Pebble Bed Reactor Neutronics and Isotopic Analysis During Lifetime of a Pebble

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Pebble Bed Reactors (PBRs) are advanced nuclear reactors that will potentially be built more frequently in the USA and the world starting in the 2030's (although some countries have already built earlier PBR designs). Due to the significantly different fuel design of PBRs from traditional light water reactors, nuclear material accountancy will be challenging. This study focused on the burnup calculations of the pebble(s) in a gas cooled PBR. MCNP is used to model X-energy's Xe-100 PBR, which has a designed thermal power of 200 MW (909 W per pebble). The pebble burnup simulations were carried out by setting a total burn time of 1304 days at full power followed by 30 days of decay. The purpose of these simulations is to compare the neutron multiplication behaviors of an infinitely large lattice of a face-centered cubic (FCC) pebble model to the single pebble model. Not only are these two geometries compared, but heterogeneous and homogeneous versions of these models are also compared. The preliminary simulation results (See Fig. 1 below) indicate that the FCC pebble model is statistically equivalent in terms of k-infinity to the single pebble model. The uranium and plutonium content analyses are in progress. However, the k-infinity for the heterogeneous and homogeneous models were noted to vary at different rates along with the burnup. In fact, this phenomenon has been noticed frequently with burnup simulations. One hypothesis is that ^{239}Pu production is higher for the pebble that burns slower. This increase in ^{239}Pu production increases the k-infinity because more fissile material is being produced than the pebble model with a high k-infinity. The second hypothesis is that the pebbles with lower k-infinity have their fissile material more diluted. With a higher diluted fissile material, the neutrons can thermalize more frequently and cause more fissions in the fuel. Over time, this effect could add up allowing for fewer non-fission reactions.

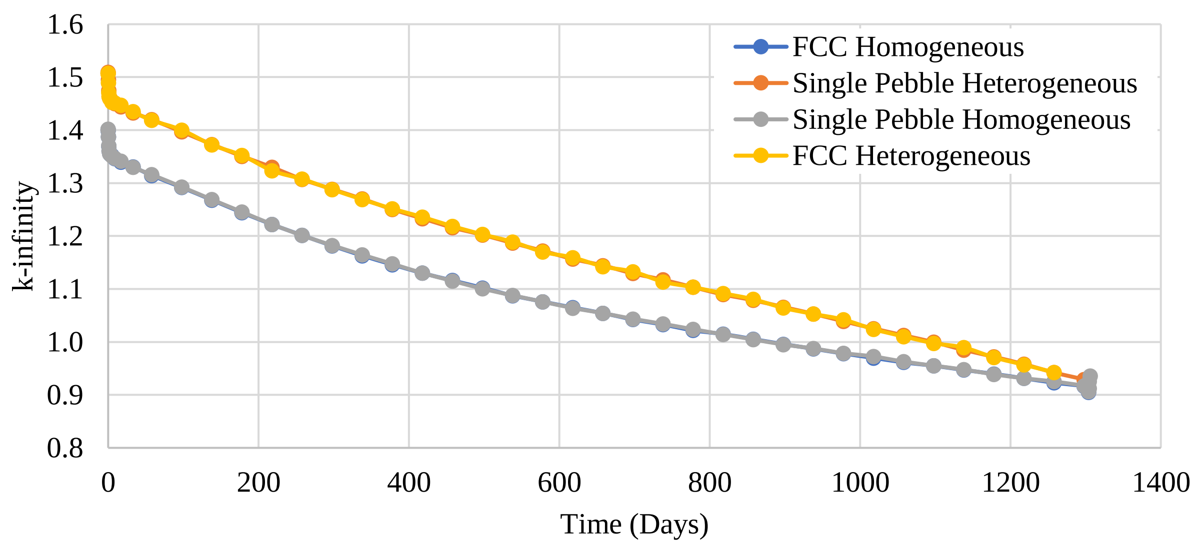

Figure 1. Plots of k-infinity as a function of irradiation time. Note that the data of the single pebble and FCC overlap due to statistically similar values.