Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, November 2-3, 2006

Fabrication and Resintering of Annular UO_2 Pellet

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1. Introduction

Nuclear fuel is one of the most important components in a PWR affecting its safety and economy. The traditional PWR fuel pellet has a shape of cylindrical tablets of about 800 μm in diameter with a chamfer and dishes. A significant reduction in its failure rate has resulted from the improvements in 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.

Recently, Massachusetts Institute of Technology (MIT) has proposed an annular UO_2 fuel with an internal cooling of each fuel rod [1]. Annular fuel pellets with a voided central region have been used in VVER reactors without an internal cooling. Annular fuels with both internal and external cooling have been proposed for high temperature gas cooled reactors [2]. However, commercial PWR reactors have not used such annular internally and externally cooled fuel rods, yet.

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 dimension tolerance and the thermal stability of a pellet are very important from the viewpoint of fabrication technology, because they have an influence on the size of the gap between the pellet and the inner/outer claddings.

In this study, annular UO_2 pellets with various densities were fabricated and then a resintering test was conducted. The changes of dimension and density of the sintered pellets were characterized.

2. Experimental

Samples were prepared from the ADU route UO_2 powder. The powder was pre-compacted under 40 MPa by using a cold isostatic press and then granulated with a 20 mesh sieve. The granulated powder was mixed with a 0.3 wt% of zinc stearate in a tumbling mixer for 30 min. The compaction was conducted in a single acting hydraulic press by using an annular shape mold. Around 8 grams of the prepared powder were charged into the annular portion of the mold and then pressed under 3 ton/cm^2. The dimensions of the annular compacts were measured by using a micrometer and an inside micrometer. The compact is about 13 mm in height and about 17.5 mm and 12.9 mm in outer and inner diameter, respectively. The green densities of the annular compacts were around 51% of the theoretical

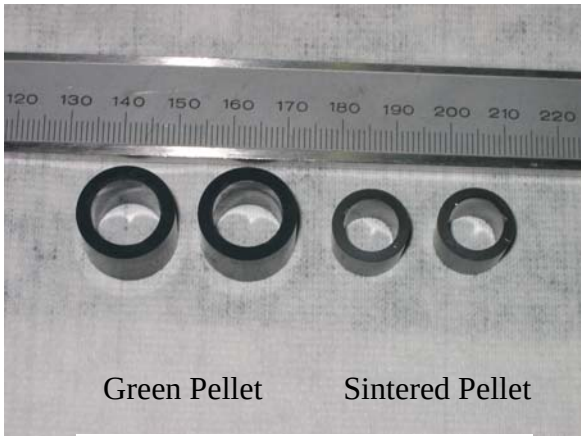

Fig. 1. Fabricated annular pellets

density. Sintering was conducted at the range of 1500 °C to 1730 °C for various times. The compacts were heated to the sintering temperature at a rate of 5 K/min in H_2 atmosphere. Sintered density was measured by the water immersion method. Some pellets were re-sintered at 1700 °C for 24 h in H_2 atmosphere. The variations of

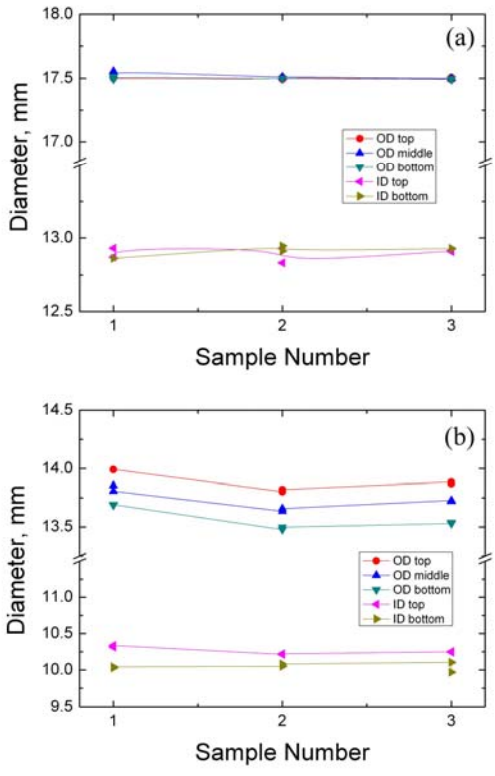

Fig. 2. Measured diameters of green and sintered annular pellets

the densities and the dimensions of the pellet were compared before and after the re-sintering.

3. Results

Figure 1 shows the annular compacts of about 17.5 mm in outer diameter and sintered pellets of about 13.9 mm in outer diameter after sintering at 1730 °C for 4 h in H_2 atmosphere.

Dimensions of the annular compacts and sintered pellets are presented in Fig. 2. Sample numbers indicates the sintering conditions; 1 represents the sintering at 1500 °C for 15 min, 2 represents the sintering at 1700 °C for 15 min, and 3 represents the sintering at 1730 °C for 4 h. The inner/outer diameters of the compacts have little variations in some positions of the samples. However, the inner/outer diameter varies directly with the height of the measuring points. All the samples show a linear shrinkage difference of around 2 % between the top and bottom of the pellet. The variation in diameters of the sintered pellet is attributed to the density fluctuation in the green pellet.

The die-wall friction during a compaction is known to result in a density fluctuation in a green pellet. In the double acting pressing, the shape of a pellet deforms during sintering from a cylindrical shape to an hourglass-like shape having a thinner diameter at its middle portion along the axial direction. In the single acting pressing, the shape of pellet deforms during sintering from a cylindrical shape to a conical cylinder having a thinner diameter at its top or bottom portion along the axial direction.

Yanai et al. [3] calculated the density distribution in a UO_2 green pellet during a powder compaction by using the FEM code and compared it with the measured local densities in the UO_2 green pellet determined by an energy dispersive X-ray analysis (EDX). They showed that about a 3 % density fluctuation exists in a double acting pressed green pellet with a 10 mm length.

Figure 3 shows the density changes during sintering at various temperatures and after resintering at 1700 °C for 24 h. All the green pellets have around 51 % of the theoretical density. The sintered densities are about 92.6 %, 95.3 %, and 97 % of the theoretical density depending on the sintering temperatures. After resintering at 1700 °C for 24 h, the densities of all the samples reached about 97.6 % of the theoretical density. Dimensional change of the resintered pellets varies directly with a density increment from 0.2 % to 2 % for a linear shrinkage.

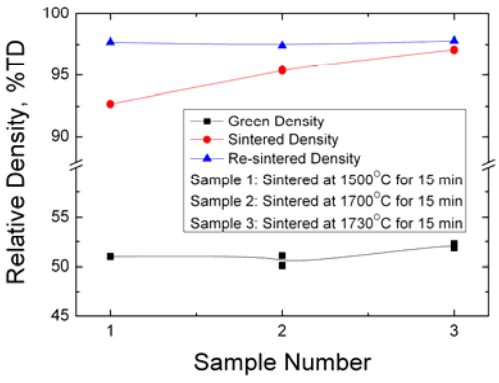

Fig. 3. Density changes in annular pellets after sintering and resintering

4. Conclusion

The annular UO_2 pellets with various densities were fabricated and then a resintering test was conducted. The sintered pellet has a shape of a conical cylinder because of the density fluctuation in a green pellet. The changes of dimensions increased with the density increment during resintering.

Acknowledgement

This work has been carried out under the Nuclear R&D Program supported by the Ministry of Science and Technology, Korea

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