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FTP/P7-04: A Feasibility Study on a Clean Power Fusion Fission Hybrid Reactor

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In this paper, a design concept of fusion-fission hybrid reactor for the purpose of high level radioactive waste transmutation was investigated. A concept of fusion based trans-uranium isotope (TRU) burner reactor (FTBR) was based on a low power tokamak (150 MW max) and annular ring shaped TRU core with metallic fuel (TRU 60 w/o, Zr 40 w/o) and adjacent fission product (FP) zone. Composition data for TRU and FP are assumed to be the same with those in spent fuel from 1,000 MWe PWR with 10 years decay cooling. Calculation for blanket part were performed using MCNP-X 2.6. Irradiation (burn) cycle was chosen to be 1,100 days (3 years). The power level of TRU core was set to be 2,000 MW and k-eff at BOC was calculated as 0.97979 and at EOC 0.85049. Calculated TBR value was 1.49 representing a self-sufficiency of fusion fuel.
TRU burning was analyzed by calculating TRU mass burned per full power year (MTRU/fpy), support ratio (SR) and percentage of TRU mass burned per year (%TRU/fpy). Same parameters were also used to analyze the FP transmutation. To account for the FP produced in TRU core the net MFP/fpy and net %FP/fpy was also calculated. For toxicity analysis of long lived TRU and FP the percentage reduction of long lived inhalation toxicity (LLIhT) and long lived ingestion toxicity (LLIgT) were also calculated.
MTRU/fpy was 747.11 kg with 14.25 MT of initial TRU mass loading, %TRU/fpy was 5.24% and SR was 2.24. FP mass produced in TRU core per fpy was 162.25 kg. LLIhT and LLIgT of TRU's were reduced by 9% and 6% respectively over the burn cycle. FP depletion calculations were performed for two different thicknesses of FP zone 30 cm and 50 cm to evaluate the FP loading effect on FP transmutation performance.
TRU transmutation performance of FTBR was also compared with Subcritical Advance Burner Reactor (SABR) design. The comparison showed good TRU transmutation performance of FTBR with a small scaled fusion facility but it still can be improved by utilizing two or three batch fuel cycle configurations and modeling the TRU core in detailed geometry. This preliminary study shows that a clean plant concept has a good potential for waste transmutation.

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