DESIGN OF B_4C BURNABLE PARTICLE MIXED IN LEU FUEL FOR HTRS

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Abstract

During the operation of a nuclear reactor, the reactivity loss due to fuel burnup and fission products poisoning must be compensated by some means of long-term reactivity control. One way for such a control is the use of burnable poison (BP) in the fuel elements. In this way, it is possible to balance the reactivity loss by the reactivity gain due to the disappearance of the burnable poison.

In this study we focus on heterogeneous poisoning, in which burnable particles (TRISO coated particles containing only burnable poison) are being mixed with the fuel particles in the graphite matrix. Because of the many degrees of freedom, the correct dimensioning of the burnable particle and the ratio of the number of burnable particles and fuel particles is not straightforward. Previous introductory studies have already shown the feasibility of this approach [Van Dam, Annals of Nuclear Energy 25 and 27, 1998 and 2000]. Therefore, in this study, the emphasis will be put to the optimization of the geometry, the size and the composition of the burnable particle and to the optimal ratio of burnable particles and fuel particles.

For the reactor type considered first, the ESKOM PMBR has been chosen with an average core power density of 3 $MW.m^{-3}$. The fuel particles contain 8% enriched UO_2 with a uranium mass per pebble of 9 grams. One pebble contains more than 13,000 coated particles, each with a diameter of 0.92 mm. The chosen burnable poison (B_4C with either natural boron or 100% enriched B^{10}) has a high thermal absorption cross section, with an absorption-to-scattering ratio of more than 1000. Consequently, the burnable particle is “black” for thermal neutron, i.e. every neutron hitting its surface is absorbed.

Numerous parametrical studies have been carried out in order to find the flattest reactivity-to-time curve. The BP geometry can be spherical or cylindrical, the diameter of the BP can vary (the larger particle, the longer it will take before it is fully burned), and also, different boron composition (natural boron or boron enriched in boron 10) have been investigated. All these design parameters of the particles provide much flexibility in selecting the BP and in tailoring the excess reactivity of a reactor as a function of burnup.

Different results could be showed for both spherical and cylindrical BP. The following graph shows the evolution of the reactivity as a function of the burn up, for one studied case: cylindrical burnable particles are considered, with a diameter of 0.92 mm; they consist in B_4C

with enriched boron (100% of B^{10}). The volume ratio between the fuel zone and the burnable particle is taken as a parameter. The case with a ratio of 10 300 leads to a reactivity swing of only 2.2% up to 1600 Equivalent Full Power Days. At this time, the BP is fully burn.