Monte Carlo Methods and Simulations in Nuclear Technology

Home Assignment 07

BY: FAISAL AHMED MOSHIUR
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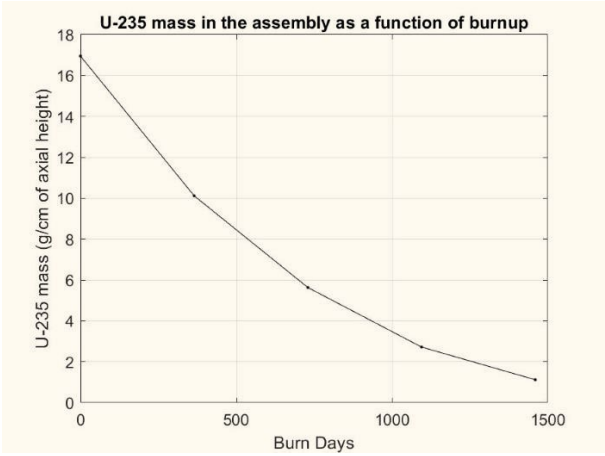
Introduction:

Nuclear fuel burnup simulations are essential for designing, optimizing, and predicting the performance of nuclear reactors. The burnup calculation estimates the changes in the isotopic composition of fuel over time due to fission and neutron capture. A burnup simulation is typically performed using Monte Carlo methods, which involve random sampling of neutron histories and tracking their interactions with the fuel assembly to predict the isotopic evolution.

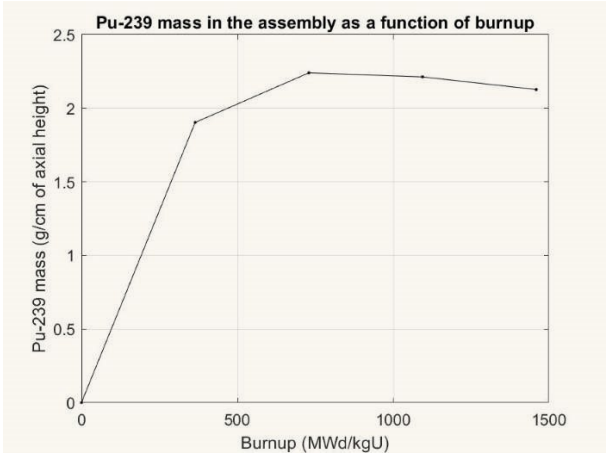
This report presents a burnup simulation procedure using the SERPENT Monte Carlo code. We choose a fuel assembly model from the SERPENT examples and extend it with cards for a burnup simulation. We specify the power appropriate for the fuel assembly and the total depletion time of 4 years, ensuring that all burnable materials are depleted. We then run a Monte Carlo burnup simulation with our input file, ensuring sufficient statistics by simulating at least a couple of CPU hours.

To test the sensitivity of the simulation results to the time step length, we repeat the simulation with various time step lengths. We then plot the time evolution of the k_{eff}, as well as the atomic concentration of ^{235}U and ^{239}Pu and compare the results among the test cases. This procedure will help us better understand the isotopic evolution of the fuel assembly over time and the sensitivity of the simulation results to the time step length. The graphs from the tasks are shown on the following pages.

Graphs:



(a)



(b)

Fig-1: Plots of (a)U235 and (b)Pu-239 in assembly as a function of burnup.

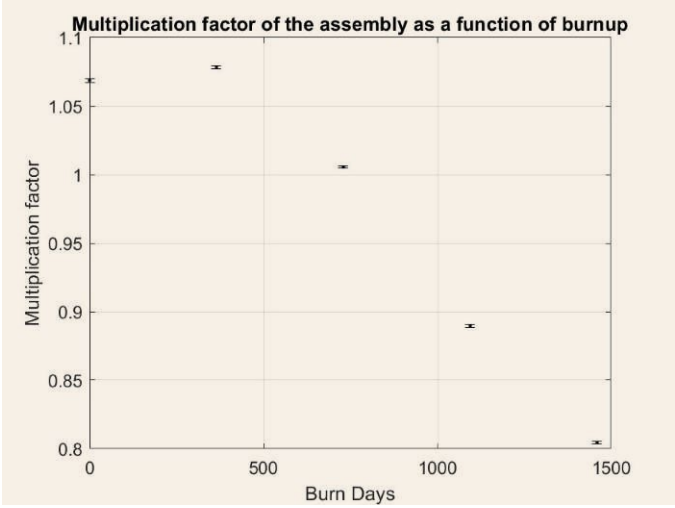


Fig-2: Plot of K_{eff} against burnup step sizes

Discussions:

In conclusion, in a Serpent Monte Carlo simulation, the day step of burnup determines the number of days over which the depletion calculation is performed. The choice of the day step size affects the accuracy and computational efficiency of the simulation. When the day step size is reduced, the simulation becomes more accurate, but at the cost of increased computational time. Conversely, a more significant day step size decreases computational time but can lead to decreased accuracy. The effective multiplication factor and atomic concentration of isotopes such as Uranium-235 and Plutonium-239 are affected by the day step size, with smaller day step sizes generally resulting in higher accuracy and more precise results. However, the appropriate day step size should be chosen based on a balance between accuracy and computational efficiency.

Reference:

[1] Jaakko Leppänen. *Serpent –a Continuous-energy Monte Carlo Reactor Physics Burnup Calculation Code. User's Manual.*

[2] http://serpent.vtt.fi/mediawiki/index.php/Main_Page

[3] Simulation is carried out in **Serpent** and plots are done on **Matlab**.