Annular Fuel Pellet Fabrication without Surface Grinding

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1. Introduction

In order to increase the power density of a Pressurized Water Reactor fuel assembly, a dual cooled annular fuel has been seriously considered as a favorable option. A configurationally inherent merit of an annular fuel such as an increased heat transfer area and a thin pellet thickness results in a lot of advantages from the point of a fuel safety and its economy [1]. Annular pellet with precisely controlled diametric tolerance is an essential element to actualize the dual cooled fuel.

An hour-glassing usually occurs in a sintered cylindrical PWR fuel pellet fabricated by a conventional double-acting press due to an inhomogeneous green density distribution in a powder compact. An inhomogeneous green density distribution in a powder compact is attributed to granule-granule frictions and granule to pressing mold wall frictions. Frictions result in an irregular pressing load distribution in a powder compact. Thus, a sintered pellet undergoes a centerless grinding process in order to secure diametric tolerance specifications. In the case of an annular pellet fabrication using a conventional double-acting press, the same hour-glass shape would probably occur.

The green density gradient in a powder compact depends on the pressing direction and the amount of the sintering deformation is inversely proportional to the initial green density. In case of a double-acting pressing, the middle portion of the green pellet has a lower green density than those of the top and the bottom portions of the green pellet. However, the top or the bottom portion which is far from the acting punch surface has the lowest green density in a single-acting pressing.

In the present study, we are trying to find a way to minimize the diametric tolerance of the sintered annular pellet without surface grinding. Annular compacting mold with inclined inner and outer surfaces was designed by considering a difference in the diametric changes depending on the pellet height during sintering. By using a compacting mold with inclined surfaces and a single-acting press, an annular pellet can be fabricated successfully with a tolerance of less than ± 13 μm which is the diametric tolerance specification of a conventional PWR fuel pellet.

2. Experimental

ADU route UO_2 powder was used for a sample preparation. The powder was pre-compacted under 70 MPa by using a cold isostatic press. Pre-compacted lump of UO_2 powder was crushed and granulated with 20 mesh sieve. Granule size was classified less than 850 μm. The granules were mixed with a 0.3 wt% of zinc stearate in a tumbling mixer for 30 min. The compaction was conducted in a single acting press by using two types of annular molds. One is an ordinary annular mold with straight inner and outer surfaces and the other is a newly designed annular mold with inclined inner and outer surfaces.

The dimensions of the annular compacts were measured by using a 3-dimensional measuring system (VERTEX 230, MicroVu). The compact is about 12 mm in height and about 18 mm and 12 mm in outer and inner diameter, respectively.

The compacts were sintered at 1730 °C for 4h 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 carefully measured as a function of pellet height by using a 3-dimensional measuring system (VERTEX 230, MicroVu).

3. Results

The green density of an ordinary annular compact pressed in a mold with straight surfaces is around 48 % of the theoretical density (TD). That of an inclined annular compact pressed in a newly designed mold with inclined surfaces is about 47 %TD. The sintered densities of annular pellets had similar values, 97 %TD for an ordinary compact and 96.5 %TD for an inclined compact, respectively.

Sintering deformation of inner and outer surfaces of an ordinary annular compact is represented in Fig. 1. Circles in Fig. 1 indicate the measured inner and outer diameters of the green annular compact and the sintered annular pellet as a function of the pellet height.

An ordinary annular green compact has constant inner and outer diameters along the pellet height direction as shown in Fig. 1. However, an inclination of pellet surfaces occurred after sintering at 1730 ℃ and the sintered pellet had different inner and outer diameters according to the pellet height. Thus, diametric tolerances of a sintered annular pellet are about ± 78 μm and about ± 106 μm for inner and outer diameter, respectively.

Figure 2 shows the sintering deformation of inner and outer surfaces of an inclined annular compact. The measured inner and outer diameters of the green annular compact and the sintered annular pellet are presented in Fig. 2 as a function of the pellet height.

Inner and outer diameters of an inclined annular green compact increased along with the pellet height as shown in Fig. 2. However, the sintered pellet appears to have constant inner and outer diameters along the pellet height direction after sintering at 1730 ℃. Thus, the

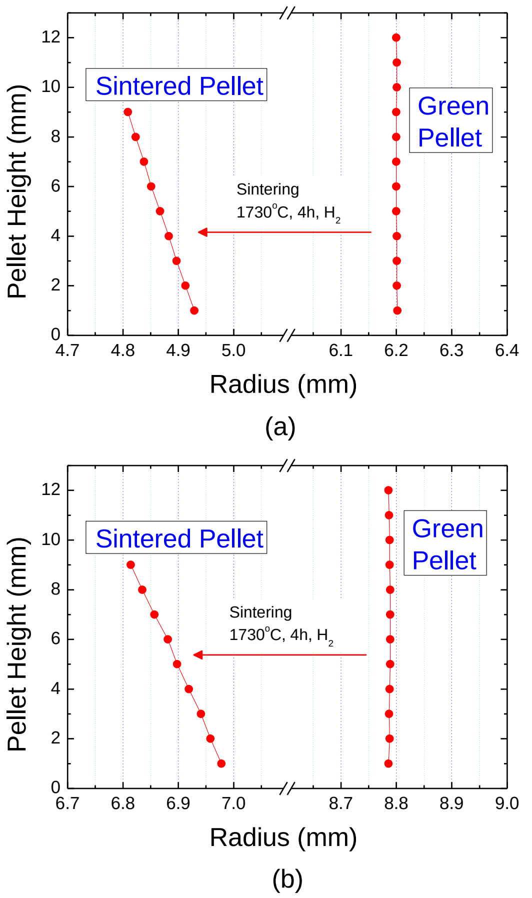

Fig. 1. Measured inner and outer diameter distributions of the ordinary annular compact and the sintered annular pellet, (a) inner diameter and (b) outer diameter.

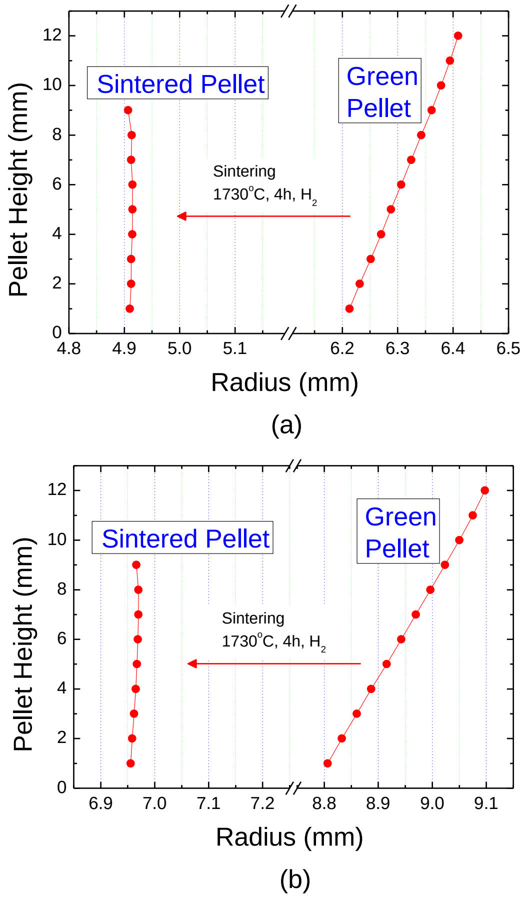

Fig. 2. Measured inner and outer diameter distributions of the inclined annular compact and the sintered annular pellet, (a) inner diameter and (b) outer diameter.

sintered annular pellet fabricated by an inclined mold has excellent inner and outer diametric tolerances of less than ± 5 µm and ± 10 µm for the inner and outer diameters, respectively.

4. Conclusions

An annular fuel pellet with highly precise diametric tolerances has been fabricated by using a newly designed compaction mold with inclined mold surfaces and a single acting press. Excellent inner and outer diametric tolerances of less than ± 5 µm and ± 10 µm, respectively, can be achieved in the sintered annular pellet which is fabricated by the new inclined mold compaction process. Those tolerance values are less than the diametric tolerance specification of the conventional PWR fuel pellet, ± 13 µm, which implies that the present annular pellet can be used without surface grinding.

REFERENCES

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