	Discrete (33, 172, 175 or 1968)	Continuous
Computational time	Faster (~minutes*)	Slower (~hours*)
Geometries allowed	1D, 2D (XY, hexagonal, RZ)	Detailed 2D or 3D
Cross section homogenization	✓ (mediums)	✓ (universes)
Macroscopic cross sections	✓	✓ (B1 and Kinf)
Directional diffusion coefficient	✓?	×
ADFs	×	✓ (only radial)
Burnup capability	✓	✓
Transparency	Black box	Open source
Simplicity of use	× Complex	✓ Simple

* 3D whole core

PRIOR CONCLUSIONS

- B1 approximation is absolutely compulsory in order to get a “good” approximation for the Diffusion coefficient
- However, B1 does not affect other XS (fission and absorption) significantly.
- In general, the errors with respect to ERANOS...
  - ➢ are much higher in the non-fissile materials
  - ➢ tend to increase in the slowest and fastest groups

  Poor statistics?
- Good agreement between ERANOS and SERPENT is observed in K-eff results for the 3D whole core

3. PARAMETERS REQUIRED BY ANDES

3. Parameters required by ANDES

- Absorption cross section (Σ_a)
- Fission cross section (Σ_f)
- Fission neutron-production cross section ($\nu\Sigma_f$)
- Fission energy-production cross section ($\kappa\Sigma_f$)
- Fission spectrum (χ)
- Scattering P0 matrix
- Diffusion coefficient (D)
- ADFs
- Kinetic parameters:
  - Effective delay neutron fraction and precursor decay constants
  - Inverse mean neutron speed

3. Parameters required by ANDES

- Absorption cross section (Σ_a) → RABSXS
- Fission cross section (Σ_f) →FISSXS
- Fission neutron-production cross section ($\nu\Sigma_f$) → NSF
- Fission energy-production cross section ($\kappa\Sigma_f$) → FISSE
- Fission spectrum (χ) → CHI
- Scattering P0 matrix → GPRODXS
- Diffusion coefficient (D)
- ADFs
- Kinetic parameters:
  - Effective delay neutron fraction (→BETA_EFF) and precursor decay constants (DECAY_CONSTANT)
  - Inverse mean neutron speed → RECIPVEL

3. Parameters required by ANDES

- Absorption cross section (Σ_a)
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- ADFs

→ Special considerations

- Kinetic parameters:
  - Effective delay neutron fraction and precursor decay constants
  - Inverse mean neutron speed

4. SPECIAL CONSIDERATIONS

DIFFUSION COEFFICIENT

SERPENT computes the diffusion coefficient through 3 different methods:

1. Based on the Migration Area
2. Based on the transport cross section (collision estimator)
3. Based on the B1 fundamental mode

However, B1 is only applicable to fissile regions

A methodology to calculate diffusion coefficient in non-fissile subdomains shall be implemented

INTERFACE / ASSEMBLY DISCONTINUITY FACTORS (ADF /IDF)

- ADF=IDF in Assembly calculations
- The use of IDFs allows nodal homogenized diffusion calculations to reproduce transport heterogeneous results.
- SERPENT computes <u>radial</u> ADFs by default: $ADF = \dfrac{\phi_s^{het}}{\overline{\phi}^{het}}$
- However, we need to compute radial and axial IDF:

$$IDF = \frac{\phi_s^{het}}{\phi_s^{hom}} \qquad \phi_s^{hom} = \phi^{ANDES} = f(J_s^{het}, \overline{\phi^{het}})$$

- We would required from SERPENT:
  - Surface currents J_s^{het}
  - Surface integrated fluxes ϕ_s^{het}
  - Average fluxes $\overline{\phi^{het}}$, given by default

5. FUTHER COMMENTS & SUGGESTIONS

5. Further Comments and Suggestions

- Given that B1 is necessary to calculate D in subdomains and...
  - B1 is only applicable to fissile regions
    - ➢ How to compute few-group xs for none fissile regions (blankets, reflectors...)?
  - B1 is applicable so far to steady state calculations
    - ➢ Would it be possible to extend it to burn-up calculations?
- Given that compared with ERANOS, the differences increase in the extreme groups...
  - ➢ How many histories (neutron/cycle) should be necessary for few-group cross section generation in sub-universes of a whole 3D core in order to get good statistics ?? →*Variance reduction techniques?*
- the resolution of the geometry plotter deteriorates for big cores
  - ➢ Would it be possible to improve the resolution?

6. SUMMARY

SERPENT could be an useful code for XS generation for Fast Reactors. However:

- Diffusion coefficients cannot be well-determined in subdomains unless the B1 approximation is employed.

  - A methodology to generate group constants (specially for the Diffusion coefficient) in <u>non-fissile subdomains</u> shall be developed and implemented
  - The extension of B1 methodology to burnup calculations would be very valuable

For UPM interests:

  - <u>Currents and fluxes integrated over surfaces</u> would be required in order to compute Discontinuity Factors

- Statistics is a topic of concern for cross section generation (especially as more energy groups are used)
  - Any technique to improve it (likewise MCNP variance reduction?)
- Resolution of the geometry plotter for big cores might be improved