# A crash introduction to GeN-Foam: simulation of the Molten Salt Fast Reactor
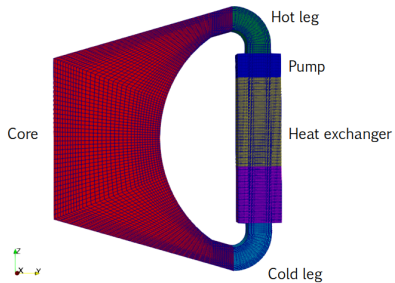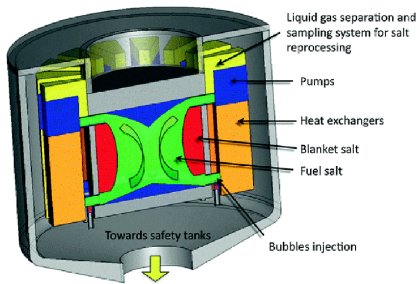
Carlo Fiorina, Stefano Lorenzi, Alessandro Scolaro

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Liquid gas separation and sampling system for salt reprocessing

Pumps

Heat exchangers

Blanket salt

Fuel salt

Towards safety tanks

Bubbles injection

Hot leg

Pump

Core

Heat exchanger

Cold leg

# Exercise 1: Assignments

- The provided startingCase contains everything done on Monday, except that in GeN-Foam we do not use fvOptions, but the phaseProperties file. And of course the controlDict is different.

- So, up to you to set them! Try to replicate the simulation we did on Monday for fluid-dynamics only (no energy solution, no neutronics, no thermal-mechanics). Run it for 10 seconds. To simulate the pump, you will need a momentum source set to -300000 $kg/m^2/s^2$ in z direction.

- Compare it with the case done Monday.

# Exercise 1: Tips

- Always try to open your case in paraFoam. What do you notice compared to Monday?

- To learn how to set a momentum source for a pump, try to browse the documentation or the tutorials. The "grep -ir pump" command in the terminal can be helpful. Or, you can ask chatGPT to create a linux command to specifically search for the keyword "pump" in files named "phaseProperties" in Tutorials

- Always take a look at fvSchemes, fvSolution. They define how a numerical solution is obtained.

- Be careful with the time-step setting(s) in controlDict

## Exercise 2: Assignments

- Starting from the previous case (copy-paste it, and keep the previous), clean up the time steps and set up a GeN-Foam case to be able to solve for diffusion-based neutronics. The nuclearData* files and the mesh are provided in the "inputs" folder. We want the power of the reactor to be 20MW.

- Spend some time trying to understand the nuclearData* files. How many energy groups? How many precursors groups? How are cross-sections parameterized?

- Try to solve for neutronics only, eigenvalue, from time zero. Use both Dirichlet (zero) and Neumann (zero) BC.

- Try to visualize the distribution of power/flux and of precursors groups 0 and 7, and look at keff.

## Exercise 2: Tips

- GeN-Foam allows using a defaultFlux field to initialize initial and boundary conditions for all the energy groups.
- Why 20MW when the MSFR should be 3GW?
- Be careful about the boundary conditions for the fluxes.
- Think about the meaning of doing "time-steps" in an eigenvalue calculation. What are, in fact, the time steps? Do we need to adjust time steps?

# Exercise 3: Assignments

- Now we want to see if the velocity field has an influence on neutronics.
- Try to run a coupled solution of fluid-dynamics and eigenvalue neutronics
- Try to plot the distribution of power/flux and of precursors groups 0 and 7 and compare with the previous exercise. What do you notice?
- Try also to look at the keff for the 2 cases. How does it change?

# Exercise 3: Tips

- What is changing physically for neutronics compared to previous case?
- Is there something that we are solving now, and that we were not solving for before? Do we need new initial and boundary conditions?
- It might also be worthwhile looking at fvSchemes in neutronics in some details this time. Is there a scheme that is always bounded? Maybe it is worth using it for *div*(*phi_*, *precStar_*) :)
- Can we start from a good guess for the fluid dynamics and limit the computational time? (Do we have a one-way or two-way coupling?)

# Exercise 4: Assignments

- Now we want to add the solution for energy.
- Copy-paste the previous case.
- Try to solve also for temperatures till the achievement of a steady-state. Assume that fluid-dynamics is not affected by temperature. Is that really the case?
- You'll need a heat exchanger to evacuate the heat produced by the neutronics. Assume an average temperature on the secondary side of 900K and a volumetric area of 200 $m^{-1}$.
- Try to plot prec7 and temperature and think about differences and similarities, and where they came from.
- How does keff change compared to a case without solution of temperature? Can you tell why?

# Exercise 4: Tips

- A simple way to emulate a heat exchanger is a fixed-temperature sub-scale structure.
- In GeN-Foam, sub-scale structures with special properties are called "powerModels."
- What boundary conditions do we use for temperature?
- Is this one-way or two-way coupling?
- Do we need to solve for fluid-dynamics again?
- Can we (do we need to) keep the neutronics solution as eigenvalue?
- Three (physical) minutes should be enough for the reactor to get to an approximate steady state.
- Avoid excessive writing of results to disk.

# Exercise 5: Assignments

- Now we want to study the transient behavior of the reactor.
- Starting from the steady state of Exercise 4, run a transient with an increase of 30 pcm in reactivity.
- Analyze the results (you can read from the log, use paraview, or use the GeN-Foam.dat file).

# Exercise 5: Tips

- Note that diffusion solvers usually require a keff to run a transient (do you know why?). GeN-Foam stores it in reactorState and use the value from previous simulation if available. Or you can give the value you prefer.

- What dictionary do we need to change to set the neutronics to transient?

- It could be useful to start tightening up the coupling. Where can we find this option? In which dictionary numerical things usually are in OpenFOAM? Is this related to a specific physics or not?

- Always be careful about initial time step. This is not adjusted by OpenFOAM.

# Exercise 6: Assignments

- Starting from the case of Exercise 4, run a transient with an exponential reduction in the pump momentum source with a time constant of 5 seconds, for 10 seconds. After 10 seconds, the reduction stops. But keep the transient going for 20 seconds.
- Analyze the results.

# Exercise 6: Tips

- How to impose a change in the momentum source? Always look at the documentation, source code, tutorials, etc. And do not forget the grep.

# Optional assignments

- Repeat the above with a steady-state power of 1W.
- What do you expect?
- Analyze the results.