Comparison of urania and thoria fuels under light water reactor conditions and investigation of fracture/relocation behavior using the BISON fuel performance code

R.T. Sweet[a], B.D. Wirth[a,b]
[a]Univ. of Tennessee
[b]Oak Ridge National Laboratory

Thoria (ThO_2) fuel has been previously used in light water reactors (LWRs), and due to its relative abundance, is viewed as a potential alternative fuel to urania (UO_2) for light water reactors. ThO_2 possesses a number of attractive material properties which may demonstrate improved in-reactor performance compared to urania. Thoria fuel has greater thermal conductivity, a higher melting temperature, and a lower coefficient of thermal expansion than UO_2. This results in a reduced temperature gradient radially across the fuel pellet, a reduction in thermally-activated phenomena, and reduced thermally-induced expansion of the fuel, respectively. Although these benefits diminish as the uranium concentration increases during neutron irradiation, thorium dioxide is expected to perform much better early in life than its UO_2 counterpart.

Fuel fracture and relocation play an important part of the thermo-mechanical evolution of nuclear fuel by affecting the fuel-cladding gap distance, which subsequently alters the heat transfer across the gap. With a decreased temperature gradient across the fuel pellet and lower coefficient of thermal expansion, ThO_2 is expected to experience reduced fracture due to thermally-induced stresses and an increased linear heat rate where fracture occurs.

For this analysis, thermal and mechanical properties of the thoria fuel have been implemented into the BISON fuel performance code. Because of their chemical similarities and a lack of thorough experimental data, data gaps in some ThO_2 constitutive models have been addressed by incorporating similar trends and mechanisms to UO_2. Simulations of both UO_2 and ThO_2 have been performed to identify integral performance differences between the fuels under irradiation in a typical PWR environment. An additional analysis of the fracture/relocation behavior during rise to power has also been performed to identify the severity and onset of cracking during the initial rise to operating power.