Business from technology

Internal Fuel Performance Module in Serpent 2 - FINIX

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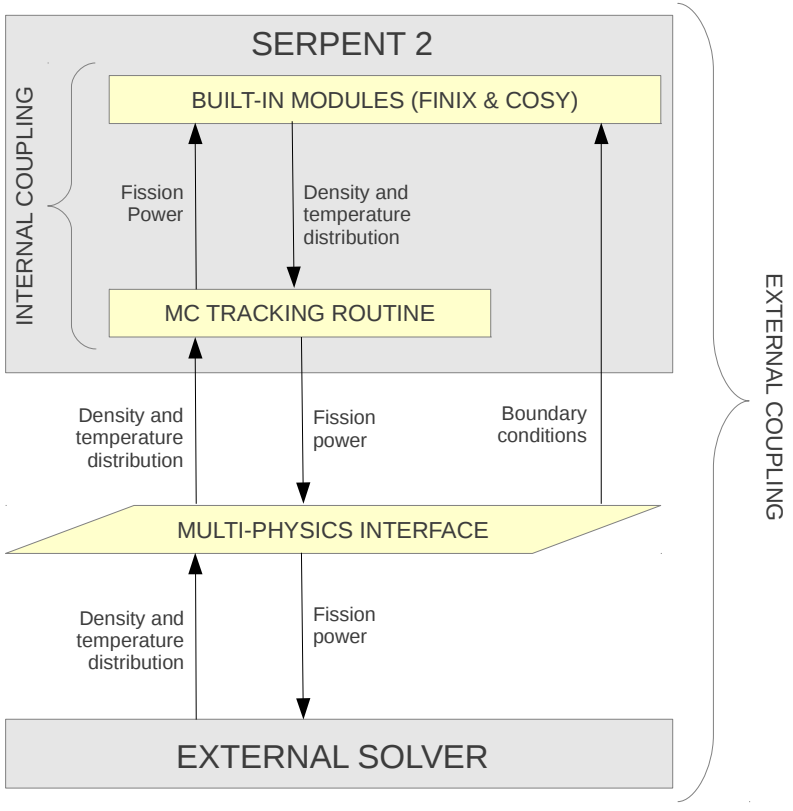
Multi-physics approach in Serpent 2



Why a built in solver for fuel behavior?

- A relatively simple way to add fuel behavior coupling to calculations.
- No need for external codes.
- Simplified user interface.

FINIX[1]

Coupled solution of fuel temperature and geometry based on fission power density and boundary conditions.
Created to answer a need for a fuel behavior solver that is:

- Lightweight.
- Capable to couple to master codes on source code level.
- Simple to use. (Usable by a reactor physicist)
- Based on publicly available correlations.
- Validated against publicly available data.

[1] T. Ikonen *et al.* "FINIX – Fuel Behavior Model and Interface for Multiphysics Applications," *In Proc. 2013 LWR Fuel Performance Meeting / Top Fuel*

Design philosophy

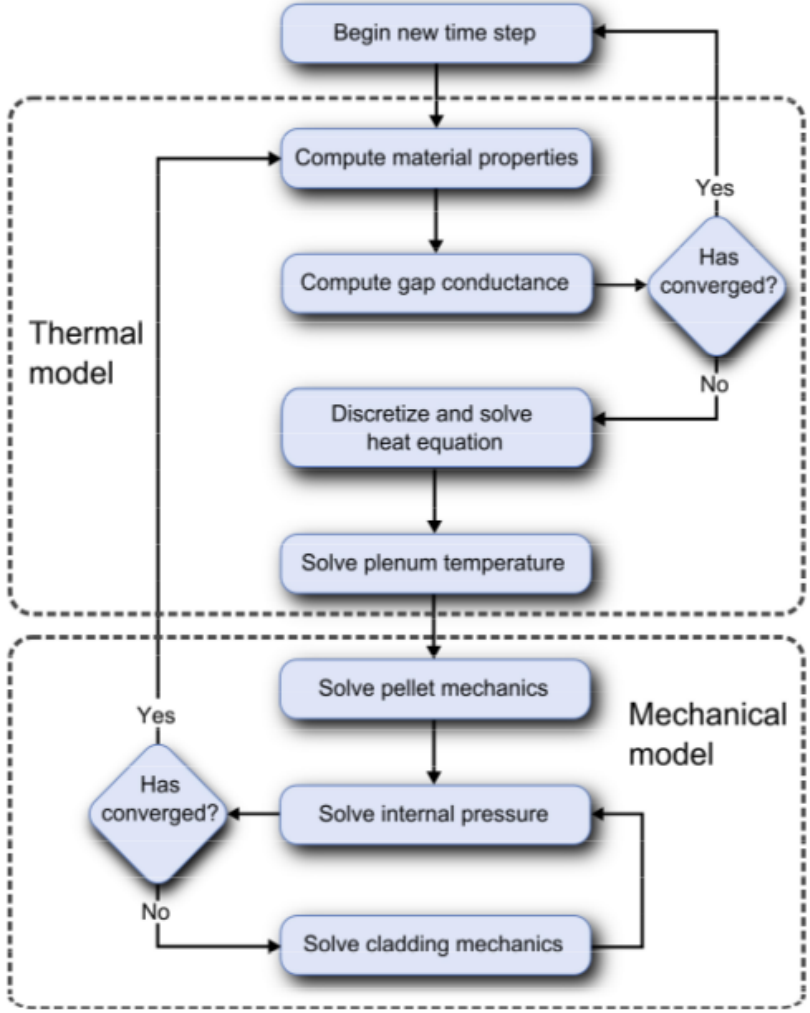
Level of modeling, detailed enough to produce usable results, but coarse enough to not deter users.

Fuel performance code VS Reactor physicist.

Fuel rod templates contain input data for representative fuel rods.

FINIX

- 1.5D Geometry representation (r,z).
- Spatial finite element method.
- Temporal implicit finite difference.
- Steady state and transient.
- Publicly available correlations (FRAPCON/FRAPTRAN)



FINIX - Mechanical model

Pellet:

- Rigid pellet
- Perfectly cylindrical (no chamfer, dish or hourglass).

Cladding:

- Thin shell approximation for cladding.
- No axial curvature.
- Completely elastic mechanical response (no plastic deformation).

FINIX - Model description

- Specific heats.
- Thermal strains.
- Initial relocation.
- Thermal conductivities (fuel, gas, clad).
- Gap heat transfer (open & closed).
- Not modeled: Fuel swelling, densification, cladding creep etc.

FINIX - Boundary conditions

Three different BC:s for temperature:

- Cladding outer temperature.
- Heat flux from cladding to coolant.
- Bulk coolant temperature + heat transfer coefficient.
  - Coolant temperature + inlet mass flux (heat transfer coefficient calculated internally).

FINIX

Finix has been thus far:

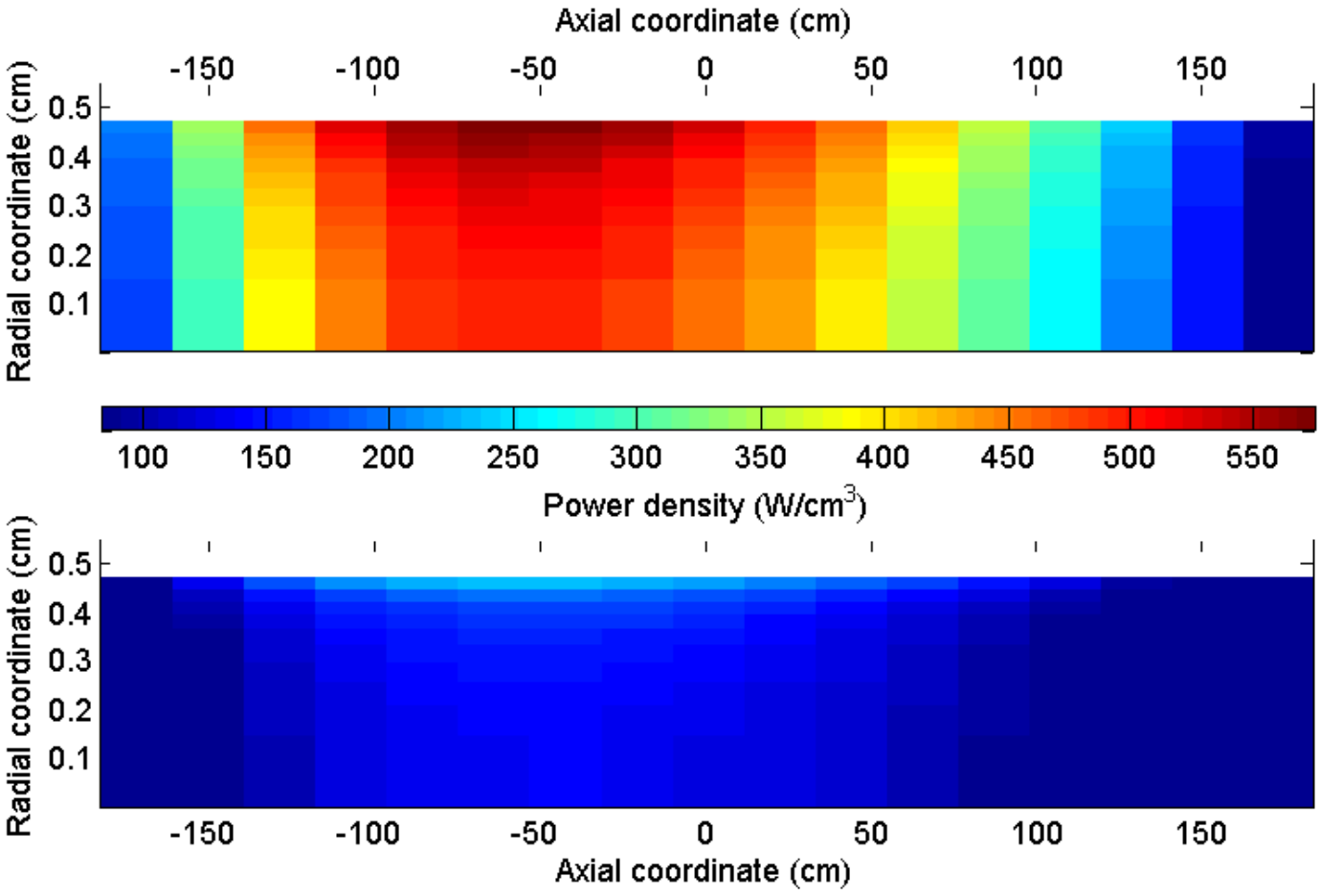
- Validated partly against Halden fuel rod data.
- Integrated to Serpent on source code level.
  - Essentially a part of Serpent 2 from user point of view.
  - Used in steady state simulations.
  - First transient implementation is ongoing.

Input-format

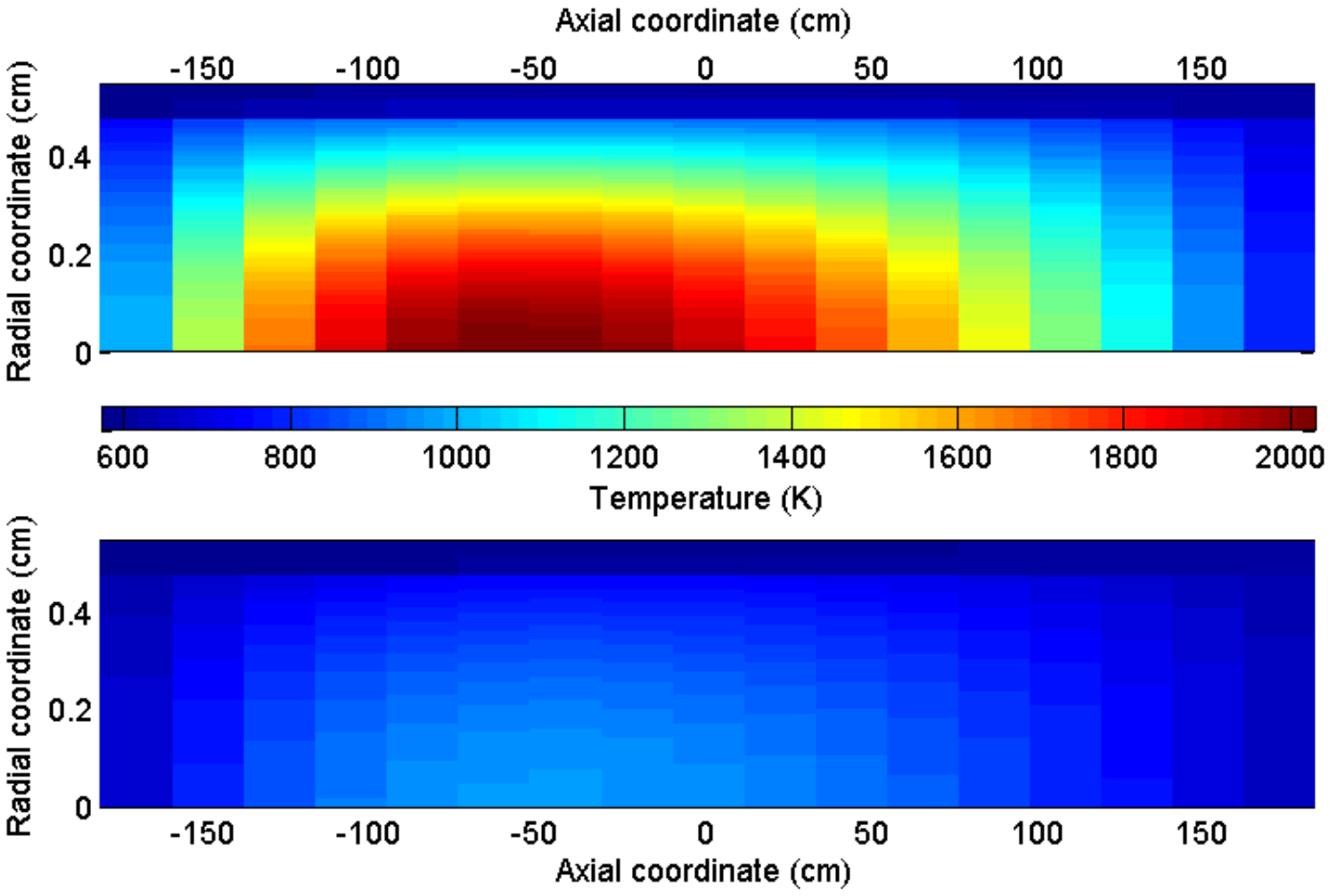
Time independent simulation

TMI-1 type PWR assembly with burnable absorber pins and an axially varying coolant density.

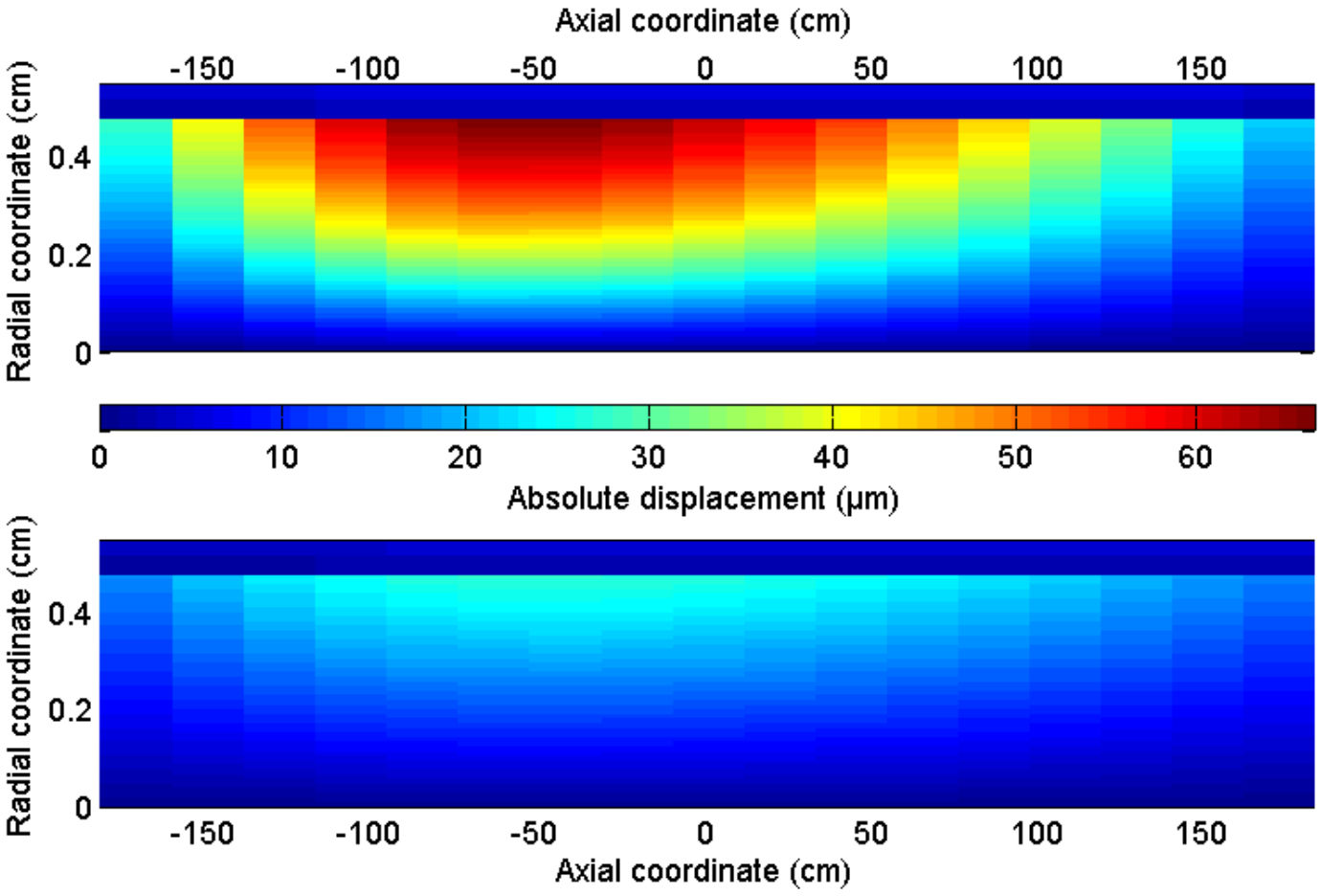
Time independent simulation



Time independent simulation



Time independent simulation



(Ongoing) Time dependent simulation

Transient simulation takes advantage of Serpent's dynamic simulation mode[2]

Special interest in fast transients, with fuel response shutdown.

[2] J. Leppänen, "Development of a Dynamic Simulation Mode in the Serpent 2 Monte Carlo Code." In Proc. M&C 2013. Sun Valley, Idaho, USA, May. 5-9 2013.

Future directions

- I/O
- Adding more fuel rod templates.
- Capabilities to account for burnup related geometry changes. Fission gas swelling. Creep.

Thank you!

Ideas, suggestions and questions are appreciated.

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