The Use of Serpent at the LTHN/CDTN

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Summary

Belo Horizonte

Where are we located?

(Image by Lonely Planet ©)

Belo Horizonte

Serra do Curral

(Image by www.temporadalivre.com ©)

CDTN

Nuclear Technology Development Center

CDTN

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CDTN

Nuclear Technology Development Center

- **(For now)** Part of Brazilian Nuclear Energy Commission.
- Founded in 1952 as IPR (Radioactive Research Institute), part of Minas Gerais Federal University (UFMG).
- In 1960, TRIGA Mark 1 reactor inaugurated - first criticality.
- Many areas related (or not) to nuclear sciences:
  - Nuclear waste management;
  - Environment applications;
  - Materials science (nanomaterials, graphene applications...);
  - Radiobiology and radioisotopes production for health applications;
  - **Nuclear engineering and Technology;**
- Post-graduation program (around 100 students).

`http://www.cdtn.br/en/`

Thermal-Hydraulics and Neutronics Laboratory - LTHN

Experimental facilities

Thermal-Hydraulics and Neutronics Laboratory - LTHN

Computer Laboratory

LTHN

Thermal-Hydraulics and Neutronics Laboratory - LTHN

Main activities

- Experimental thermal-hydraulics: spacer grids, counter current fluid flow, PIV.
- IPR-R1 TRIGA modelling, uncertainty propagation in MC simulations.
- Fusion-fission simulations, advanced fuel burn-up (**SERPENT**).
- Software development ($\star$).
- Modelling and simulations of RMB.
  (Brazilian Multipurpose Reactor $\rightarrow$ detailed project phase).
- Neutron imaging (2020).

Serpent2

Projects exclusively using Serpent2

1. OpenFOAM + Serpent2 coupling;
2. Hybrid fusion-fission system;
3. ADS simulations with Thorium and Uranium;

OpenFOAM + Serpent2 coupling

Problem description

Fidelity on the simulation of nuclear systems

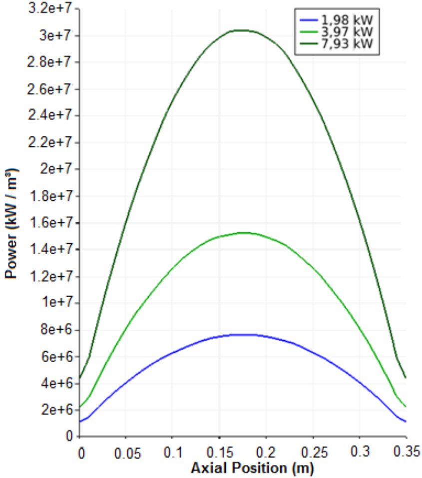
- RMB: Brazilian Multipurpose Reactor $\rightarrow$ under design.
- Why CFD + Monte Carlo $\rightarrow$ High accuracy level.
- Initially a simplified model $\rightarrow$ fuel pin.

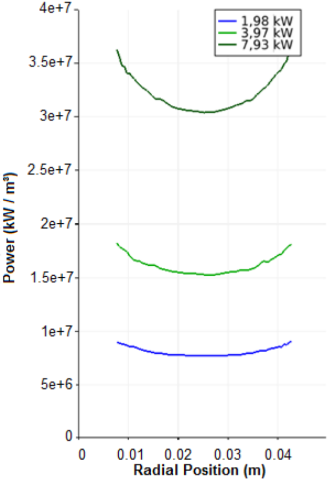
But why modelling a fuel pin for a plate fuel reactor?

- Previous work [Vasconcelos et al., 2018], a fine mesh for a **TRIGA** fuel/pin;
- Straightforward to extend the methodology to an approach using MC (Serpent `ifc` interface);

OpenFOAM + Serpent2 coupling

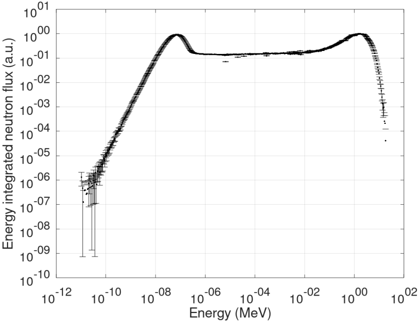
Preliminary Results

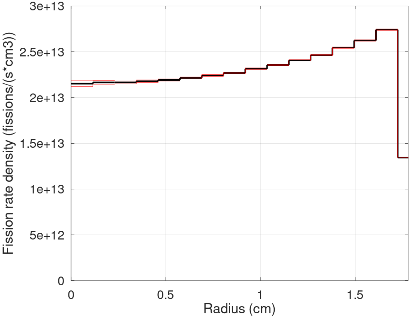




OpenFOAM + Serpent2 coupling

Preliminary Results





OpenFOAM + Serpent2 coupling

Current issues

Zirconium hydride: the pin modelled is actually a TRIGA fuel element.

```
Fatal error in function OTFSabScattering:
Energy grids differ in OTF S(a,b) interpolation
Simulation aborted.
```

On file `otfsabscattering.c` we get:

```
/* NOTE: tää on kohtuullisen harvinainen sirontalaki, johon */
/* törmää esim. h/zr ja zr/h -kirjastoissa. Ei ole kunnolla */
/* testattu. */
```

OpenFOAM + Serpent2 coupling

Current issues

'Same nuclide on different materials when using `ifc 9` interface gets only the lower value of temperature read. For example: a system with water at 310K and fuel at 423K, where water and fuel contains hydrogen. (`1001.03c`)'.

'This issue gives a non-negligible differences in K_{eff} and reaction rates (tested). In this case, apparently, TMS was not used.'

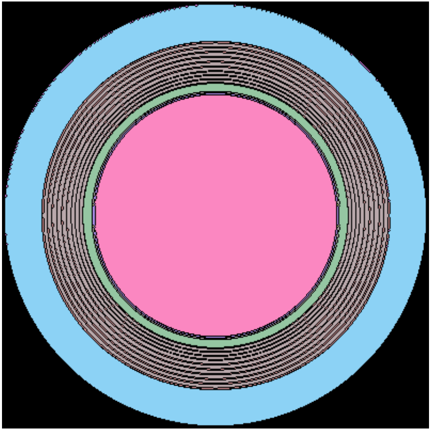
Fusion-fission simulation

Problem description

- Simulation of a hybrid fusion-fission system.
- Geometry: concentric spheres, nine zones filled with RFS with thorium and ten zones with coolant $Li_{17}Pb_{83}$.
- The source was produced by the D-T fusion reaction generating neutrons of 14.1 MeV and placed in the central sphere with a radius of 250 cm.

Fusion-fission simulation

View



Fusion-fission simulation

Results

Table: k_{eff} Results for different NPS

NPS	k_{eff}(analog)	95% confidence interval
10000	0.59490	0.53182 – 0.65798
20000	0.69282	0.64750 – 0.73802
30000	0.74796	0.71240 – 0.78352
40000	0.77101	0.74249 – 0.79953
50000	0.76816	0.73942 – 0.79690
60000	0.79388	0.76734 – 0.82042
100000	0.82596	0.80478 – 0.84714
500000	0.88611	0.87775 – 0.89447
1000000	0.89095	0.88547 – 0.89643
10000000	0.90109	0.89905 – 0.90313
20000000	0.90142	0.90012 – 0.90272

Fusion-fission simulation

Current issues

’We are having problems to understand how NPS value influences the results of k_{eff}(analog) in those simulations. It was noticed that the values of k_{eff}(analog) increases considerably when the value of NPS is also increased. Even for high values of NPS (larger than 500000), the values of k_{eff}(analog) obtained for various NPS are considerably different.

’Similar behavior is verified when we use SERPENT to simulate ADS. Is there an inferior limit to NPS?’

Four ADS cases

1. GANEX fuel spiked with 50% of thorium;
2. GANEX fuel spiked with 50% of depleted uranium;
3. UREX$+$ fuel spiked with 50% of thorium;
4. UREX$+$ fuel spiked with 50% of depleted uranium;

Geometry
the subcritical core is a cylinder of $12.0m^3$ filled with a hexagonal lattice formed by 120 $^{232}ThO_2$ rods (gray fuel rods) and 36 rods with reprocessed fuel (green fuel rods). Lead was used as a coolant and as a reflector.

Materials

’For all materials, cross-sections libraries available in SERPENT were specified at working temperature, which is 1200 K for containing fissile/fissionable material and 900 K for the remaining regions. The parameters for the simulated particle population in external source mode were set to run 2 million source neutrons. The burn-up calculation was performed for 10 years with the same parameters in both cases and all nuclides were included in the `dep.m` output file.’

ADS

View

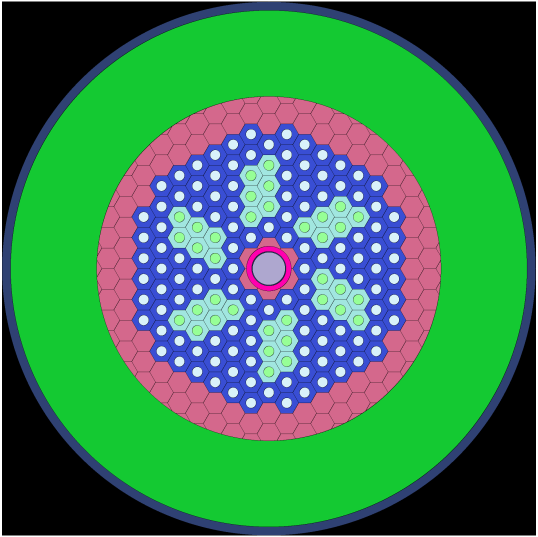


Table: Computational time

Case	Computational time
Case 1 (GANEX + Th)	$194:18:44$
Case 2 (GANEX + U)	$287:25:16$
Case 3 (UREX + Th)	$208:41:45$
Case 4 (UREX + U)	$300:43:54$

ADS

Current issue (?)

'When we use reprocessed fuel spiked with uranium the computational time is considerably higher. Any ideas why?'

Conclusions related to Serpent2

And some future intentions

- Roughly, half of the activities of neutronic modelling and simulation at the LTHN are done using Serpent2.
- Brings reliable results;
- Relatively easy to use - multiphysics interface;
- Wiki-page is better than the manual...
- ... However the sensation that information is scattered, no easy way to go straight to related information to the topic being read.

Thank you!

References

Vasconcelos, V., Santos, A., Campolina, D., Theler, G., and Pereira, C. (2018).
Coupled unstructured fine-mesh neutronics and thermal-hydraulics methodology using open software: A proof-of-concept.
Annals of Nuclear Energy, 115:173 – 185.