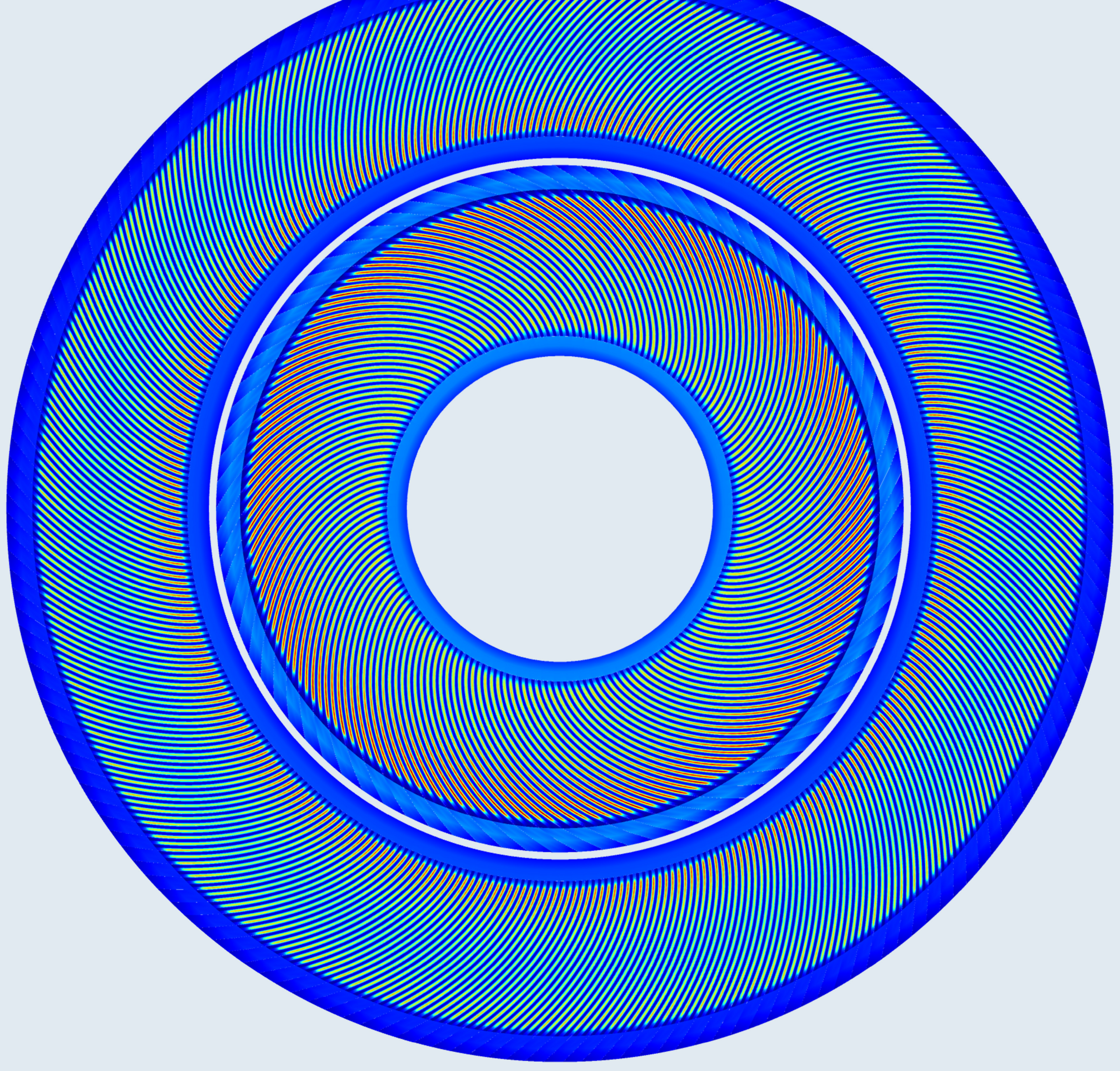

Multiphysics Modeling Results for the High Flux Isotope Reactor to Support Its LEU Conversion

Advanced multiphysics computational fluid dynamics models were developed in COMSOL® to simulate the steady-state operating conditions for the current highly-enriched uranium (HEU) U_3O_8-Al (uranium oxide dispersion) fuel designs and the proposed low-enriched uranium (LEU) U_3Si_2-Al (uranium silicide dispersion) fuel designs.

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Introduction

Ongoing engineering design studies at Oak Ridge National Laboratory are exploring the feasibility of converting the High Flux Isotope Reactor[1] (HFIR) from HEU to LEU fuel. HFIR is a pressurized, light-water–cooled and –moderated research reactor with a core composed of involute-shaped fuel plates and coolant channels. COMSOL is being used for high-fidelity multiphysics analysis to support design decisions and confirmatory safety evaluations.

COMSOL models for the HFIR inner fuel element (IFE) and outer fuel element (OFE) incorporate various essential inputs and physics, such as spatially dependent nuclear heat deposition, multilayer heat conduction, conjugate heat transfer, turbulent flows (using Reynolds-Averaged Navier–Stokes turbulence models), structural mechanics (thermal-structural interactions and fuel swelling), and oxide layer buildup.

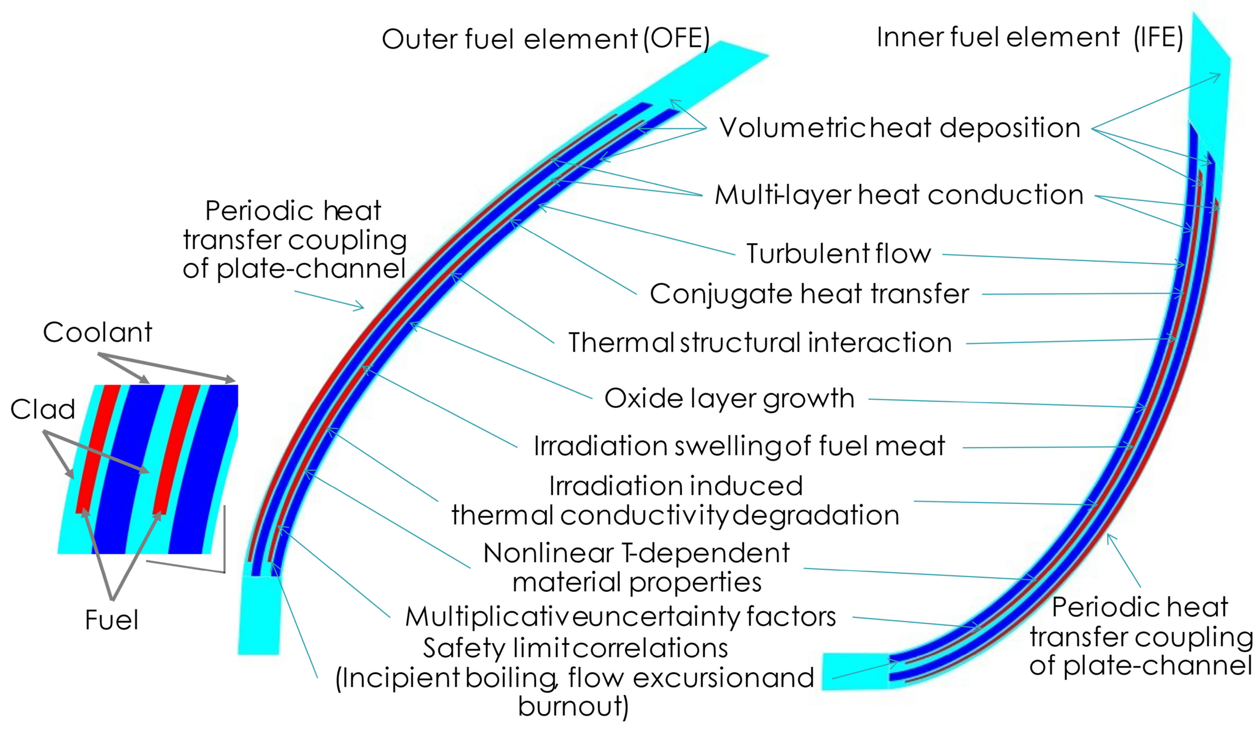

Figure 1. Multiphysics in the COMSOL design and safety basis model of HFIR[2].

Methodology

Three-dimensional, steady-state, incompressible, k-ε Reynolds-Averaged Navier–Stokes equations are solved for the turbulent flow. These equations include continuity and momentum, as well as the k-equation for transport of turbulent kinetic energy and the ε-equation for turbulent dissipation. Additionally, energy equations are solved in the solid (heat conduction) and fluid (heat conduction and convection) regions of the model. The Kays–Crawford model is used to account for the turbulent Prandtl number in the fluid region. Thermal expansion of the fuel plate (meat and clad) affecting the spatial coolant channel thickness is modeled. Furthermore, a time- and temperature-dependent oxide layer growth correlation, the Griess correlation, is used to predict the oxide buildup on the clad surface. A thermomechanical V&V was performed in a separate study[3] against the Cheverton-Kelley experiments.

Results

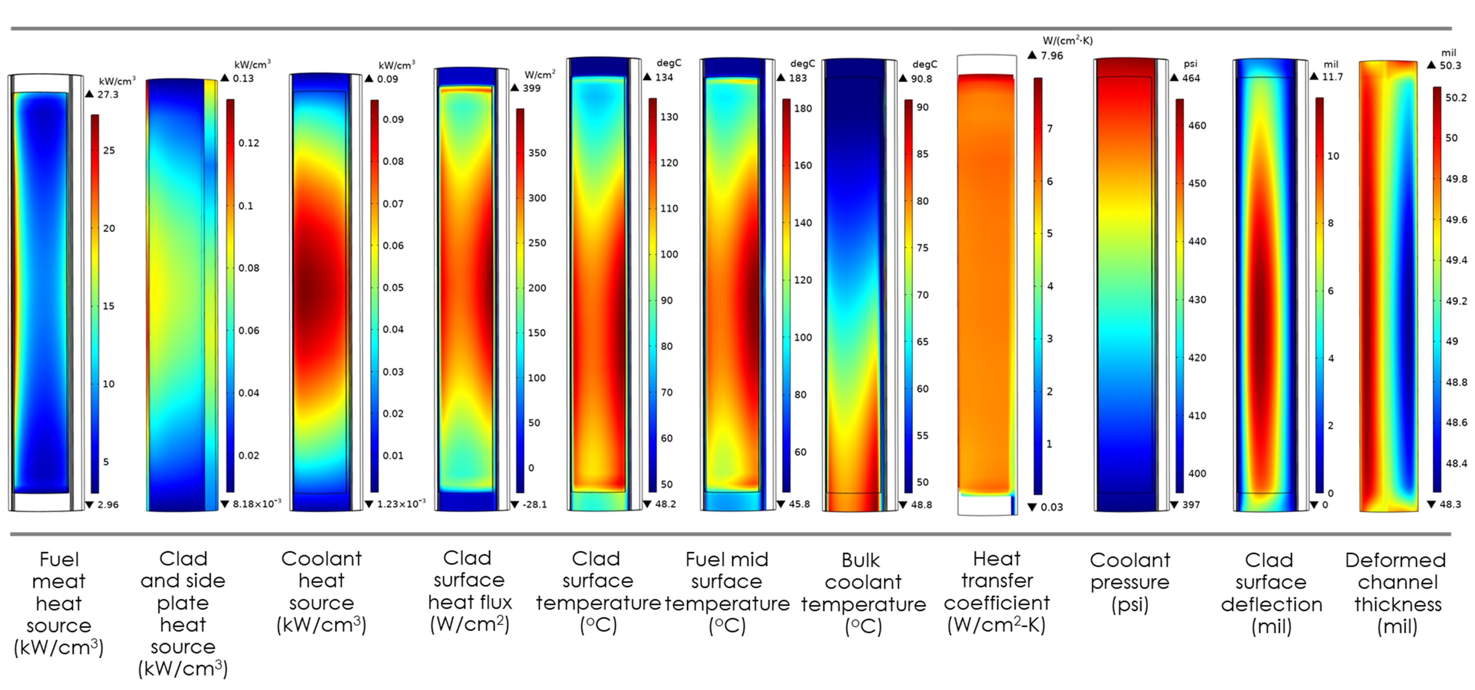

Figure 2. IFE results for the high-density optimized LEU silicide design[4] at 95 MW nominal operating condition for the beginning of cycle.

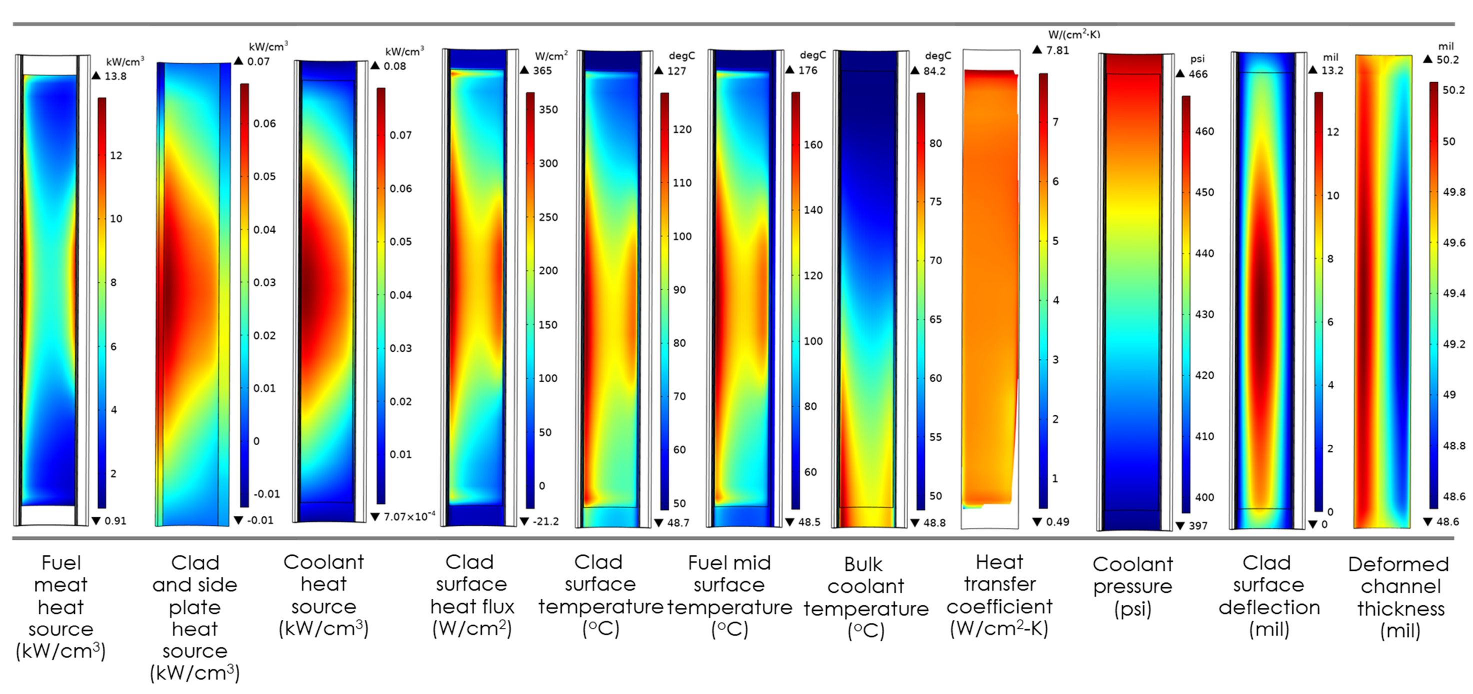

Figure 3. OFE results for the high-density optimized LEU silicide design[4] at 95 MW nominal operating condition for the beginning of cycle.

REFERENCES

1. High Flux Isotope Reactor https://neutrons.ornl.gov/hfir.
2. Prashant Jain, COMSOL Multiphysics Modeling Results for the Low-Enriched Uranium-Silicide Conversion of the High Flux Isotope Reactor, Presentation at the 20th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH-20), Washington DC, August 20–25, 2023.
3. Sitek, M. et al., Thermomechanical analysis and modeling of involute-shaped fuel plates using the Cheverton–Kelley experiments for the High Flux Isotope Reactor, Nuclear Engineering and Design, 409, 2023, 112334.
4. Bae, J., et al., 2021, High Flux Isotope Reactor Low-Enriched Uranium High Density Silicide Fuel Design Parameters, ORNL/TM-2020/1799, United States.

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