NEUTRONIC ANALYSIS OF ACCIDENT TOLERANT FUEL CONCEPTS IN SPECTRAL SHIFT REGULATION CONDITIONS

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The study of Accident Tolerant Fuels (ATFs) has gained significant attention due to their potential to enhance the safety and reliability of nuclear reactors, especially under severe accident conditions. This work investigates the neutron-physical performance of ATF concepts in Light Water Reactor (LWR) using spectral shift regulation (SSR). The SSR mechanism, which adjusts the moderator-to-fuel ratio, by means of mechanical displacers that run in the guide tubes, enables spectral hardening during the initial cycle and softening toward the end, optimizing fuel utilization and reactor safety. Using collision probability method with the GETERA simulation tool, this study evaluates various ATF designs, including chromium-coated zirconium (CrZry), FeCrAl alloys, and SiC composites, combined with uranium silicide (U3Si2) and uranium nitride (UN) fuels. Key metrics such as neutron economy, isotopic composiotion, and fuel burn-up efficiency were analyzed. Results demonstrate that SiC cladding paired with UO2 or U3Si2 fuels offers superior neutronic characteristics, requiring slightly lower uranium enrichment. Conversely, thin FeCrAl claddings showed higher enrichment needs but still around enrichment level of the fuel in Light Water Reactors, when paired with combination with U3Si2, and it has improved resilience against high-temperature oxidation. The integration of SSR in the LWR reactor enhanced burn-up efficiency while burning produced plutonium and reduced waste, resulting in lower natural uranium consumption. Among the ATF options studied, SiC materials showed exceptional promise for guide tube and displacer applications, owing to their neutron transparency and thermal stability. This research emphasizes the synergistic benefits of combining ATFs with SSR strategies, aligning with the European Green Deal's objectives of promoting sustainable and innovative nuclear technologies. Future work will focus on integrating multi-physics reactor level simulations with different tools to further evaluate fuel performance under dynamic operational scenarios.

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