INL/EXP-21-63714-Revision-0

IMPLEMENTATION OF TURBULENCE MODELING FOR THE COUPLED GRIFFIN-PRONGHORN SIMULATION OF THE MOLTEN SALT FAST REACTOR FOR THE VIRTUAL TEST BED

Ramiro Oscar Freile, Abdalla Abou Jaoude, Guillaume Louis Giudicelli, Sebastian Schunert, Paolo Balestra

Changing the World's Energy Future

Idaho National Laboratory

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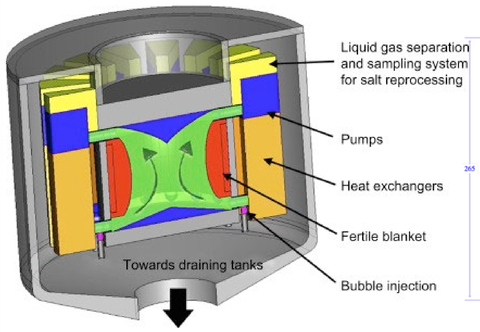
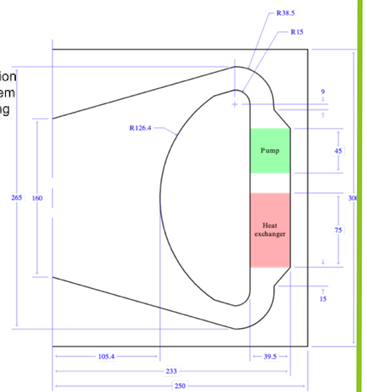
Freile R., Giudicelli G., Abou-Jaoude A., Harper S., Schunert S., Balestra P.

Introduction

- In support of the **Virtual Test Bed** (VTB) repository, the **Molten Salt Fast Reactor** (MSFR) concept is modeled using MOOSE-based tools, notably **Griffin** and **Pronghorn**, employing newly implemented initial turbulence models.
- The models must be adapted to Pronghorn's spirit of a multidimensional **coarse-mesh intermediate fidelity** code.



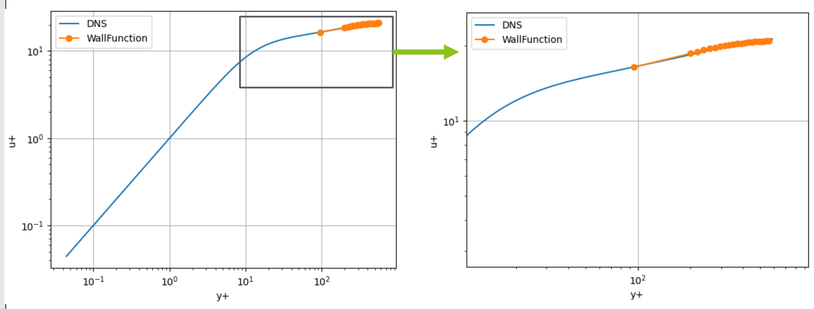
MSFR concept [1]



2D RZ steady state coupled multiphysics model of the MSFR

Velocity Wall Functions

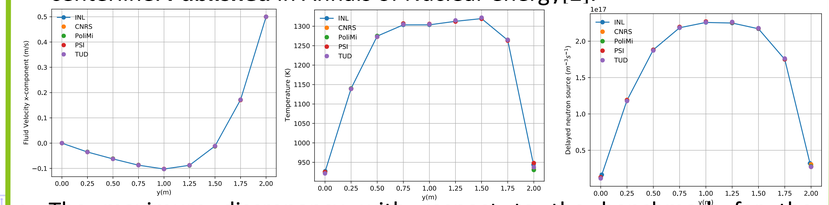
- **Standard velocity wall functions** have been developed to impose an algebraic wall shear stress boundary condition at the walls, allowing for the use of coarser meshes without losing significant accuracy.



Validation of the standard wall function BC against Direct Numerical Simulations

CNRS Benchmark

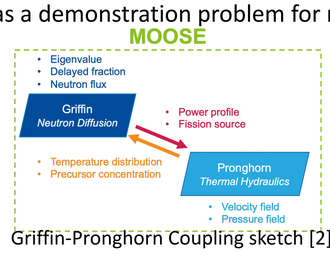
- An international **MSFR lid-driven cavity benchmark** is used. The X-Velocity, Temperature and DNP source are plotted at the vertical centerline. **Published** in Annals of Nuclear energy[2].



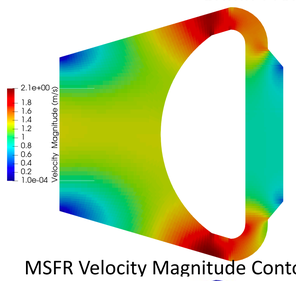
- The maximum discrepancy with respect to the benchmark for the velocity, temperature and DNP are 0.35%, 0.19% and 0.1%, respectively.

MSFR Steady State Results

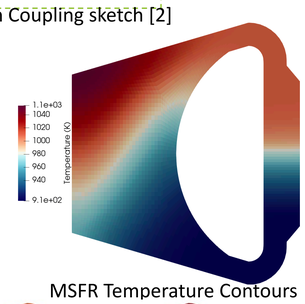
- The coupled physics modeled for the MSFR are shown in the next sketch.
- The simulation is hosted on virtual test bed of the National Reactor Innovation Center as a demonstration problem for molten salt reactors.



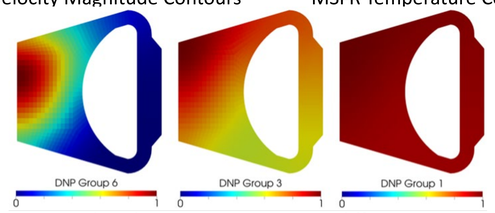
Griffin-Pronghorn Coupling sketch [2]



MSFR Velocity Magnitude Contours



MSFR Temperature Contours

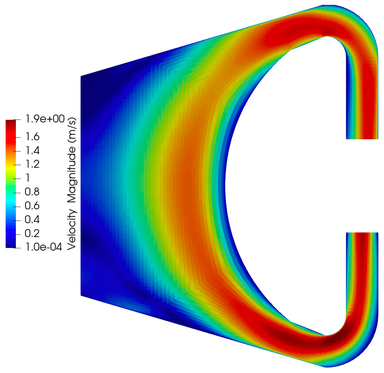


MSFR Delayed Neutron Precursors in different Groupings

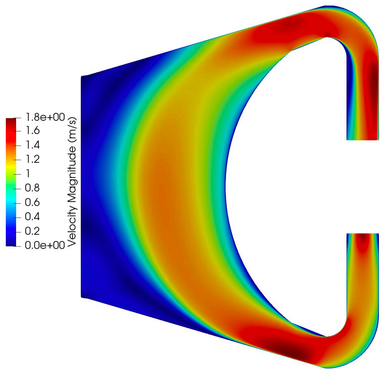
- The **uniform turbulent viscosity** model over-predicts diffusion near the wall.
- This is not expected to be entirely representative of the MSFR.

Capped Mixing Length Model

- A **zero-equation capped mixing length model** is implemented in Pronghorn following Escudier's [3] modification of Prandtl's original mixing length model.
- Results are compared against high fidelity Nek5000 simulations for a Reynolds number of 40,000.
- As seen below, the over-diffusive behavior at the center of the MSFR is no longer present. **Manuscript submitted** to ANS conference review committee. [4].



Pronghorn Velocity Magnitude Contours



Nek5000 Velocity Magnitude Contours

Future Work

- **Full Multiphysics** simulation of the MSFR concept will be performed using the capped mixing length model.
- High-fidelity Nek5000 simulations of several Reynolds numbers will allow us to **calibrate the parameters** in the current turbulence model.
- Use a **data-driven approach** to generate a **Stochastic optimized** model to provide Pronghorn with a spatial turbulent viscosity field dependent on the Reynolds number in the MSFR.

References

[1] Allibert, M., et al. "Molten salt fast reactors." *Handbook of generation IV nuclear reactors*. Woodhead Publishing, 2016. 157-188.

[2] Abou-Jaoude, A., **Freile R.**, et al. "A Workflow Leveraging MOOSE Transient Multiphysics Simulations to Evaluate the Impact of Thermophysical Property Uncertainties on Molten-Salt Reactors" *Annals of Nuclear Energy*.

[3] Escudier, Marcel Paul. *"The turbulent incompressible hydrodynamic boundary layer." (1967).*

[4] **Freile R.**, *et al. Coupled Griffin and Pronghorn simulation of the molten salt fast reactor (MSFR) for the virtual test bed".* To be presented at ANS Winter Meeting 2021.