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INTRODUCTION

The Advanced Graphite Creep test, AGC-1 [1], is planned for irradiation in the Advanced Test Reactor (ATR) in support of the Next Generation Nuclear Plant program. The experiment requires very detailed neutronics and thermal hydraulics analyses to show compliance with programmatic and ATR safety requirements. The MCNP [2] model used for the neutronics analysis required hundreds of tally regions to provide the desired detail. A method for visualizing the hundreds of tally region geometries and the tally region results in 3 dimensions has been created to support the AGC-1 irradiation. Additionally, a method was created which would allow ABAQUS [3] to access the results directly for the thermal analysis of the AGC-1 experiment.

DESCRIPTION OF THE ACTUAL WORK

Modeling experiments to be irradiated in the Advanced Test Reactor, ATR, often requires small tally regions covering large components to provide the detailed information needed for the safety analysis. In MCNP this can be accomplished by dividing the large component into multiple small cells or by segmenting the component tally.

The AGC-1 experiment will be irradiated in a large flux trap of the ATR. The experiment capsule contains a sample holder made of graphite and a thermal heat shield which both extend beyond the 48 inch active core. The graphite samples extend nearly the full 48 inches of the active core with the smallest samples being 0.25 inches in length. Using the 0.25 inch length as the smallest axial tally length requires 192 axial tally segments over the 48 inch length. Since the experiment contains seven sample stacks there are 1.344 tally segments for just the samples.

The irradiation is planned for the south flux trap of the ATR which has fuel surrounding only half of the flux trap. This creates a neutron and photon flux gradient across the experiment which also needs to be captured in the analysis. To analyze the flux gradient, the graphite holder was segmented into 2 radial segments and 6 azimuthal segments in addition to the 192 axial segments. Add to this the six azimuthal segments and 192 axial segments for both the thermal shield and the experiment pressure boundary and the number of tally regions becomes almost 6000 in total.

Troubleshooting the geometry of the tallies can generally be done by analyzing the results and looking for anomalies, but a 3D plot of the tally segment geometries can be a very useful tool. A 3D plot of the results over the geometry is also a very useful design tool and can be used for troubleshooting the tally definitions.

Since the results from the analysis are used in the finite element code ABAQUS, the segment results need to be input into the correct ABAQUS element. The ABAQUS model of the AGC-1 experiment contains over 400,000 elements. Manual data entry for the more than 400,000 elements becomes a time-consuming, error prone task. An automated data entry method was needed to eliminate possible errors and facilitate parametric studies.

Visualization of the AGC modeling results and an interface to allow ABAQUS to access the results directly required the development of custom software to generate the necessary mesh, associate the results with the appropriate locations on the mesh, and provide an interface where ABAQUS could access the results directly, without human interaction.

Generation of the necessary mesh required the extraction of individual surfaces and cells from the MCNP input file. These surfaces and cells were then combined using standard Constructive Solid Geometry (CSG) operations and a mesh was generated using the NETGEN [4] meshing library. The resulting mesh was then placed in a standard silo database. The MCNP results for individual cells were then associated with the appropriate mesh nodes and added to the silo database. Once the silo database is complete, it is usable by any tool that understands its interface and structure. VisIt [5] was used to access the silo database and provide a 3D visualization of the results.

An interface that allows ABAQUS to also access the silo database containing the AGC results was created, implemented as a function to be called from a standard user subroutine. This subroutine receives an xyz location to retrieve the results for and interfaces directly to the silo database to locate the appropriate cell containing the requested location. The result associated with the requested location is then returned to the calling module. To enhance performance, results are cached in memory by location to minimize references to the silo database.

RESULTS

This work resulted in the ability to visualize MCNP tally segment geometry in 3 dimensions as well as viewing the results overlaid on the geometry in 3 dimensions. Figure 1 shows the MCNP heating results overlaid on the geometry in VisIt. A large number of histories were run in MCNP to keep the relative error of the results at around 1%. With the automated data entry, the ABAQUS runs complete in less than 2 hours.

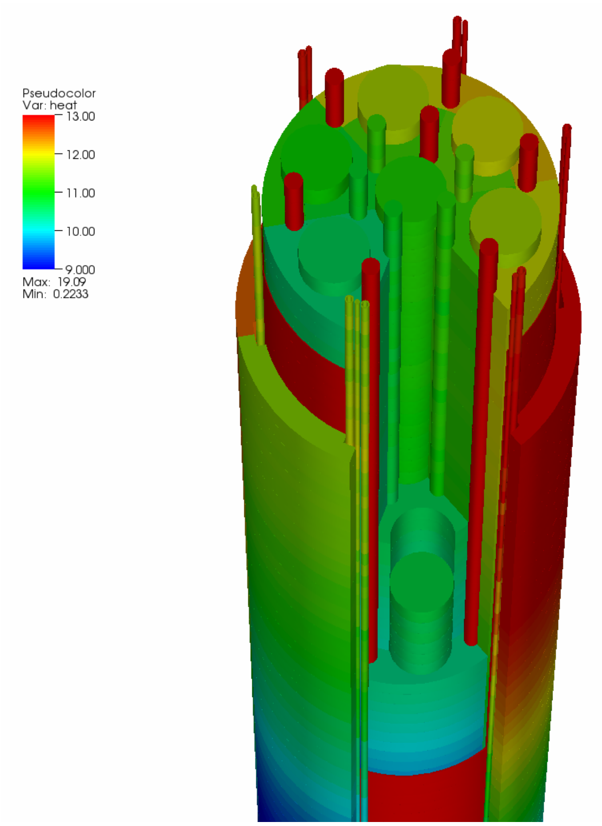

Fig. 1. Heat rate results overlaid on the MCNP geometry using VisIt.

REFERENCES

1. R. L. Bratton, "AGC-1 Irradiation Experiment Test Plan," INL/EXT-06-11102, Idaho National Laboratory, May 2006.
2. T. Goorley, J. Bull, F. Brown, et. al., "Release of MCNP5_RSICC_1.30," MCNP Monte Carlo Team X-5, LA-UR-04-4519, Los Alamos National Laboratory, November 2004.
3. Hibbitt, Karlsson, & Sorensen, Inc., ABAQUS/Standard, Version 6.6-1.
4. J. Schöberl. Netgen, Version 4.4, Johannes Kepler University Linz, www.hpfem.jku.at/netgen.
5. VisIt, Version 1.5.3, Lawrence Livermore National Lab, http://www.llnl.gov/visit.