Comprehensive Modeling of the L-MSR exercising current capabilities

Rodrigo de Oliveira, Mauricio Tano, Parikshit Bajpai, Ramiro Freile

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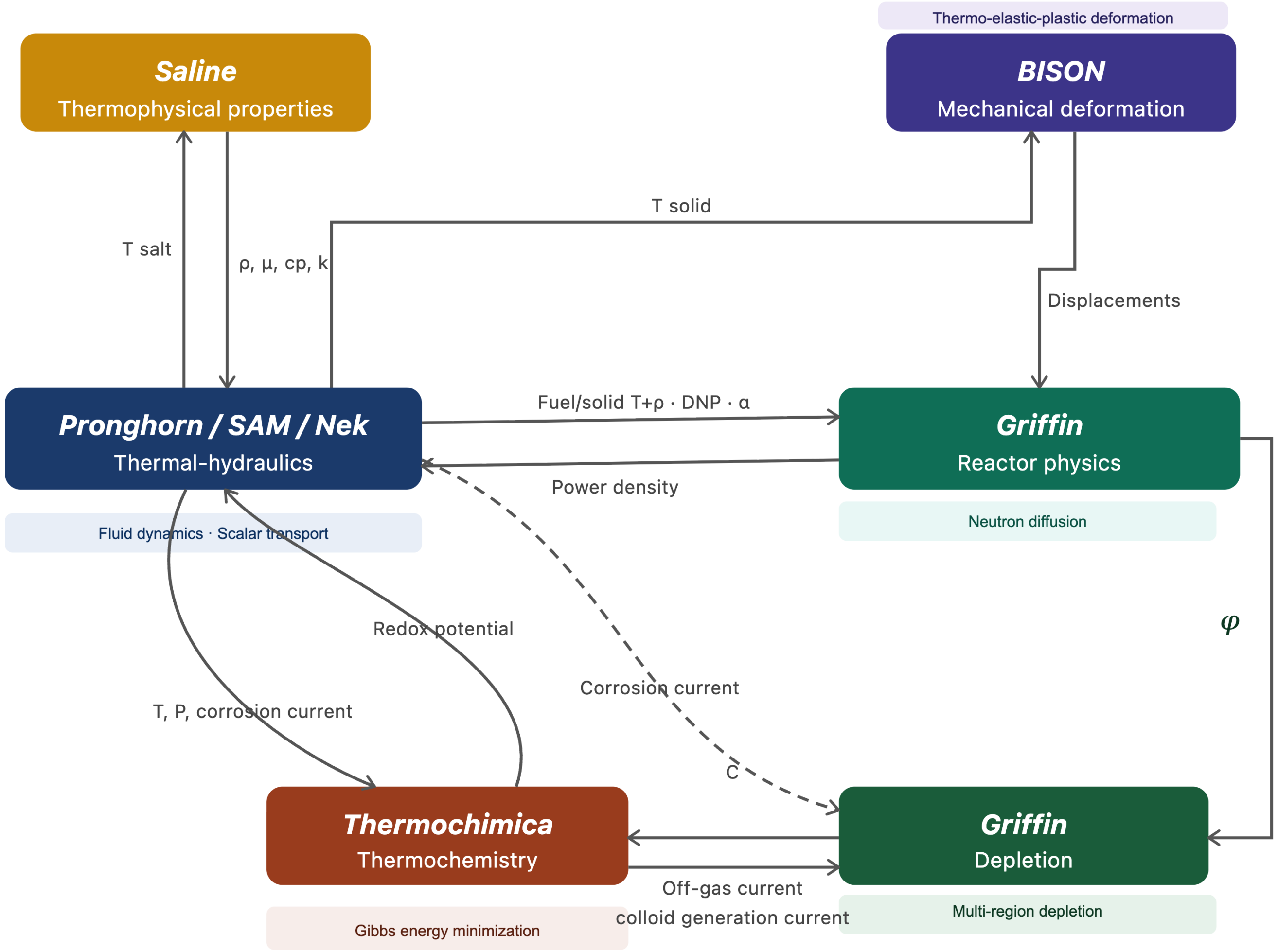
ART-MSR Program Review

Introduction

- Goals
  - Exercise the capabilities of the codes
  - Develop the architecture through code usage
  - Find limitations and fix them

- The L-MSR
  - Based on open-source MCRE data
  - Gives support to a reactor that is supposed to be built
  - Also the reactor informs development

Current architecture



Geometry

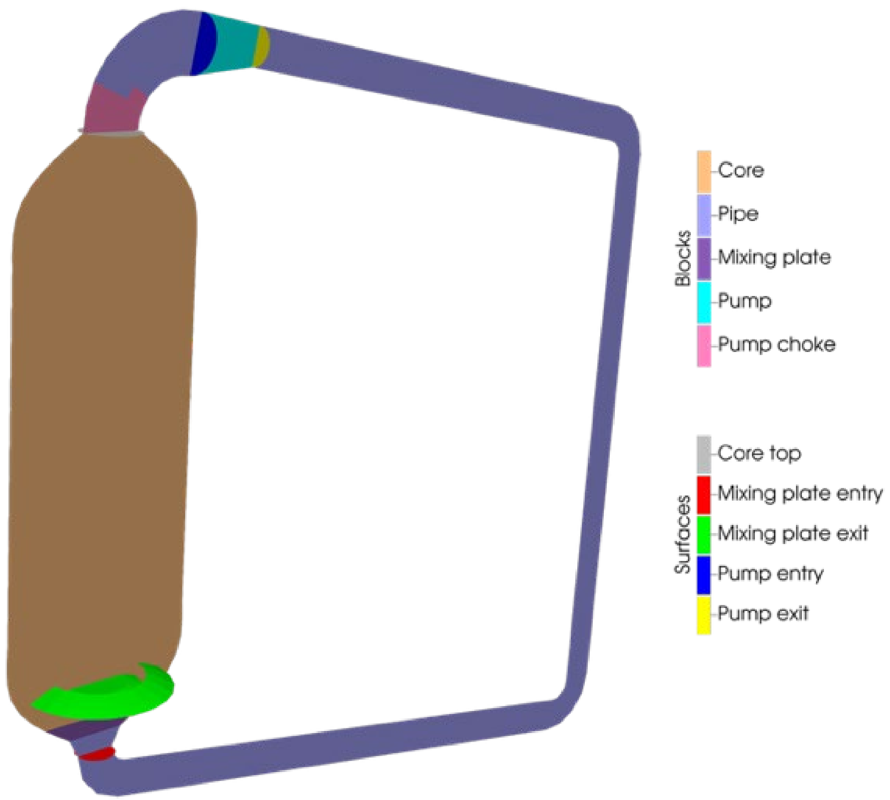


Figure 2. Simplified homogeneous model

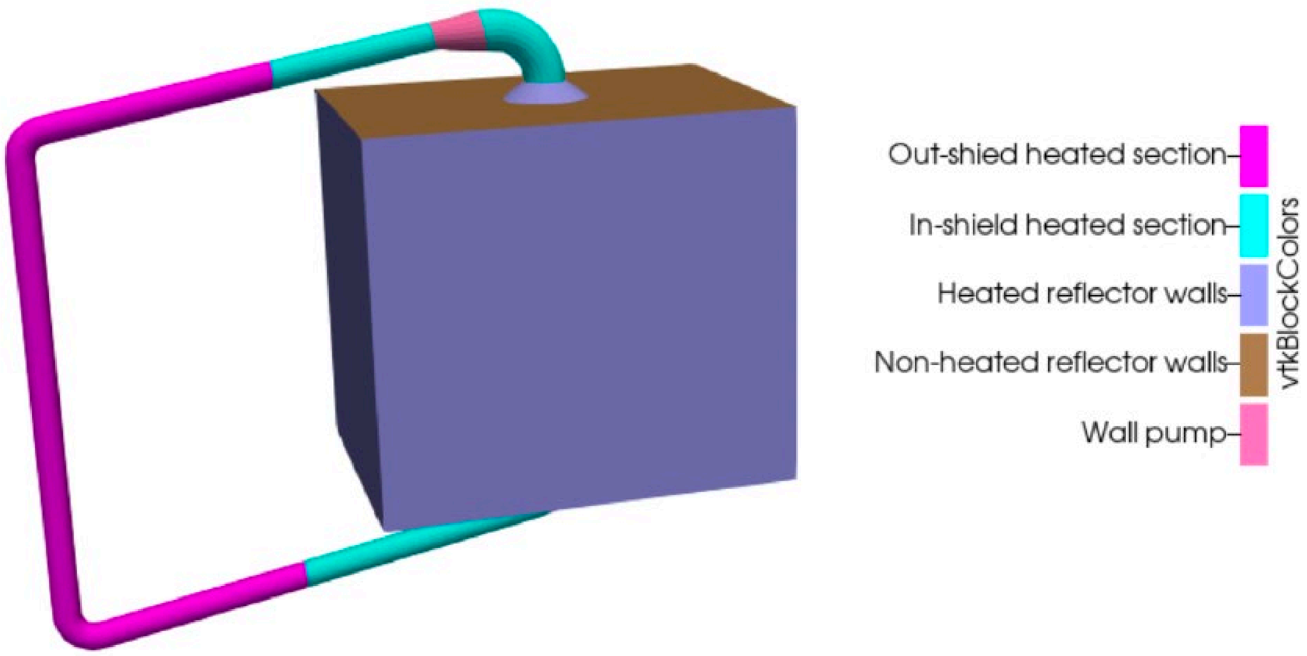


Figure 3. With reflector

Key parameters

Parameter	Value	~
Core Power [KWth]	25	
Operation Temperature [K]	900	
Mass Flow Rate [kg/s]	100	
Fuel Salt Composition [mol %]	NaCl [33.3%] – UCl3 [66.7%]	
Fuel Enrichment (235U) [wt %]	93.2	
Fuel Salt Density [kg/m3]	$\rho = 4.213 \times 10^3 - 1.0686\, T[K]$	3251 kg/m3
Specific Heat Capacity [J/(kg.K)]	$C_p = 8.900439 \times 10^3 - 1.377936 \times 10^1\, T[K] + 6.400369 \times 10^{-3}\, T[K]^2 - \frac{8.443758 \times 10^8}{T[K]^2}$	641 J/kg K
Thermal Conductivity [W/(m.K)]	$k = 5.6820 - 8.7832 \times 10^{-3}\, T[K] + 4.0967 \times 10^{-6}\, T[K]^2 - \frac{5.7642 \times 10^{-5}}{T[K]^2}$	1.095 W/m K
Dynamic Viscosity [Pa.s]	$\mu = 1.505 \times 10^{-4} \exp\left(\frac{2.666 \times 10^4}{8.314 \times T[K]}\right)$	5.31E-3 Pa s

Steady state benchmark

- Data from high-fidelity LES
- Course mesh model for pressure drop calibration
- Good agreement with high-fidelity results
- But… it’s no surprise. It was calibrated for that.

	Mass Flow Rate [kg/s]	Δp_{pipe} $[Pa]$	Δp_{mixing_plate} $[Pa]$	Δp_{core} $[Pa]$	Δp_{pump_choke} $[Pa]$
LES Model	25.0	1.07e4	2.60e3	1.27e3	7.38e4
Pronghorn Model	25.0	1.067e4	2.576e3	1.273e3	7.97e4
Absolute Error [Pa]	-	-32	-24.4	3.1	5910
Relative Error	-	-0.3%	-0.94%	-0.24%	8.1%

Table. Pressure drops per block and comparison with reference LES model.

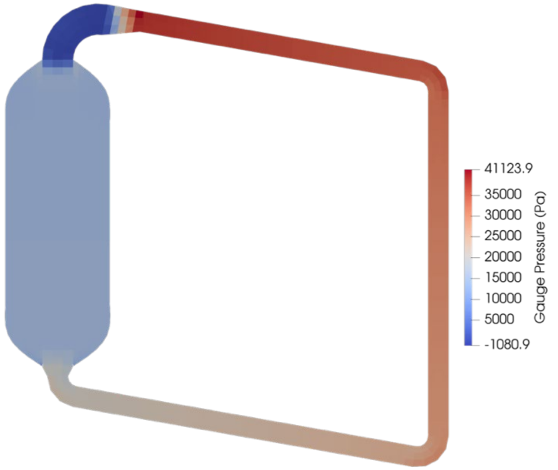


Figure 4. Gauge pressure field, with a reference point at the elbow before the pump inlet.

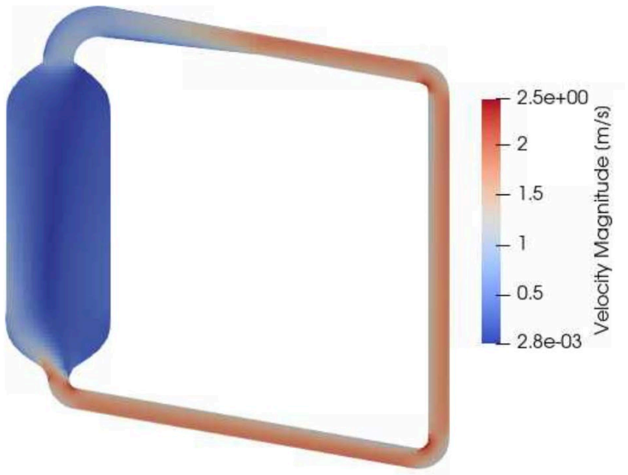


Figure 5. Velocity field.

Corrosion

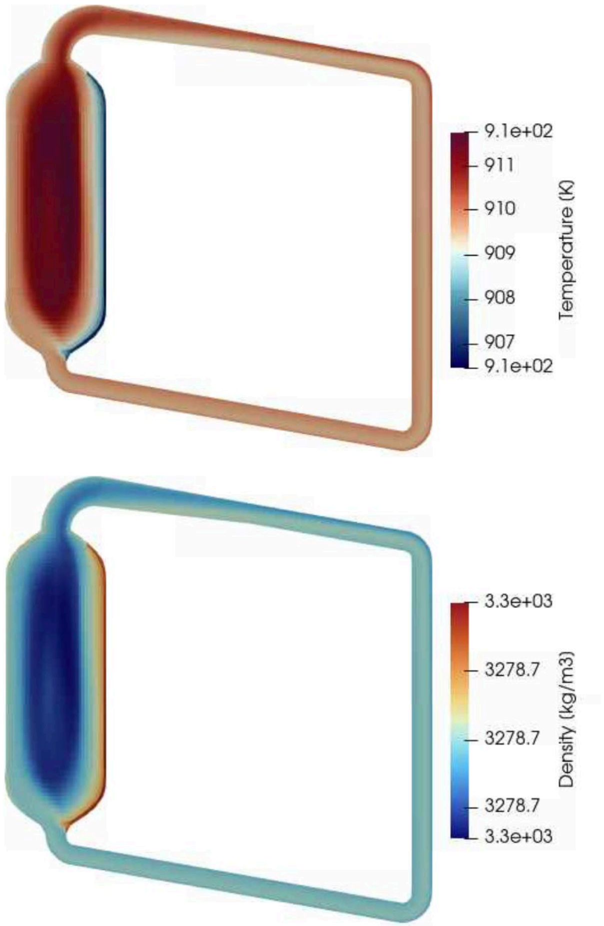


Figure 6. Temperature (top) and density (bottom) field during the operation of the L-MSR.

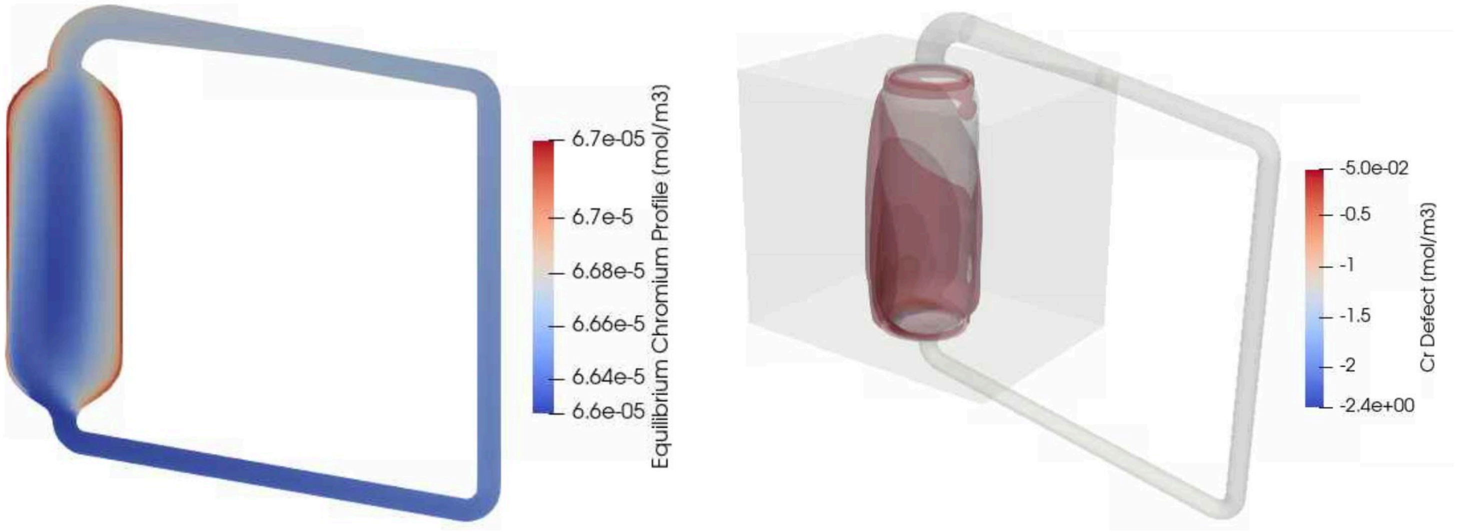


Figure 7. Chromium concentration in the fuel salt (left) and defect in the reactor vessel (right) by the end of operation of the L-MSR.

- Slightly preferential corrosion on the hot side
- Nice exercise, but an artifact of the lack of flow distributor

Plating

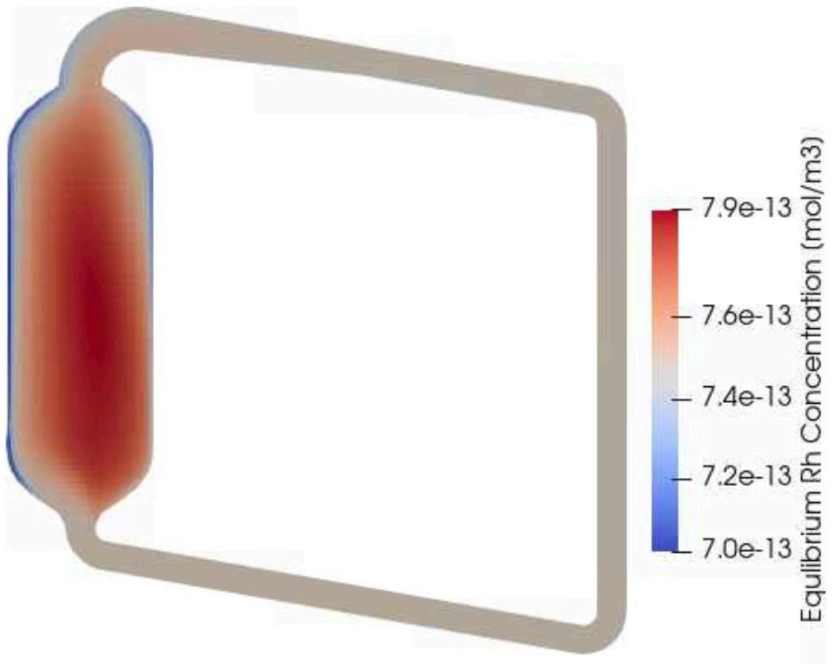


Figure 8. Rhodium concentration in the fuel salt by the end of the operation of the L-MSR.

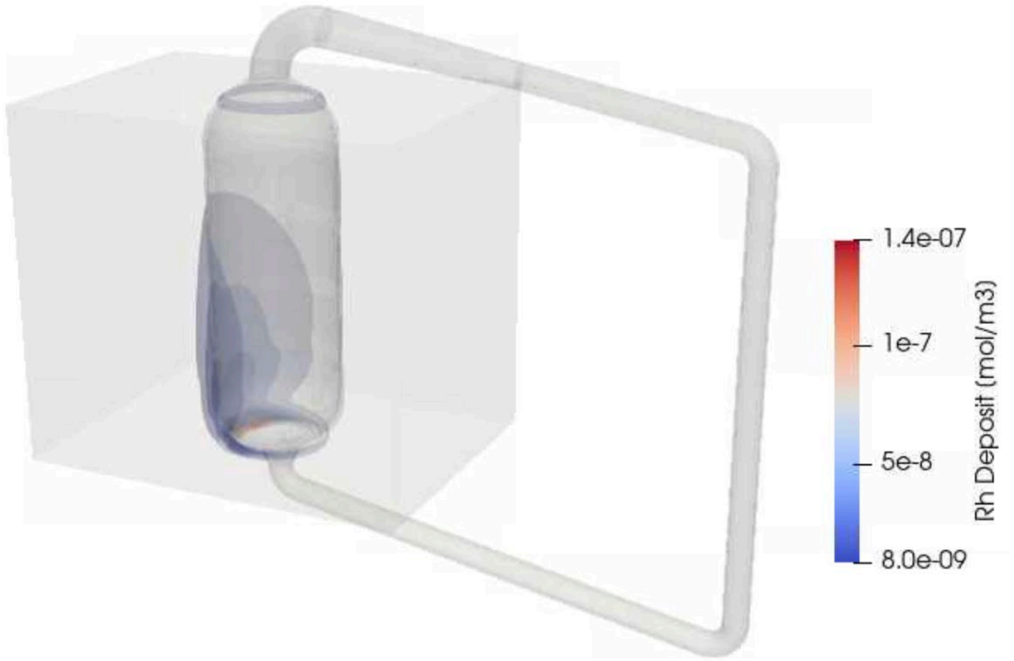


Figure 9. Rhodium concentration in the reactor vessel by the end of the operation of the L-MSR.

- Plating at the walls (reduced concentrating in the liquid)

- The opposing pair, pointing at deposition at walls

Unprotected LOFA

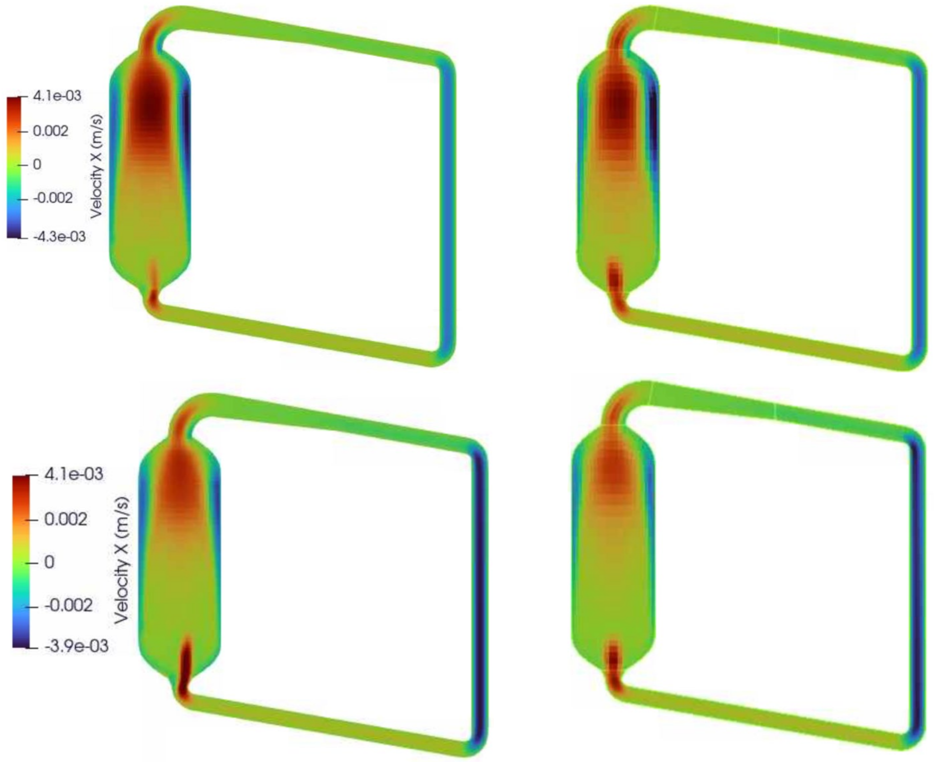


Figure 10. Natural convection vertical velocity
(a) Ph at 900s. (b) CFD at 900s.
(c) Ph at 1500s. (d) CFD at 1500s.

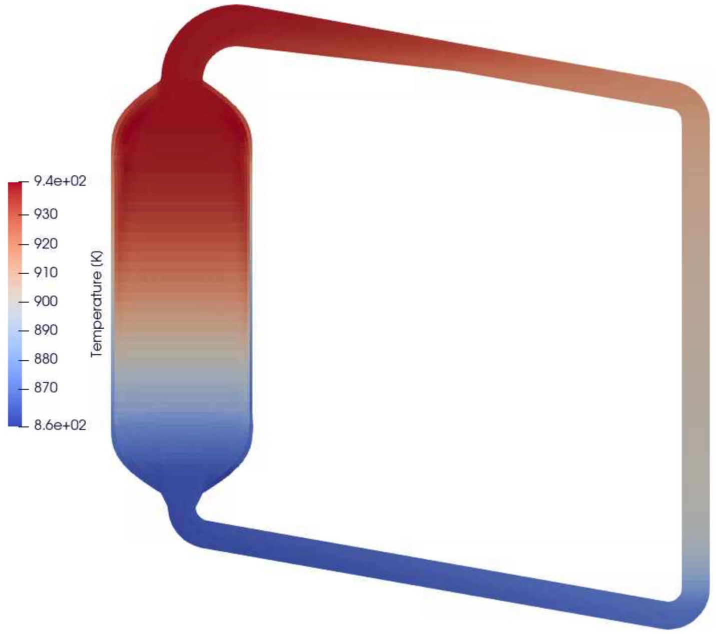


Figure 11. Final temperature distribution after LOFA.

- Pronghorn and CFD match very well
- A temperature gradient is established on LOFA

Unprotected LOFA quantitative

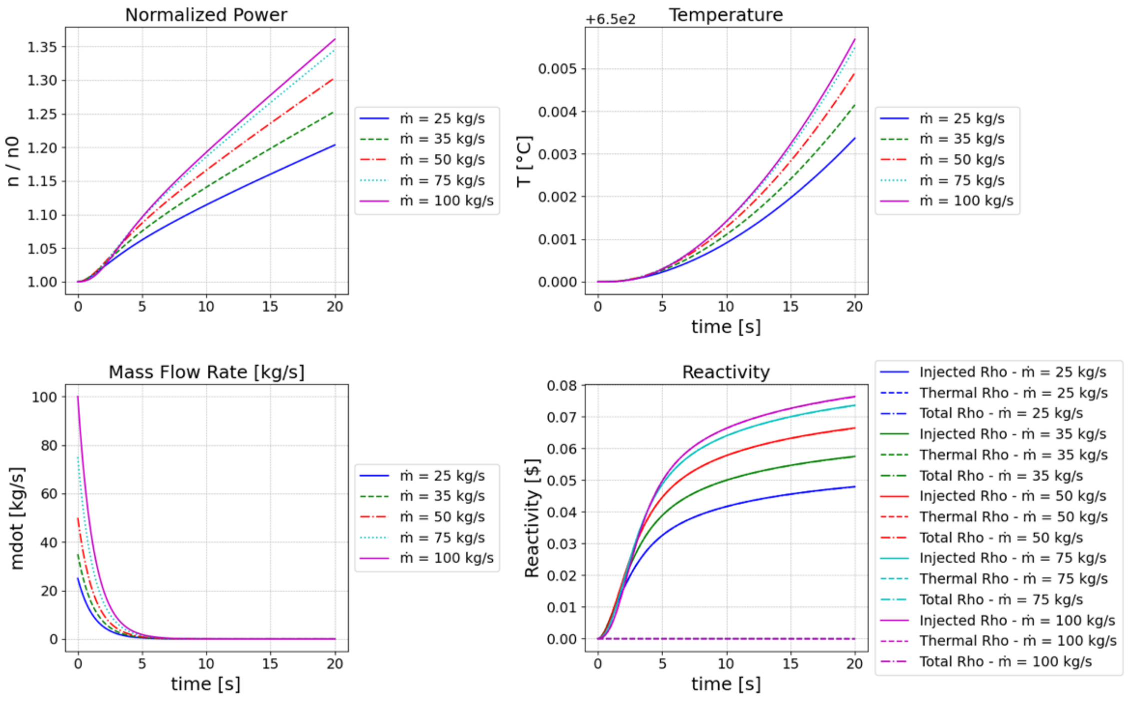


Figure 12. Short-term reactor response under LOFA.

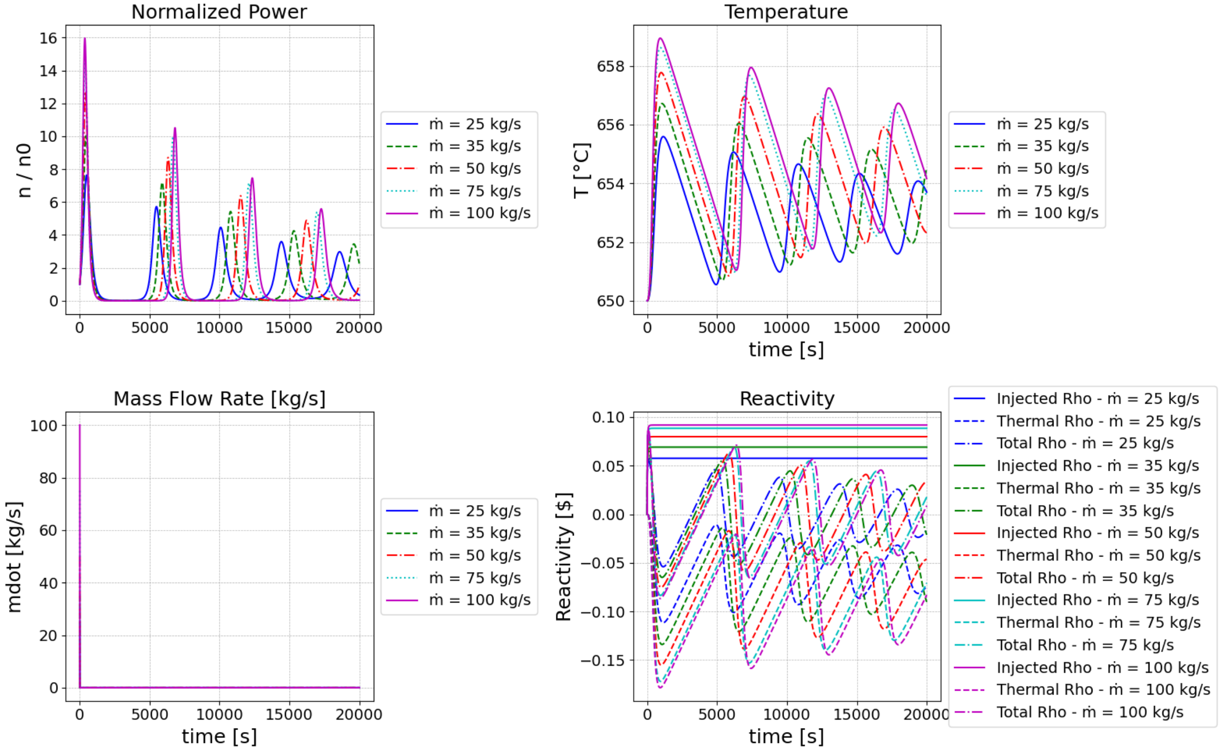


Figure 13. Long-term reactor response under LOFA.

Conclusion

- L-MSR as a development driver
  - Keeps development on point and relevant
  - Allow immediate leveraging of capabilities
  - Problem looking for a solution, not the inverse

- Current modeling capabilities have become comprehensive and elaborate

- L-MSR-like reactors benefit directly

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Contact

- Rodrigo de Oliveira (rodrigo.deoliveira@inl.gov)