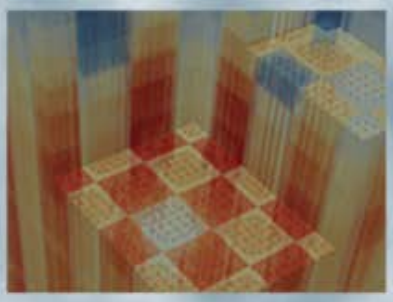
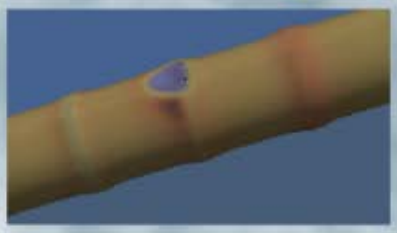
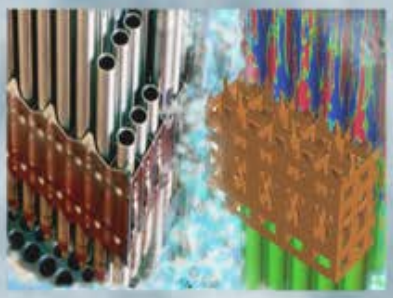
CASL-U-2015-0249-000

Rod Cusping Treatment in MPACT







Aaron Graham and Tom Downar
University of Michigan

Ben Collins
Oak Ridge National Laboratory

July 7, 2015

CASL-U-2015-0249-000

Rod Cusping Treatment in MPACT

UNIVERSITY OF MICHIGAN

CASL Student Workshop 2015

Aaron Graham, UM; Ben Collins, ORNL; Tom Downar, UM

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.

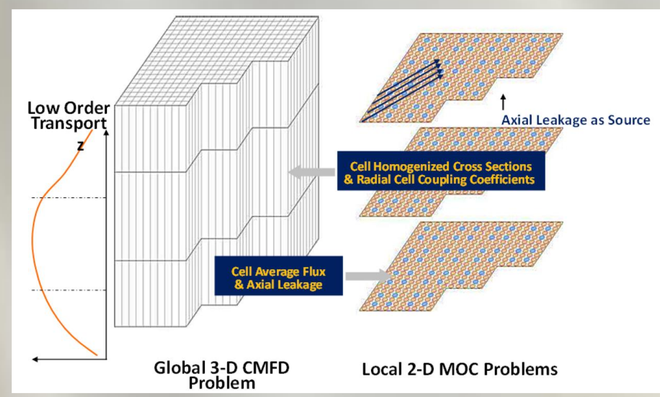


Figure 1: Depiction of 2D/1D problem formulation. The global, low order problem shown on the left with the higher-order planar transport problems are shown on the right

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.

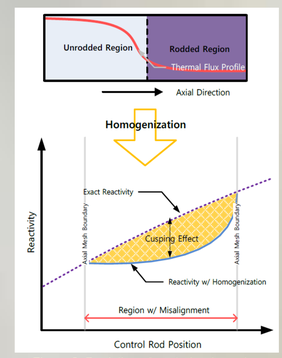
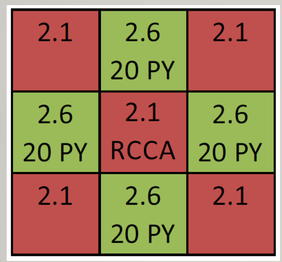


Figure 2: Depiction of control rod cusping effects due to homogenization of partially inserted control rod [1]

Homogenization Correction

The first step in correcting the rod cusping effects was to implement a simple correction that would improve results while more advanced methods are developed. The problem used to do this consists of a 3x3 array of 17x17 assemblies, with a control rod bank inserted in the center assembly. This problem was simulated using AIC, B_4C, Tungsten, and Stainless Steel control rods. Simulations were performed using coarse and fine axial meshes to quantify the rod cusping effects for each material.



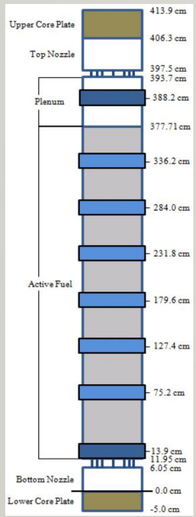


Figure 3: Radial layout of fuel enrichments, pyrex, and control rods (left) and axial structure of fuel assembly (right) [2]

The results of these simulations were used to develop polynomials that would correct the rod cusping effects. When homogenizing the control rod, the volume fraction of the control rod is reduced by an amount corresponding to one of these polynomials, correcting the eigenvalue and local pin power results. Results for this correction method are shown below. Results are averaged over 7 rod positions for each control rod. Stainless steel is not shown because its rod cusping effects are minimal.

Control Rod Material	k-eff Error (pcm)		Max Pin Power Error	
	No Correction	Correction	No Correction	Correction
AIC	-5.7	0.6	8.9%	1.4%
B_4C	-6.6	0.6	10.1%	2.2%
Tungsten	-7.3	0.6	4.3%	1.3%
Heterogeneous (B_4C tip with AIC follower)	-7.9	0.5	9.93%	1.99%

Table 1: Eigenvalue and power comparisons with and without homogenization correction factor. Fine mesh solutions were used as reference results

Future Work -- Subplane Method

The subplane method is currently under development to handle rod cusping effects more rigorously. This method uses a finer axial mesh for the 3D CMFD acceleration than for the 2D MOC calculations. This allows the axial effects of the control rod to be captured by the accelerator instead, rather than increasing the amount of time required for the 2D transport calculations. The CMFD mesh will be split at the tip of the control rod and use the correct material cross-sections, then provide improved homogenized cross-sections for the 2D transport calculations.

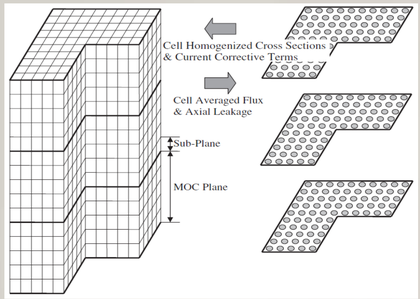


Figure 4: Depiction of the subplane method being implemented in MPACT

Acknowledgments

This research was supported by the Consortium for Advanced Simulation of Light Water Reactors (www.casl.gov), an Energy Innovation Hub (http://www.energy.gov/hubs) for Modeling and Simulation of Nuclear Reactors under U.S. Department of Energy Contract No. DE-AC05-00OR22725.

This research also 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 Contract No. DE-AC05-00OR22725.

This material is based upon work supported under an Integrated University Program Graduate Fellowship.

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-2015-0249-000