# Evaluating the Performance of Solution Algorithms for Parallel Coupled Neutronic and Thermal-Hydraulic Simulations

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*Abstract*

Determining the steady-state power and temperature distributions within an operating nuclear reactor is an important component of reactor design and analysis. This task requires simultaneously solving equations describing the distribution of neutrons throughout the reactor in addition to the transfer of heat through the fuel and structural materials and into fluid coolant regions. Current core analysis methods typically rely on the use of a Picard iteration, alternating between solving individual physics components. Although this approach offers a simple path to coupling different physics codes due to the minimial code interaction required, there can be significant drawbacks.

This presentation evaluates the performance of multiphysics coupling algorithms on a light water nuclear reactor core simulation. The simulation couples the k-eigenvalue form of the neutron transport equation with heat conduction and subchannel flow equations. The neutron transport equation is solved using a multi-group approximation in energy, simplified spherical harmonics (SPn) in angle, and finite-difference in space. A Galerkin finite element formulation is used to solve the conjugate heat transfer model for energy conservation within a suite of nuclear fuel rods with heat removal through convection models along the outside of the rods. We compare Picard iteration (block Gauss-Seidel) with Anderson acceleration and multiple variants of preconditioned Jacobian-free Newton-Krylov (JFNK). The efficiency and robustness of the methods are evaluated over a range of energy group sizes, boron concentrations and core power levels. A novel physics-based approximation to a Jacobian- vector product has been developed to mitigate the impact of expensive on-line cross section processing steps. Numerical experiments demonstrating the efficiency of JFNK relative to standard Picard iteration are performed on a 3D model of a nuclear fuel assembly.