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Evaluation of Carbon Dioxide Concentration Profile around a Coated Particle Fuel Kernel

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1. Introduction

Coated particle nuclear fuels have been attracted attention for their application of a high temperature gas cooled reactor for hydrogen production[1,2]. The coated fuel consists of three types of graphite layers and one silicon carbide layer on the spherical uranium oxide or uranium carbide fuel. In case of tri-isotropic (TRISO) coated fuel particles, the layers are low-density, porous pyrolytic carbon (PyC) buffer layer adjacent to the spherical uranium oxide fuel kernel, followed by an isotropic inner PyC layer, a silicon carbide layer and dense outer PyC layer. One of the problems of the coated uranium oxide fuel under the irradiation condition is so called "Amoeba Effect", which is the phenomenon occurring by the unidirectional movement of particle fuel kernel and eventually causing destruction of coated fuel[3,4]. There is a number of numerical modeling describing this phenomenon. However, most of their study have been oriented to the failure probability of the coated fuel on the viewpoint of physics, nuclear engineering and mechanical engineering. Hence, simple numerical approach was carried out to describe a process occurred in the "Amoeba Effect". Emphasis is on the concentration profile of carbon dioxide gas around a fuel kernel.

2. Numerical Approach

Fig. 1 is a typical cross section of a coated particle fuel, which shows fuel kernel, buffer PyC, inner PyC, SiC and outer PyC layers. Average thicknesses of the coated layers are 95, 25, 30 and 28 μm, respectively.

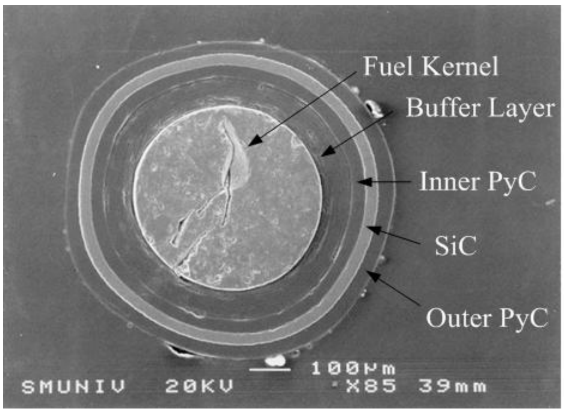

Fig. 1. Cross Sectional View of Coated Fuel [2]

Fig. 2 is schematic diagram of oxygen flow occurring in coated particle fuel[2]. As shown in this figure, the oxygen reacts with carbon to produce carbon monoxide which is decomposed by radiolysis and carbon dioxide which migrates through porous buffer layer. This model assumes that oxygen diffusion in the UO_2 kernel is the rate controlling mechanism. That is, the oxidation/reduction of C, CO, and CO_2, and also the flow of CO and CO_2 through the buffer PyC are so fast that the migration of the kernel depends on how fast the oxygen ions diffuse from the cold to the hot side within the kernel. Density of the carbon dioxide does not change due to the chemical reaction in the buffer, whose transport is mainly driven by convection. Additional assumption is that the flow pattern through the porous buffer layer around kernel is resolved using Navier-Stokes and continuity equation [5]. The equation of motion and the mass balance equations were coupled to solve the concentration profile from hot region to cold region. Boundary conditions were defined from the assumption of symmetry at the lateral boundaries and from the direction of the gas flow from cold side to hot side.

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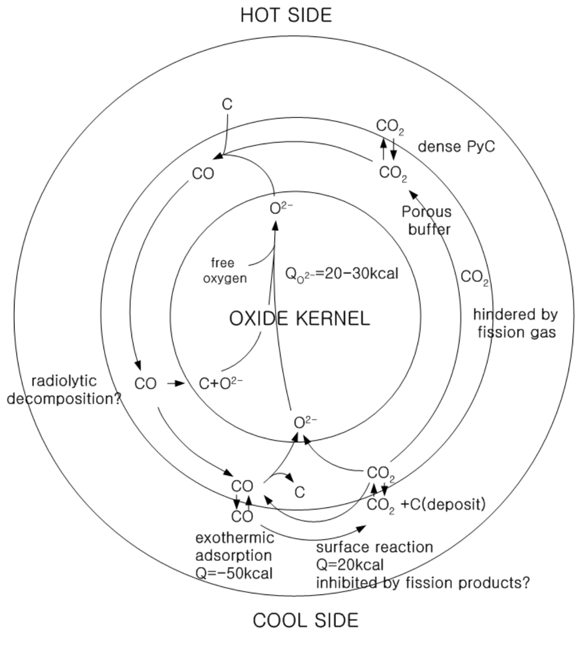
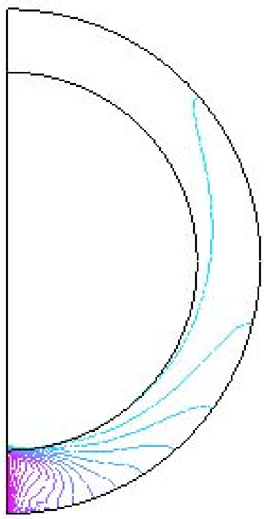


Fig. 2. Oxygen Flow Model in a Coated Fuel [3]

Fig. 3 is the concentration profile of carbon dioxide around kernel, which shows a non-symmetrical concentration distribution along the outer surface of kernel. The concentration is far thinner than behind the kernel. Depletion of the carbon dioxide gas along the direction form cold region to hot region exists.

Hot region



Cold region

Fig. 3. Concentration Profile of Carbon Dioxide Gas around Kernel

3. Summary

Concentration profile of carbon dioxide around kernel during fuel migration was evaluated to describe "Ameboa behavior" with various assumption based on so-called "Oxyen flow model" reported by Dragon Project. A non-symmetrical concentration distribution along the outer surface of kernel can exist in which the carbon dioxide gas becomes depleted along the direction from cold region to hot region.

Acknowledgements

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