Karissa Currie

April 2020

SAND

Random Variation of ACRR Core Report

The research presented in this paper is to be a contribution to a larger research project. The project was designed to test the safety standards of Sandia National Laboratories' ACRR. The MCNP model of the ACRR core is being used to simulate the environment. To test the safety standards, the dimensions and density of the fuel in the core were varied randomly. Each rod had its own dimension and density assigned to it randomly. Ten different cases of the ACRR core were randomly created. The different cases were studied using 640-group neutron fluxes. The fluxes were compared to see how the variations affected the system.

The MCNP ACRR model was used for this project. The model was then modified to vary all the density, inner and outer diameters of the fuel rods. First the 230 separate universes were created on for each fuel rod including both the regular fuel rods and those at ninety percent. Within these universes a key phrase in square brackets was used as a substitution for the density of the fuel. Once all the separate fuel universe cards were created the lattice structure within the file was changed include the new universe cards. Inner and outer surface cards were also added to the file. The radius for each surface was also replaced with a key phrase in square brackets. There are 230 separate surface cards for both the inner and outer radii.

At this point calculations were performed to determine what the ranges should be for the densities, inner, and outer radii. For the inner and outer radii it is important to consider all possibilities. This way it can test the limits of the system and nothing considered to be improbable was left out. Inside the fuel is a void so there was no hard surface which restricts the expansion of the fuel. For this reason, a minimum inner radius of 0.003 cm was chosen. This prevents a total closure of the fuel but still allows for a large range of possibilities. The maximum inner radius was left as 0.2413 cm which is the usual MCNP inner radius for the fuel. This maximum inner radius was chosen because the concern for this project has to do with the effects of the expansion of the fuel.

The outer radius minimum remains 1.71725 cm, this is also the regular MCNP ACRR outer radius for the fuel. The reason this number was chosen follows the same reasoning as that of the inner radius maximum. The minimum was chosen based on the gap between the fuel and the niobium. Because 0.003 cm had been chosen to be the inner radius minimum, the outer radius maximum was chosen to fill up to within 0.003 cm of the niobium. The result is 1.640 cm.

For the density ranges the two types of fuel were calculated using the same process. In order to determine the range an original version of ACRR MCNP file was run. The volume and mass for each were taken from the table given in the output file. The volume of the unknown densities was then calculated. Finally, using the new volume and the mass the densities could be calculated. The density fuel for the total fuel is 3.1504-3.3447 g/cc. The range for the ninety percent fuel is 2.8353-3.0102 g/cc.

A python script was then created to perform mass substitution. The python script opens the MCNP file and replaces all the density, inner and outer radii with random numbers within the ranges. The script replaces each key phrase in square brackets with the random numbers for all the different variables. The script also makes it possible to create as many MCNP files with their own random variables as needed. For this project 10 different files were used. In the pictures below the effects of randomly varying the core can be seen. Figure 1 shows an overall view of one of the randomly varied cores. Figure 2 compares a section of the ACRR core the left side shows a randomly varied core and the right side shows the original. In the randomly varied core, it is very easy to see how the core is changing dimensionally form rod to rod. This is only representative of one of the ten cases. Each case would show that the rods are different based on each case, as each case would have its own unique rod variation.

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S.Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.
SAND No. 20XX-XXXX.

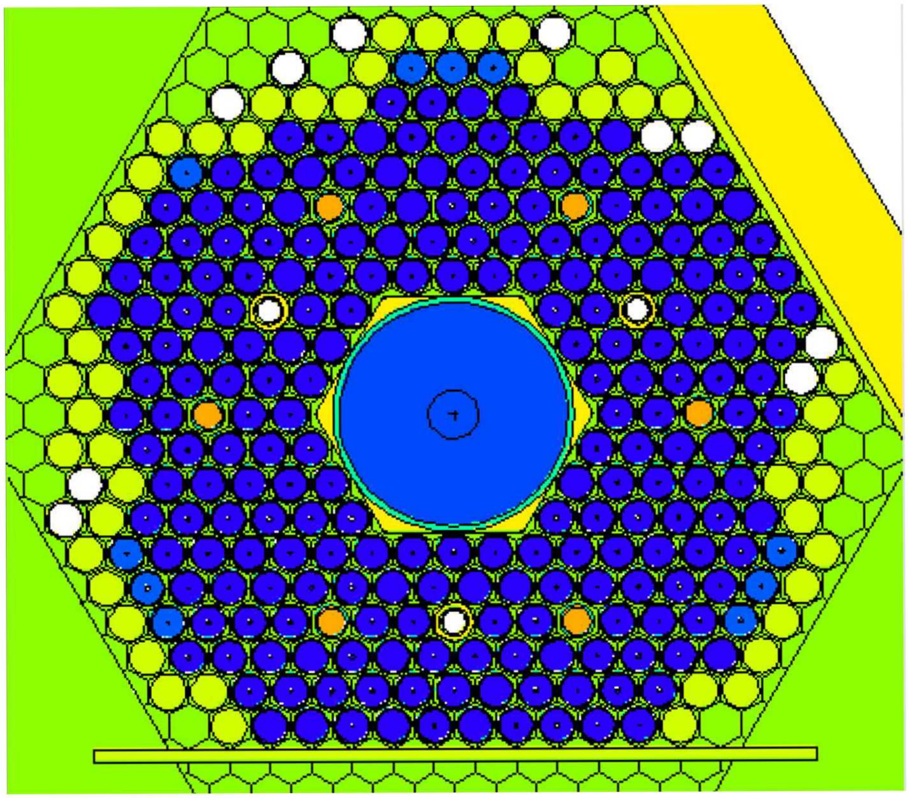

Figure 1: ACRR core Random Dimensions and Densities

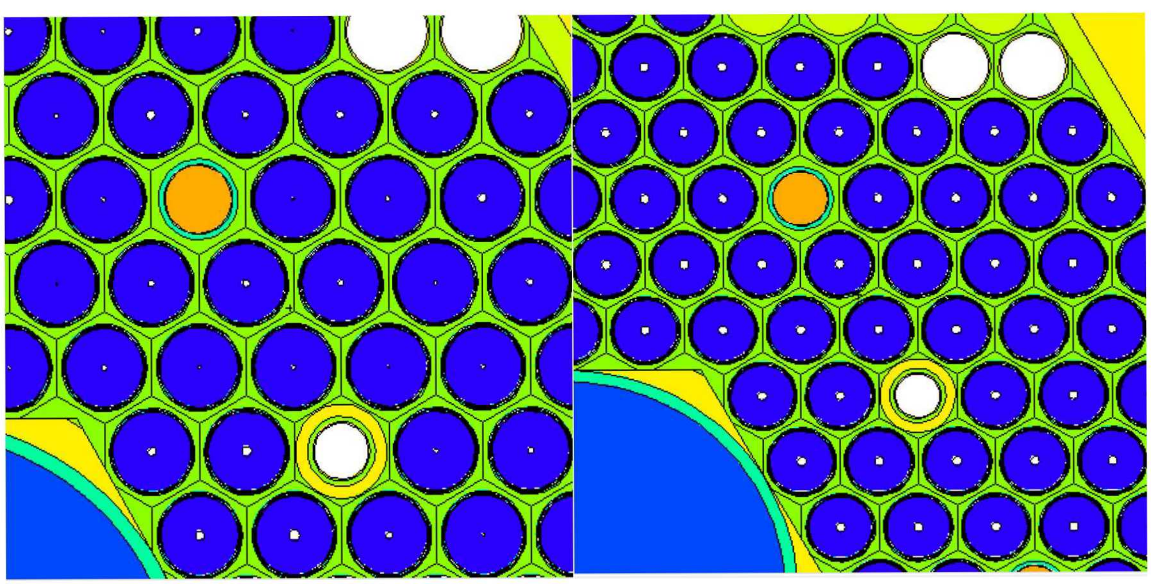

Figure 2: Comparison Random ACRR Core vs Original

The 640-group data from the runs were extracted and evaluated using excel. The fluence was plotted on a log-linear plot to clearly see results. The below fluence graphs show that the main shape of the fluence graph is consistent for all 10 cases, however there is a large amount of fluctuation from case to case. The fluctuation is better visualized in the thermal region graphed in Figure 4. These results show that the complete random variations in the core does cause the system to vary slightly form case to case.

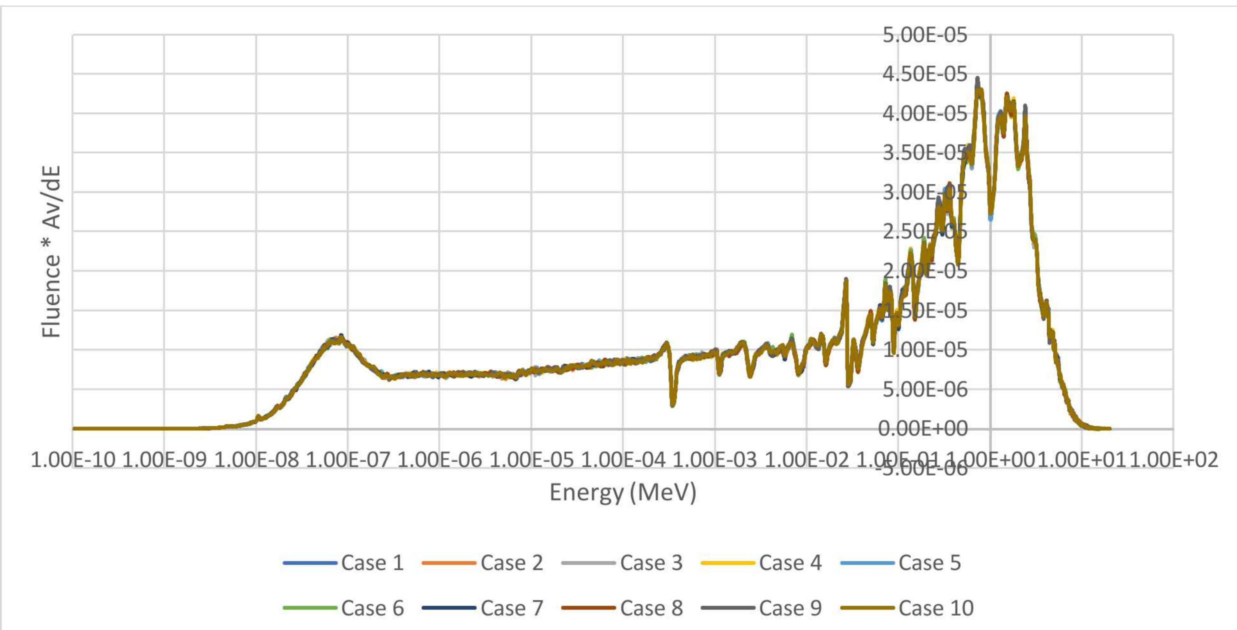

Figure 3: 640 Group Fluence Graph

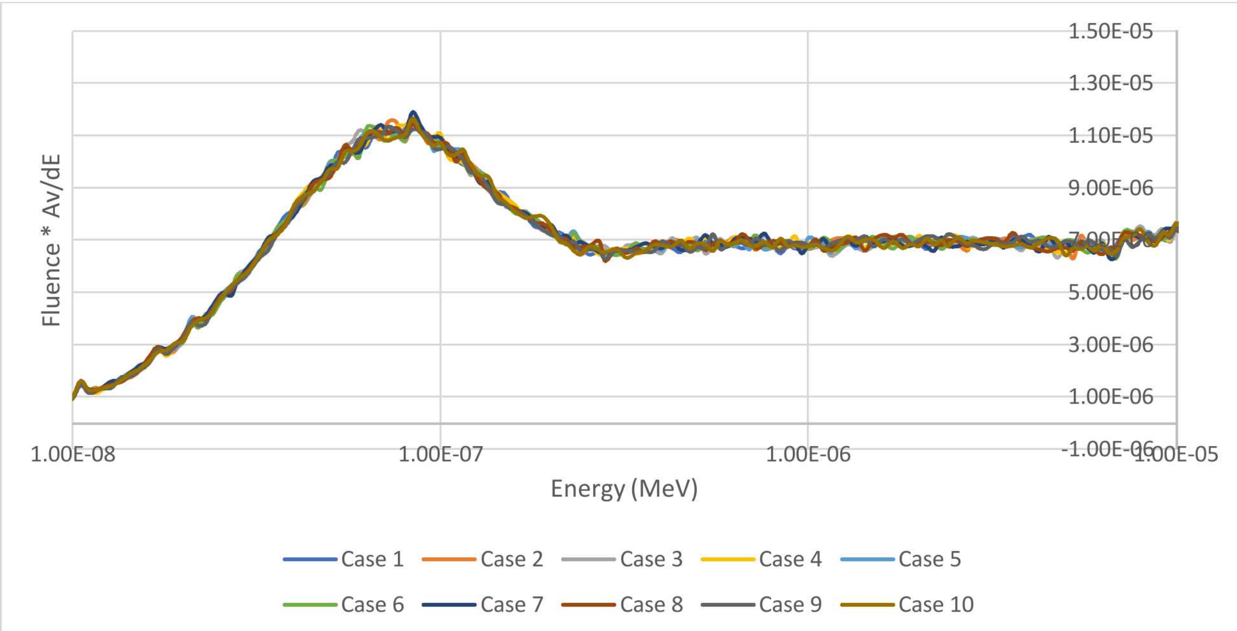

Figure 4: Thermal Region Fluence Graph

The results in this report show a promise for future work. As this was only a small portion of a larger project the results help to show that the system is indeed very random. The results help to prove that this is a good path to take for the end goal of finding the uncertainties within the ACRR core using random sampling. It is important to note that ten cases are only a very small portion of the number of cases that will be studied in the future. Moving on from here over two hundred plus cases will be studied and evaluated.