Fabrication of Annular Pellet for HANARO Irradiation Test of Dual Cooled Fuel

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1. Introduction

One of the most important components in a Pressurized Water Reactor affecting its safety and economy is a nuclear fuel. The traditional PWR fuel pellet has a shape of cylindrical tablets of about 8 mm in diameter with a chamfer and dishes. A significant reduction in its failure rate has resulted from the improvements in the fuel and cladding quality. Enhanced fuel assembly design allowed appreciable power density increases. However, it is difficult to achieve a significant increase of a power density under the current fuel pin design.

An internally and externally cooled annular fuel has been considered seriously as a promising solution for an extended power uprate of a PWR fuel assembly. A dual cooled annular fuel shows a lot of advantages from the point of a fuel safety and its economy due to its unique configurational merit such as an increased heat transfer area and a thin pellet thickness [1].

There must be a lot of considerations in the various fields to introduce an annular internally and externally cooled fuel to commercial PWR reactors. The dimensional changes of the annular fuel pellets during the early irradiation stage are very important, because they have an influence on the size of the gap between the pellet and the inner/outer claddings.

In order to gain an insight to how the annular pellets deform, a HANARO irradiation test is planned for annular pellets with 5 different types. The detailed specification of the annular pellet was shown in Table 1. It is noted that Type C has the same pore structure as a commercial PWR pellet. The purpose of this paper is to report on the manufacturing process of an annular fuel pellet for a HANARO irradiation test.

Table 1. Annular fuel pellet specification.

	Enrichment (wt%)	Sintered density (%TD)	Outer diameter (mm)	Inner diameter (mm)
Type A	2.67	90±1	14.62±0.03	10.28±0.03
Type B	2.67	93±1	14.62±0.03	10.28±0.03
Type C	2.67	96±1	14.62±0.03	10.28±0.03
Type D	2.67	98±1	14.62±0.03	10.28±0.03
Type E	2.67	98±1	14.68±0.03	10.28±0.03

2. Experimental

Annular fuel pellets were prepared by the Integrated Dry Route (IDR) UO_2 powder. The powder was pre-compacted under 10 MPa by using a cold isostatic press. Pre-compacted lump of UO_2 powder was crushed and granulated with 20 mesh sieves. The granules were mixed with a 0.3 wt% of zinc stearate in a tumbling mixer for 30 min.

In order to achieve annular fuel pellets with the same dimensions and various sintered densities, we control the green density and the sintering temperatures.

The compaction was conducted in a double acting press by using an annular shape mold. Different amounts of the granules were charged to the pressing mold and then the green densities were varied from about 50 %TD to about 56%TD. The green annular pellets have the same height. The dimensions of the annular compacts were measured by using a 3-dimensional measuring system (VERTEX 230, MicroVu). The compact is about 11 mm in height and about 18 mm and 12.4 mm in outer and inner diameter, respectively.

The compacts were sintered at the temperature ranges of 1450 °C and 1730 °C for 1.5-4 h in H_2 atmosphere. The heating and cooling is at a rate of 5 K/min. Sintered density was measured by the water immersion method. The inner and outer diameters of the sintered pellets were measured carefully as a function of the pellet height by using a 3-dimensional measuring system (VERTEX 230, MicroVu). Centerless grinding was conducted to control the outer diameter.

3. Results

Figure 1 shows the annular fuel pellets of 14.62 mm and 14.68 mm in outer diameter and 10.28 mm in inner diameter after sintering and outer surface grinding. Table 2 shows the sintered density and dimensions of the annular fuel pellet, which satisfy the pellet specification.

Shrinkage factor of the inner diameter of an annular fuel pellet during sintering was calculated carefully and reflected in the mold design, because it is not easy to grind the inner surface of an annular pellet. In this case, the shrinkage factor during sintering was about 17 % to

Fig. 1. Fabricated annular pellets

meet the designed inner diameter, 10.28 mm.

In order to attain both the designed sintered density and the shrinkage factor, the green density of an annular compact and the sintering temperatures were controlled. Type A pellet had a green density of around 50 %TD and then sintered at 1450 °C for 4 h in H_2 atmosphere. Type B pellet was compacted to a green density of around 51 %TD and then sintered at 1500 °C for 1.5 h in H_2 atmosphere. Type C-E pellet a green density of around 56 %TD and then sintered at 1730 °C for 4 h in H_2 atmosphere. In the Type C pellet, 0.5 wt% of a pore former was added to reduce the sintered density.

Figure 2 shows the pore structures of the sintered annular pellets with various sintered densities. Pore structure of Type E was not presented because Type D and E have the same density and the same pore structure. It is noted that Type C has the same pore structure as a commercial PWR pellet.

Table 2. Sintered density and dimension of annular pellet.

	Sintered density (%TD)	Height (mm)	Outer diameter (mm)	Inner diameter (mm)
Type A	89.7±0.24	8.540 ±0.009	14.627 ±0.002	10.286 ±0.008
Type B	92.4±0.11	8.635 ±0.007	14.625 ±0.002	10.289 ±0.007
Type C	96.0±0.31	8.752 ±0.012	14.625 ±0.002	10.290 ±0.004
Type D	97.9±0.13	8.709 ±0.009	14.620 ±0.001	10.285 ±0.010
Type E	98.0±0.05	8.699 ±0.003	14.685 ±0.003	10.271 ±0.002

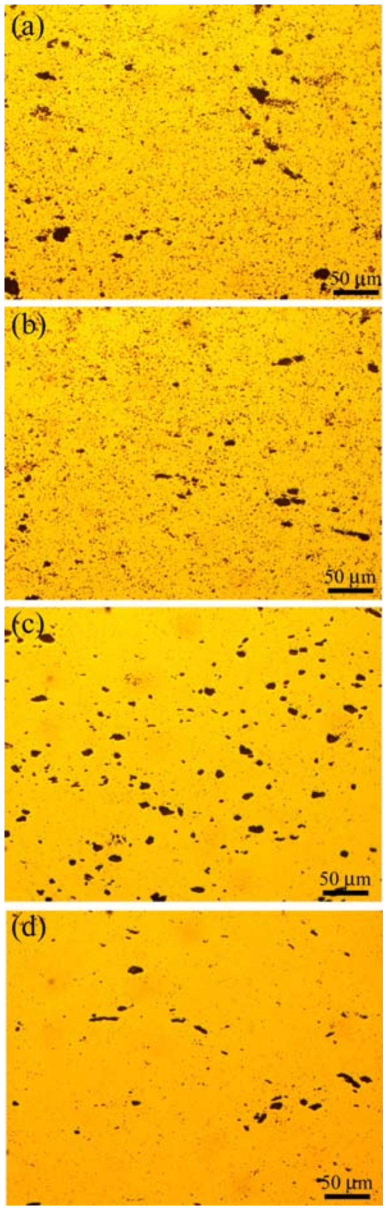

Fig. 2. Pore structures of the fabricated annular pellets; (a) Type A, (b) Type B, (c) Type C, (d) Type D.

4. Conclusions

Annular fuel pellets with the same dimensions and various sintered densities were fabricated successfully. They satisfy the pellet specification of the HANARO irradiation test.

Acknowledgement

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REFERENCES

[1] M.S. Kazimi, et al., "High Performance Fuel Design for Next Generation: Final Report," MIT-NFC-PR-082, MIT, Cambridge, MA 2006.