Functionality Isolation Test for Fuel Cycle Code ORION - MOX Fabrication and Depletion

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This paper outlines Functionality Isolation Test (FIT) results for the Nuclear Fuel Cycle (NFC) simulation code ORION [1]. The FIT is a global effort in the NFC code developer community to communicate and improve confidence in the calculations in the NFC codes. FIT tests individual functions to facilitate relevant, detailed comparisons between codes.

In this FIT, we characterize ORION simulation of Mixed Oxide Fuel (MOX) fabrication and depletion. In the test case, two streams, a plutonium stream and a depleted uranium stream, are fabricated into MOX fuel, which is then depleted in the reactor model. We vary the plutonium vector of the incoming plutonium stream to observe differences in total plutonium content in the MOX fuel, as well as variations in depletion calculation results.

ORION [1] is a systems dynamics analysis tool developed and maintained at U.K. National Nuclear Laboratory (NNL). It can simulate the full range of nuclear-related facilities, including storage, fabrication, enrichment, and reprocessing facilities, as well as reactors. The facilities are connected in a flow diagram to form a fuel cycle model, where the facilities are modeled as fleets. The code tracks over 2,500 nuclides, and it models decay and in-reactor irradiation of fuel.

ORION's in-reactor depletion calculations are performed using either cross sections or recipes. Prior to an ORION analysis, detailed lattice physics calculations are completed to generate burnup-dependent cross section libraries. The cross sections can be generated using reactor physics models such as SCALE. Standalone utility codes called SCORI and FISOR were developed and used to reformat the one-group cross sections from SCALE into an ORION burnup-dependent cross section library format, thus loosely coupling SCALE to ORION.

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These libraries are used in an ORION calculation using the MEEMS Pseudo Reactor (MPR) mode. The MPR mode depletes the fuel by calculating the flux at a user-defined power density using quadratic interpolation, then solving the Bateman equations using the cross sections from the library.

When assuming simple fixed-fraction fuel fabrication and a recipe fuel depletion model, a perturbation in the plutonium vector of a plutonium supply will not cause any change in plutonium concentrations in fuel manufactured from that supply, since the model does not 'see' the different fissile worth of different plutonium isotopes. On the other hand, a more complex fuel fabrication and fuel depletion model would change its fresh fuel plutonium concentration and depleted fuel composition depending on the plutonium vector in the source plutonium stream.

This work shows that NFCs that involve constant recycling of used fuel require more complex methods than simple recipe methods to model fuel fabrication and fuel depletion. The fixed fraction method for fuel fabrication and recipe depletion method do not take into account the dynamic changes in plutonium stream quality caused by multi-stage depletion and recycling.

References

[1] R. GREGG and K. HESKETH, "The benefits of a fast reactor closed fuel cycle in the UK," American Nuclear Society - ANS; La Grange Park (United States) (2013).