



Burn-up calculation of the neutronic and safety parameters of thorium-uranium mixed oxide fuel cycle in a Westinghouse small modular reactor

Edwin H. Uguru^{1,2}  | Siti F. Abdul Sani¹ | Mayeen U. Khandaker³ |
Mohamad H. Rabir⁴  | Julia A. Karim⁴ | Daniel U. Onah² | David A. Bradley^{3,5}

¹Department of Physics, University of Malaya, Kuala Lumpur, Malaysia

²Department of Industrial Physics, Ebonyi State University, Abakaliki, Nigeria

³Centre for Biomedical Physics, School of Healthcare and Medical Sciences, Sunway University, Bandar Sunway, Malaysia

⁴Nuclear and Reactor Physics Section, Nuclear Technology Center, Technical Support Division, Malaysian Nuclear Agency, Kajang, Malaysia

⁵Centre for Nuclear and Radiation Physics (CNRP), Department of Physics, University of Surrey, Guildford, UK

Correspondence

Edwin H. Uguru and Siti F. Abdul Sani, Department of Physics, University of Malaya, Kuala Lumpur 50603, Malaysia. Email: ugurueddy2008@yahoo.com (E.H. Uguru) and s.fairus@um.edu.my (S.F.A. Sani)

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Summary

Thorium fuel is presently a globally known future nuclear fuel alternative, having good neutronic, physical and chemical properties in addition to its spent nuclear fuel characteristic proliferation resistance. This research focused on the neutronic and safety parameters of thorium-uranium mixed oxide fuel cycle, utilising three fissile enrichment zones, a departure from the conventional single enrichment. The aim was to determine the range of three fissile zones adequate for thorium-uranium fuel cycle; investigating the performance efficiency of the fuel neutronic and inherent safety parameters in response to temperature differentials, which determines the viability of the fuel and core composition. Use was made of the MCNPX 2.7 code integrated with the CINDER90 fuel depletion code for steady-state and burn-up calculations. The k_{eff} , moderator temperature coefficient (MTC) and fuel temperature coefficient (FTC) of reactivity are affected by the range of fissile enrichment and fuel temperature which decreased with their respective increases. The MTC for all the moderator temperatures was within 0 to -40 pcm/K design value for UO_2 fuel. Similarly, the FTC was within -3.5 to -1 pcm/K design value for all the fuel temperatures except after 2000 days, where a positive reactivity feedback was introduced. At ~ 86 MWd/kgHM single discharge burn-up, the result shows that $\sim 90\%$ of the initial fissile load was utilised for energy production at the normal reactor operating temperature (600 K) with a slight reduction at higher fuel temperature. The total fissile inventory ratio (FIR), $^{233}\text{U}/\text{kg}$ - ^{232}Th and $^{239}\text{Pu}/\text{kg}$ - ^{238}U inventory ratios were significantly large and increased with burn-up. It is remarkable that the FIR and the $^{233}\text{U}/\text{kg}$ - ^{232}Th inventory ratio did not reach conversion equilibrium until exit burn-up. The large percentage fuel utilisation supports the advantage of fissile enrichment zoning in a thermal nuclear reactor core, making the chosen novel three fissile enrichment zones for thorium-uranium fuel cycle reliable.

KEYWORDS

coefficient of reactivity, fissile enrichment zones, neutronic, safety parameters, small modular reactor, thorium fuel cycle