DESIGN OF B$_4$C BURNABLE PARTICLES MIXED IN LEU FUEL FOR HTRS

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Abstract

The purpose of this study is to design burnable particles in the fuel elements of High Temperature Reactors (HTR) in order to control reactivity as a function of burn up. We focus on heterogeneous poisoning in which burnable particles (particles containing only burnable poison) are mixed with fuel particles in a graphite matrix. There are many degrees of freedom in the design of the burnable particle and the emphasis is put here on the optimization of its geometry (spherical or cylindrical), its size (different radius), and its composition (B$_4$C with either natural boron or 100% enriched in $^{10}$B). As a result, we have designed burnable particles that reduce considerably the reactivity swing during irradiation (up to 2.5%).

Introduction

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

With homogeneous poisoning it seems impossible to obtain a flat reactivity curve as a function of burnup [1]. More promising is heterogeneous poisoning, in which burnable particles (particles containing only burnable poison) are being mixed with the fuel particles in the graphite matrix. Because of the many degrees of freedom, correct dimensioning of the burnable particles and the ratio of burnable particles and fuel particles is not straightforward. In this study, the emphasis is put on optimization of the geometry, size and composition of the burnable particle as well as on the optimal ratio of burnable particles and fuel particles, in order to minimize the reactivity swing as a function of irradiation time.

The first part of this paper presents the description of the fuel and the burnable particles as well as the computational model. The second part shows the calculations for two different geometries: spherical and cylindrical.

Computational Model and Reactor Type

Computational Model