Fabrication of CSBA-loaded UO_2 Fuel Pellets for HANARO Irradiation Test

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1. Introduction

Burnable poison rods are utilized in modern pressurized light water nuclear reactors to control excess reactivity during the early stages of fuel burnup. These rods consist of burnable absorber(BA) fuel pellets, which are made up of UO_2 fuel and neutron-absorbing elements such as Gadolinium and Erbium with a large neutron absorption cross-section. These elements are uniformly mixed with UO_2 and eventually diffuse into the UO_2 lattice, forming solid solutions.

Recently, to increase economic efficiency and safety in nuclear reactor operation, various promising strategies have emerged. These include using enriched fuels higher than 5% to achieve long-fuel cycle length, flexible operation, and developing small modular reactors with Boron-free operation. The strategies mentioned above commonly require the development of burnable absorber pellets that contain a larger amount of BA, enabling efficient reactivity control [1]. However, doping burnable absorber elements also decreases thermal conductivity due to an increase in phonon-point defect scattering [2], the addition of Gd significantly reduces fuel melting temperature and mechanical strength also.

In order to resolve the issues of conventional BA pellets made of mixed oxide UO_2-Gd_2O_3, KAIST has proposed conceptually innovative BA designs such as the centrally-shielded burnable absorber (CSBA) [3-5]. CSBA is a typical PWR UO_2 pellet loaded with lumped BA in its centerline, which can offer high neutronic flexibility as the geometric volume-to-surface-area ratio of CSBA lumps and their number per pellet dictate the spatial self-shielding effect. Additionally, thermal conductivity degradation of the BA fuel can be minimized, as the gadolinia lump is completely separated from the UO_2 fuel. [3]

In this work, in order to investigate the irradiation effects on CSBA-loaded UO_2 Fuel pellets by HANARO irradiation test, the fuel pellet fabrication was preceded by the preparation of Gd_2O_3 CSBA disks. The fabricated BA fuel pellets were characterized with the dimensional aspects of internal structures, microstructural integrity and the densities of BA disks and UO_2 matrix.

2. Experimental and Result

The irradiation test pellets were fabricated with following steps. Thin CSBA disks were firstly prepared in green form by uniaxial press of Gd_2O_3 powder. Two types of CSBA disks were prepared by varying the density through changes in pressure. The amount of Gd_2O_3 were calculated to meet the expected target density and volume dimensions. An integrated CSBA-UO_2 fuel pellet was fabricated using a specially designed method and a pressing platform. 4.5% enriched UO_2 and CSBA disks were loaded alternately in a mold die and then pressed into a green pellet. The green pellets were sintered at 1730°C for 4 h in a flowing H_2 atmosphere as conventional sintering condition. The sintered densities of BA pellets were determined using an immersion method, the densities of CSBA disks were also evaluated. The microstructures of the sintered pellets were observed using optical microscopy and SEM. CSBA disks were found to be placed in the specified location, and the pellet integrity was found to be sound with minimal defects such as cracks around disks. (see Fig.1) The microstructural properties were satisfied during fuel pellet production. In addition, an investigation of the fuel performance of the BA fuel pellets is also necessary, and a further study is planned to investigate the thermo-physical behaviors of the pellets, as well as the interfacial interaction of UO_2 and Gd_2O_3 [6]

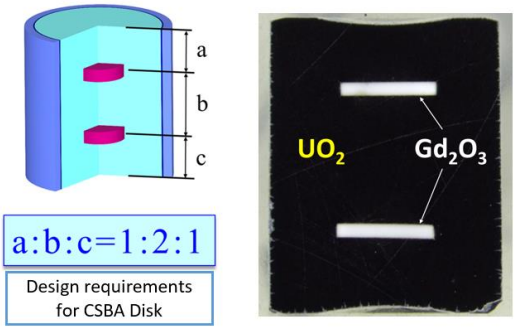

Fig. 1. Schematics of CSBA-loaded UO_2 fuel pellet design and the cross-section of a fabricated BA Pellet.

3. HANARO Irradiation Test

Irradiation tests of the innovative integrated BA fuel rod are planned using in-reactor and post-irradiation testing with the HANARO research reactor at KAERI.

The fuel rods are composed of CSBA-loaded UO_2 fuel pellets and multi-layered claddings, and the irradiation rig of fuel rods, consisting of upper and lower sections, are designed for the evaluation of three

stages of test fuel rods with a single set replacement during the inspection period.

The fabrication of the irradiation capsule is in progress now, after undergoing safety evaluations such as hydraulic testing, irradiation tests will commence. (see Fig.2)

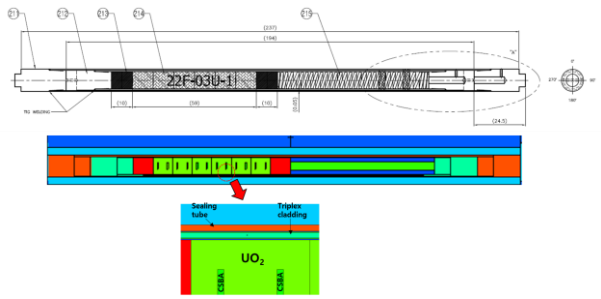

Fig. 2. Schematic illustration model of the irradiation test fuel rod for safety analysis by MCNP6.

4. Summary

In this paper, CSBA-loaded UO_2 fuel pellets were fabricated and investigated the microstructural integrities with process parameters. CSBA disks were found to be successfully placed in fuel matrix as designed, and the pellet integrity was sound. The irradiation tests will start, and thermo-physical investigations of the pellets will be conducted. The experimental results could suggest the possibility of increasing the enrichment of fuels for longer cycles with burnup extension while maintaining safety margins and economic feasibility.

ACKNOWLEDGEMENT

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