

Analysis of Minor Actinides Incineration Adopting an Innovative Fast Reactor Concept

B.Vezzoni¹, F.Gabrielli¹, A. Rineiski¹, M. Marchetti¹, W.Maschek¹, M.Salvatores¹, A.Schwenk-Ferrero¹, V.Romanello¹, G.Forasassi²

¹ Karlsruhe Institute of Technology (KIT), Germany.

² University of Pisa (UNIP), Italy.

Abstract

For the long term nuclear energy sustainability, the transition to a fast reactor (FRs) based fleet and the adoption of closed fuel cycles is envisaged for answering both for resources optimization and waste reduction.

The fuel cycle actually implemented is a once-through cycle based on uranium consuming reactors with thermal spectrum. In this cycle, only ~1% of the uranium extracted is used and the spent fuel is sent to disposal without reusing the fissile material (e.g. Pu239). This leads to a high demand on disposal capacities in terms of masses, radiotoxicity and heat load.

Due to specific features of fast spectrum reactors, fuels containing a fraction of Minor Actinides (MAs) can be loaded into their cores and closed (or partially closed) fuel cycles can be implemented thus providing an option for MAs transmutation. However, advantages in sustainability should not lead to a lower safety level.

Within the Collaborative Project on European Sodium Fast Reactor, CP-ESFR, reference designs for cores with oxide and carbide fuels were proposed by CEA (France). Both systems show a positive Sodium Void Reactivity Effect (SVRE) at BOL.

In the present paper, the optimization process followed for reducing the BOL SVRE is described. Only the oxide core has been considered. The main modifications are related to the axial structure by introducing a larger Na plenum (60 cm) close to the core, an absorber layer above and a lower fertile blanket. All together these attempts allow improving neutron leakages under voided conditions and therefore reducing the SVRE. In the paper, we refer to the optimized configuration as CONF2.

The low SVRE in CONF2 (about 2\$ less than the reference configuration) offers an opportunity for introduction of MAs in core. Heterogeneous and homogeneous strategies have been considered within the CP-ESFR project.

In the present paper, we focus only on homogenous loadings considering the introduction of 2 and 4%wt. AmO₂ in core plus lower blanket. The results in terms of safety and fuel cycle characteristics have been compared.

The introduction of MAs implies the deterioration of safety parameters (void, Doppler, etc.) but allows the core burning its own waste.

The advantages of Am loading in terms of fuel cycle have been evaluated considering the impact on fuel cycle facilities, fuel composition evolution, radiotoxicity and heat load.

In order to assess these parameters, a simplified reference scenario representative of a country that wants to develop nuclear energy in isolation has been selected. A constant nuclear energy production in the period 2020-2200 has been defined to better underline the parameters affecting the dynamic of the transition from Light Water Reactors (LWRs) to FRs.

Only Pu and MAs actinides produced in the cycle have been considered focusing on the characteristics of the reactor in transmuting its own waste by reaching an equilibrium composition.

Neutronic analyses have been performed by means of the deterministic ERANOS code systems using JEFF3.1 data library and scenarios mentioned above have been modelled with the COSI6 code, the dynamic scenario code developed at CEA (France), widely used in Europe.