Technical area 8: Molten Salt Reactors
Technical area 9: Accelerator Driven Systems

OPTIMIZATION OF CONCEPTUAL DESIGN OF CASCADE SUBCRITICAL MOLTEN SALT REACTOR

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The concept of the future nuclear power with closed fuel cycle based on reactors of different types and purposes is extensively developed in Russian Research Center "Kurchatov Institute" during last decades. According to this concept, the problems of burning of minor actinides (MA), transmutation of some long-lived fission products (FP) and plutonium utilization can be solved with the help of homogeneous molten-salt reactors-burners (MSR). Both critical MSR and subcritical MSR, driven by accelerator, are currently considered.

Fluoride-based molten salts seem the most perspective solvents for fuel composition of MSRs, when they are a part of closed fuel cycle with non-aqueous reprocessing of spent fuel of traditional solid fuel fast and thermal reactors. The solubility of fuel fraction in the considered fluoride salts is limited by about one mole percent. In case of critical MSR, the MA amount is limited by plutonium fraction, necessary to provide reactor criticality. In subcritical systems small value of $k_\infty$of fuel composition based on MA without adding extra plutonium is compensated by the external neutron source. Thus, subcritical reactor systems can be considered as more efficient 'burners' of radwastes. Moreover, the external neutron source enhances MSR safety providing a prompt reactivity control tool.

Concept of the Cascade Subcritical Molten Salt Reactor (CSMSR) is suggested to reduce demands to accelerator power in accelerator-driven MSR, improving economical efficiency. The basic advantage of the cascade neutron multiplication is that for the same subcriticality and power levels CSMSR requires less intensity of external neutron source (less accelerator power) compared to homogeneous subcritical MSR (HSMSR).

The proposed CSMSR core consists of two coaxial homogeneous zones: the central zone with molten salt fuel composition, providing fast-resonance neutron spectrum and k_∞ >1 and the main transmutation zone with resonance-thermal spectrum and k_∞<1. The central zone has small volume and serves for the neutron source amplification. The external neutrons are born in the central zone as a result of spallation of high-energy protons on the nuclei of proton target and/or molten-salt fuel composition. Then, the number of external neutrons is multiplied due to fissions in the central zone with high value of k_∞. As a result of scattering, these neutrons enter the main zone of transmutation. Absorber of thermal neutrons is dissolved in the salt of the central zone to decrease fissions by thermal neutrons returned into the central zone after moderation in the transmutation zone. That allows to reduce the power peaking factors on the boundary of two CSMSR zones and to reduce the k_{eff} value in case of failure of the tube, separating two zones.

To obtain advantages of the cascade scheme CSMSR design become more complex than HSMSR one. In addition to problems common with HSMSR (transport of precursors of delayed neutrons, proton target cooling, optimization of beam window design, etc.), CSMSR has the following specific problems and limitations:

- need in organization of additional circuit for cooling the central zone;
- decrease of average neutron flux in the CSMSR transmutation zone compared to HSMSR of the same power and subcriticality level;
- high power peaking factors and respectively high power density in the central zone;
- high neutron and proton fluences on the tube, separating two CSMSR zones, etc.

Some analysis on CSMSR possible design optimization of such reactor parameters as neutron cascade multiplication efficiency, average neutron flux in the transmutation zone, power peaking factors, neutron fluence on structural materials, etc are presented in the paper.