Development of Visualization Tools for ZPPR-15 Analysis

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1. Introduction

The Korea Atomic Energy Research Institute is developing deterministic models using ANL code suites such as MC^2-3 and DIF3D/VARIANT for ZPPR-15 experiments [1]. ZPPR-15 cores consist of various drawer masters that have great heterogeneity. In order to build a proper homogenization strategy, the geometry of the drawer masters should be carefully analyzed with a visualization. Additionally, a visualization of drawer masters and the core configuration is necessary for minimizing human error during the input processing. For this purpose, visualization tools for a ZPPR-15 analysis has been developed based on a Perl script.

In the following section, the implementation of visualization tools will be described and various visualization samples for both drawer masters and ZPPR-15 cores will be demonstrated.

2. Methods and Results

The visualization tools developed in this work generate VTK (Visualization Toolkit) files, which include geometry and isotopic information of drawer masters or the whole core. VTK files are a standard format for visualization, and they can be easily processed by the VISIT program, which was developed in LLNL USA (https://wci.llnl.gov/simulation/computer-codes/visit/). The process for generating VTK files and the final visualization results by VISIT processing will be described in this section.

2.1 General Steps for VTK file writing

The first step for generating a VTK file is preparing geometry information into the VTK file. The geometry of a VTK file consist of *POINTS, CONNECTIVITY* and *CELLS* data sets. *POINTS* are the position vector of each vertex, *CONNECTIVITY* is an array of *POINT* indexes that forms a mesh, and *CELLS* indicates the mesh type. If the same vertex has multiple *POINTS*, the visualization will crash, and thus the vertexes provided for *POINTS* should be unique. This can be a hassle for writing a VTK file since all geometric relations of the meshes should be known in advance. However, a hash data structure makes this task very simple as follows:

1. Generating a hash key using vertex *P*. For example, key *h* for $P(x,y,z)$ can be simply the string *xyz*.

2. If a key does not exist, assign a hash as *hash {key} = index*;
3. Indices stored in a hash can be used for building *CONNECTIVITY*.

In this manner, a duplication of POINTS can be prevented, and a *CONNECTIVITY* can be built with only vertex information.

The second step is providing mesh data by *CELL_DATA* data sets. The actual data stored into the VTK file can be multiple values, typically the material or region number, number density of each isotope, boundary of the x, y, z direction are written in VTK file.

2.2 Visualization of Drawer Masters

In the ZPPR-15 experiments, drawer masters play a role of assemblies in a typical reactor core. They have real drawers, and thus the geometry of the drawer masters are very similar to a 1D slab geometry for the x-axis. However, the actual geometry of drawer masters are complicated since various drawers are inserted into the z-axis as well the as x-axis, and they have cover structures for fuel and coolant. The finial objective of the visualization of the drawer master is finding the best 1D homogenization model for MC^2-3 calculation. Therefore, the tools should have capabilities of visualization for not only the geometry itself, but also the distribution of each isotope.

The VTK files for drawer masters are generated based on as-built MC models. Mesh indexes for the x and z directions should be carefully considered in the VTK files since they are utilized for determining a 1D homogenization model. The procedure for writing the VTK file follows the previously mentioned steps.

After processing the VTK file via VISIT, 3D visualized results of a drawer master can be shown as plotted in Fig. 1. Note that the actual drawer master is very long for the z-direction, and thus the scale is transformed into 0.1 for the z-direction for better visualization results. The same VTK file can be used in a different way; by applying a threshold operator for different isotopes, and applying a slice operator for the x-z view, the isotopic distribution of the drawer master can be easily determined as plotted in Fig. 2, showing an isotopic number density of U-235 (orange), Na-23 (purple), and Pu-239 (green). Additionally, applications of visualization are possible, such as finding the material index or mesh index, by enabling a label plot mesh boundary or material index.
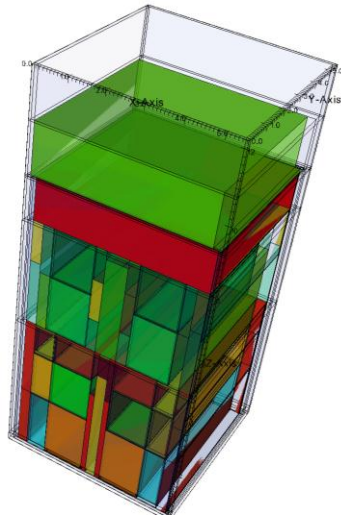
Fig. 1 3D visualization of a drawer master

Fig. 2 Isotopic distribution in drawer master

2.3 Visualization of ZPPR-15 Core Configurations

VTK file generation for the core configuration is based on a DIF3D input file. Actually, the recent DIF3D code package provide a visualization tool named dif3d_to_vtk (https://rsicc.ornl.gov/codes/ccc/ccc7/ccc-784.html), but the purpose of dif3d_to_vtk is the post-processing of DIF3D output data, and thus visualization data is only available after DIF3D calculation finishes. In order to find human error during input processing, it is necessary to verify the core configuration prior to the actual calculation. For this purpose, a tool that convert DIF3D input into a VTK file has been developed. Note that the basic procedure for writing a VTK file is the same as the tool for drawer master visualization.

Fig. 3 shows two figures of the same ZPPR-15 loading; one is a loading pattern given as an excel file and the other is a visualized core configuration from a DIF3D input. By comparing these two figures, the user can check whether the input is properly generated. Additionally, voided sodium regions in the sodium void reactivity experiment can be visually verified by plotting the Na-23 distribution as plotted in Fig. 4.
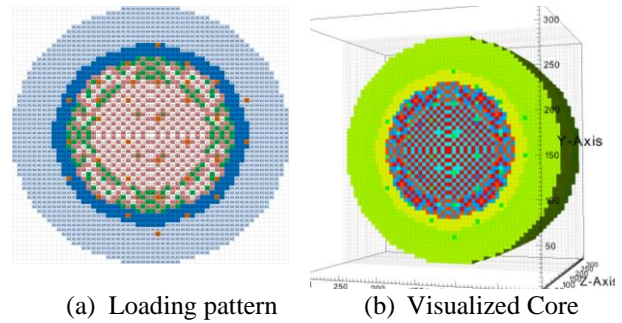

(a) Loading pattern   (b) Visualized Core

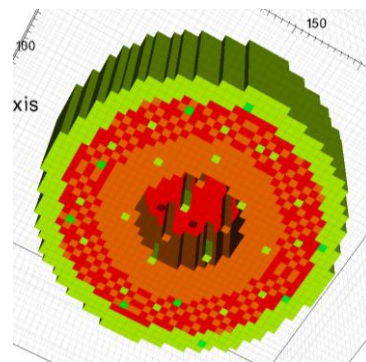**Fig. 3 Visualization of ZPPR-15 core configuration**

Fig. 4 Na-23 distribution in a ZPPR-15 core

In addition to these visualization results, VTK files can be utilized for various purposes such as checking the fuel loading, finding the control rod position.

3. Conclusions

Visualization tools for drawer masters and a core configuration were successfully developed for a ZPPR-15 analysis. The visualization tools are expected to be useful for understanding ZPPR-15 experiments, and finding deterministic models of ZPPR-15. It turned out that generating VTK files is handy but the application of VTK files is powerful with the aid of the VISIT program. Thus, the procedure described in this paper will be helpful for other neutronics analysis with visualization.

Acknowledgement

REFERENCES

[1] H. F. McFarlane, et. al., "Benchmark Physics Tests in the Metallic-Fueled Assembly ZPPR-15," Nuclear Science and Engineering, Vol. 101, p.137-152, 1989.