Fabrication of Annular Pellet with Minimized Density Increase for Dual Cooled Fuel

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1. Introduction

For a higher burnup and extended cycle, one of the innovative nuclear fuel concepts being developed has a new fuel geometry design that is of an annular sintered pellet, inner and outer cladding, and a dual cooling system which is cooled by both an internal and external coolant (dual cooled fuel) [1].

In the development of the dual cooled fuel concept, a ‘heat split’ behavior of the fuel is one of the issues that must be significantly considered. The heat split is a phenomenon with an unbalanced distribution of heat flux between inner and outer coolant-direction.

If the inner or outer coolant-directional heat flux is unbalanced, a temperature of coolant and cladding can be increased by the excessive heat flux. And then, the fuel integrity and performance can be negatively influenced. In particular, on the temperature increase of coolant and cladding, the excessive heat flux of inner coolant-direction will affects more serious, because the inner coolant channel is narrower than the outer coolant channel [2].

The phenomenon can be occurred by a difference of thermal resistance between inner and outer gap in the dual cooled fuel. The thermal resistances of fuel pellet, gap, fuel cladding can affect to the heat split. However, it can be said that an influence of a thermal resistance of the gap is dominant, because the gap width can be changed by densification and swelling of fuel pellet during a reactor operation.

The dual cooled fuel has two gaps on both sides of the annular pellet. In the densification of the annular pellet, inner gap of fuel will be changed narrower than outer gap of fuel. And then, the thermal resistance of inner gap will decrease lower than that of outer gap. Finally, the heat flux of inner coolant-direction will rise higher, and the temperature of inner coolant and cladding will increase.

Therefore, if an annular sintered pellet with a higher thermal stability can be fabricated, the dual cooled fuel performance in the reactor can be remarkably improved. That is to say, the annular pellet with a minimized dimensional decrease by densification needed.

In this study, an annular sintered pellet with a higher dimensional thermal stability was fabricated. To verify the thermal stability of the fabricated annular pellet, a resintering test was performed [3,4]. The diametric change between the sintered and resintered pellets was analyzed using a precise 3-dimensional measuring system.

2. Experimental

ADU-UO_2 (Ammonium Diuranate) powder was mixed with TiO_2 and TiO_2+CaO powder using a Turbula mixer for 0.5 h, respectively. Also, AZB as a pore former and zinc stearate as a lubricant were added. The powder mixture was compacted using a double acting press, and sintered at 1730 ºC for 4 h in a flowing H_2 atmosphere. The sintered annular pellets were then resintered at 1700 ºC for 24 h in a flowing H_2 atmosphere.

The sintered and resintered densities of the annular pellet were determined using a gas pycnometer (AccuPyc II 1340, Micrometritics), and the dimensions of the annular pellet were measured using a precise 3-dimensional measuring system (VERTEX 230, MicroVu). And a microstructure of the sintered pellet was observed using optical microscopy.

3. Results

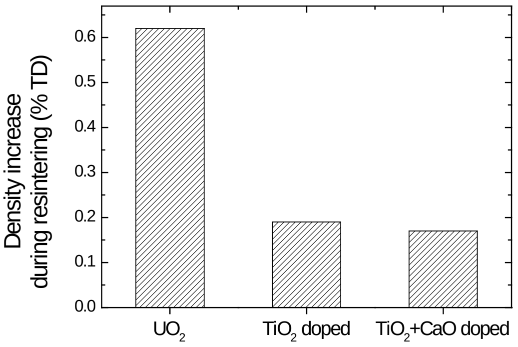

Fig. 1. Comparison of density increase of UO_2 with TiO_2 and TiO_2+CaO doped annular pellet.

UO_2, TiO_2 doped and TiO_2+CaO doped annular sintered pellets with ~96% of theoretical density were fabricated, respectively. And the resintering test about the fabricated pellet was performed. Figure 1 shows the density change of the annular sintered pellet during the resintering test.

During the resintering test, the density increase of TiO_2 and TiO_2+CaO doped annular sintered pellets remarkably reduced. Also, the decrease of an inner diameter of the annular pellet reduced due to the control of density change of annular pellet.

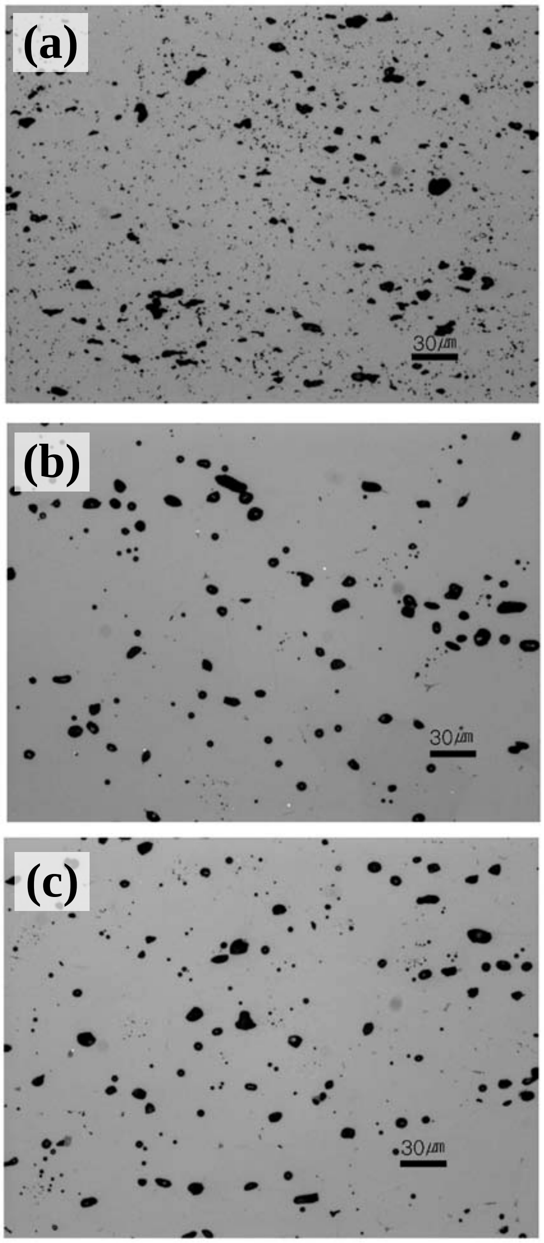

Fig. 2. The optical microscopic image (×200) of fabricated annular pellets: (a) UO_2, (b) TiO_2 doped, and (c) TiO_2+CaO doped.

These results could be explained by the difference of microstructure between doped and undoped pellet. Figure 2 shows the optical microscopic image of the fabricated annular sintered pellets.

In Figure 2 (a), the coexistence with large and small pores in the UO_2 annular sintered pellet could be observed. Among these pores, small pores affect the density increase during the resintering test. That is to say, because of a disappearance of the small pores, the density increase of the sintered pellet can be occurred.

On the other hand, in Figure 2 (b) and (c), the small pores in the TiO_2 and TiO_2+CaO doped annular pellet were hardly observed. Therefore, the density increase of TiO_2 and TiO_2+CaO doped annular pellet was much lower than that of UO_2 annular pellet. That is to say, it can be said that the thermal stability of the annular pellet is considerably enhanced.

4. Summary

An annular sintered pellet with a high thermal stability was fabricated, and then a resintering test for the sintered pellets was performed.

During the resintering tests, it could be thought that the density increase of sintered pellet was mainly caused by the disappearance of the small sized pore. In the microstructure of TiO_2 and TiO_2+CaO doped annular pellet, small pores could be nearly observed. Therefore, the density increase of TiO_2 and TiO_2+CaO doped annular pellet was much lower than that of UO_2 annular pellet.

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