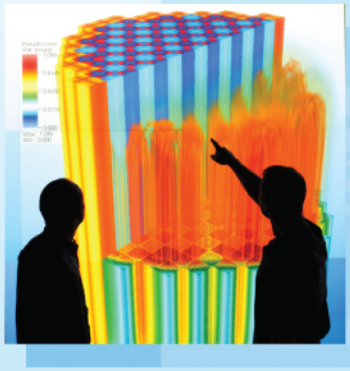
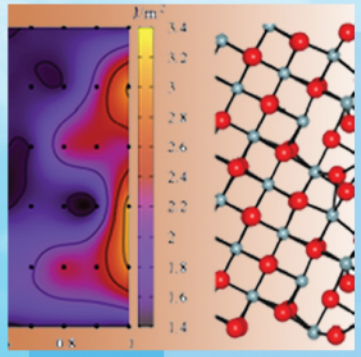
CASL-U-2014-0135-000

Power uprates
and plant life extension



Engineering design
and analysis

Science-enabling
high performance
computing



Fundamental science

Plant operational data

Consortium for Advanced Simulation of LWRs

Rod Cusping Treatment in MPACT

Aaron M. Graham
University of Michigan

August 4, 2014

U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Rod Cusping Treatment in MPACT

Aaron M. Graham– The University of Michigan

Mentor: B. Collins **With:** M. Jessee **Program:** NESLS Reactor Physics Group, Reactor and Nuclear Systems Division

Introduction

CASL is currently developing a new core simulator called MPACT to solve neutron transport problems for light-water nuclear reactors. MPACT uses the 2D/1D approach, which is an iterative method with two primary steps in each iteration. The first step consists of a series of high-fidelity calculation in 2D planes, which resolves much of the heterogeneity in the core. These calculations are then coupled through lower-order axial calculations.

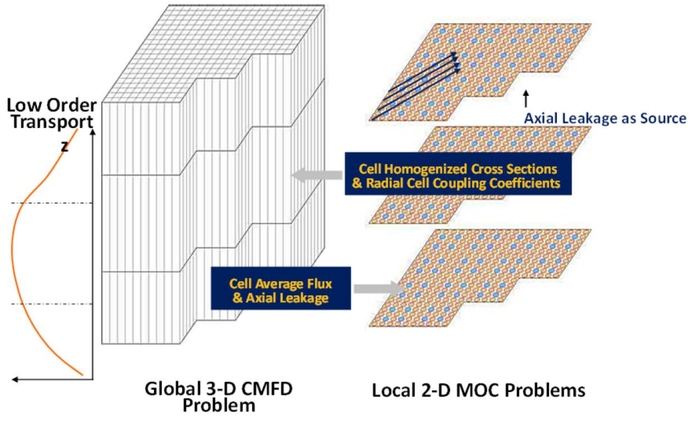


Figure 1: Depiction of 2D/1D problem formulation. The global, low order problem shown on the left with the higher-order planar transport problems are shown on the right

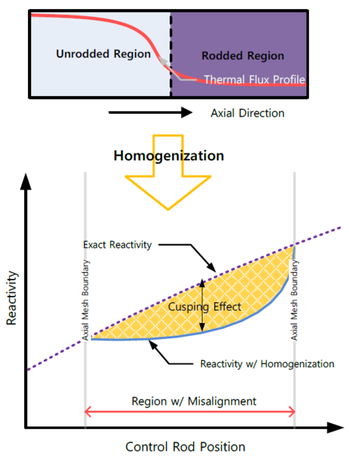


Figure 2: Depiction of control rod cusping effects due to homogenization of partially inserted control rod [1]

Rod Cusping Effect

When performing the 2D calculations, MPACT homogenizes materials axially within each plane. In many simulations, control rods are partially inserted into a plane. This results in rod "cusping" effects: artificially low neutron fluxes around the tip of the control rod. This occurs because the control rod material is being homogenized into a greater volume than is physically present in the reactor.

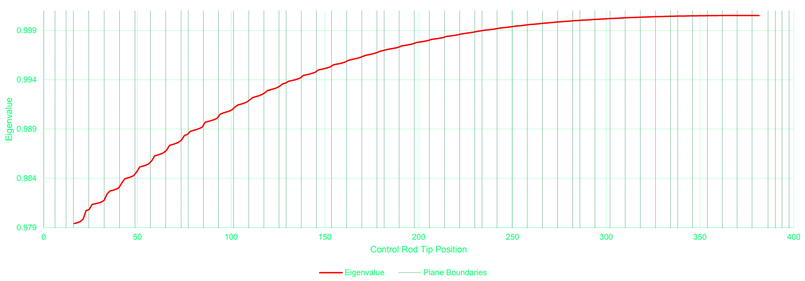


Figure 3: Simulations displaying rod cusping effects during rod withdrawal

3x3 Assembly Problem

The problem used to develop the rod cusping treatment consists of a 3x3 array of 17x17 assemblies, with a control rod bank inserted in the center assembly. This problem was simulated with a heterogeneous AIC control rod at various positions within a plane to characterize the cusping effects for the rod. A sixth-order polynomial fit was then used in MPACT to generate a correction factor for the control rod homogenization.

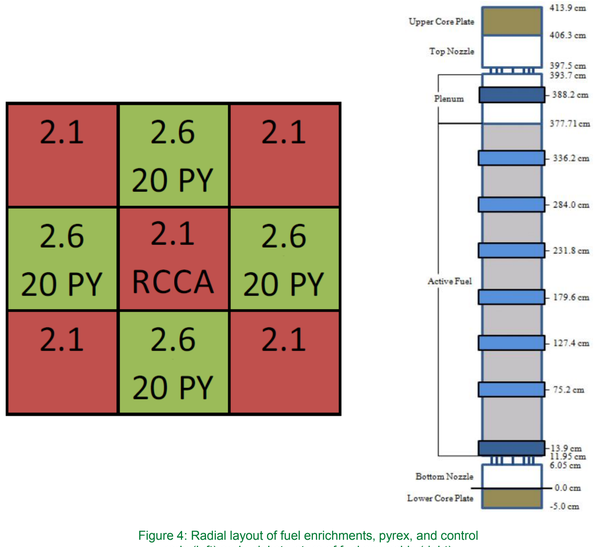


Figure 4: Radial layout of fuel enrichments, pyrex, and control rods (left) and axial structure of fuel assembly (right)

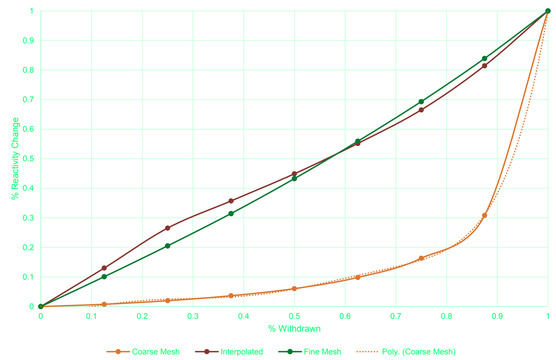


Figure 5: Eigenvalue data for homogeneous control rod simulations

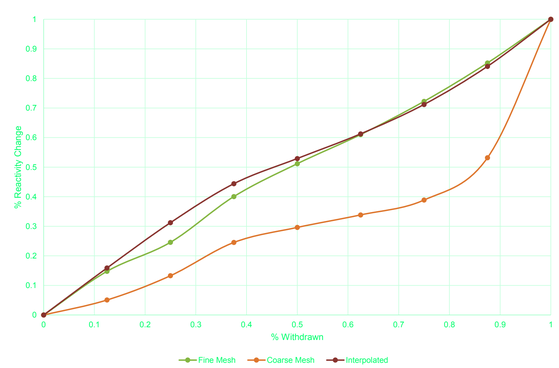


Figure 6: Eigenvalue data for heterogeneous control rod simulations

Summary

The polynomial used to calculate the correction factor was generated using a homogeneous AIC control rod. The correction was also applied to a more realistic heterogeneous rod, with AIC, B_4C, and stainless steel regions. With the more complicated rod, the correction still proved effective in error reduction, showing that it can be used to easily improve the answers for a variety of problems.

Calculation Type	Average k-eff Difference (pcm)
Homogeneous rod, no correction	-5.88
Homogeneous rod, with correction	0.164
Heterogeneous rod, no correction	-7.92
Heterogeneous rod, with correction	0.973

Table 1: Eigenvalue and power comparisons with and without homogenization correction factor

Acknowledgments

This research was supported by the Consortium for Advanced Simulation of Light Water Reactors and made use of resources of the Oak Ridge Leadership Computing Facility at the Oak Ridge National Laboratory, which is supported by the Office of Science of the U.S. Department of Energy under U.S. DOE Contract No. DE-AC05-00OR22725.

References

[1] Yeon Sang Jung, Han Gyu Joo. "Control Rod Decusping Treatment based on Local 3-D CMFD calculation for Direct Whole Core Transport Solvers," Presented at ICAPP, Charlotte, USA, 2014.

[2] Andrew T. Godfrey. "VERA Core Physics Benchmark Progression Problem Specifications (Rev. 2)," Tech. Rep. CASL-U-2012-0131-002, ORNL, (2013).

CASL-U-2014-0135-000