Control of Diametric Tolerance of Annular Pellet using CIP with Metal Rod Insertion

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1. Introduction

The typical fuel geometry of a PWR (Pressurized Water Reactor) is composed of a cylindrical pellet with a tubular cladding. And the outer surface of the cladding is cooled with water. However, to allow for a substantial increase in the power density, an additional cooling is necessary. One of the best ways is a new fuel geometry that is of an annular shape and has both an internal and external cooling [1]. For the new fuel geometry, a fabrication method for an annular UO_2 pellet must be developed.

In developing the fabrication technology for an annular pellet, there are various methods which can be used. But a die pressing method was dominantly considered, because it is profitable for a mass production of nuclear fuel pellet.

In the die pressing method, a density gradient in the green pellet occurs, because the partial densities of a powder compact have a difference according to the distance between punch and powder. Therefore, an axial deviation of a sintered annular pellet diameter due to the gradient of the green density occurs. The sintered annular pellet as nuclear fuel must be satisfied with a diametric tolerance of <0.03 mm [2]. The outer diametric tolerance of pellet can be easily reduced by using a centerless grinding machine. However, it isn't easy for the inner diametric tolerance of pellet to be lowered. So the technology to minimize the diametric tolerance – especially, that of a pellet inner diameter – must be developed.

To reduce the diametric tolerance of an annular pellet, in this study, the two-step pressing method (usual double acting pressing, CIP (Cold Isostatic Press) with metal rod insertion) was used.

2. Experimental

ADU-UO_2 (Ammonium Diuranate) powder was granulated with a pressure of 70 MPa and a 20 mesh (aperture: 850 μm) sieve. The granulated powder was mixed with a lubricant powder (0.3 wt% zinc stearate) by using a Turbula mixer for 0.5 h.

The two-step pressing method was performed. First, the powder mixture was compacted with a pressure of 300 MPa by using a usual double acting press, and then the compact was re-pressed by using a CIP with a pressure of 300 MPa. At this time, a tungsten metal rod (rod diameter: 12.00 mm) was inserted into the annular compact (figure 1). Finally, the compact was sintered at 1730 ℃ for 4h in a flowing H_2 atmosphere.

The sintered density of the annular pellet was determined by using an immersion method, and the dimensions of the pellet were measured by using a 3-dimensional precise measuring system (VERTEX 230, MicroVu).

Figure 1. The annular compact which the tungsten metal rod was inserted (before CIP).

3. Results and Discussion

Figure 2 shows the measured diameter distribution of the annular green pellet and a comparison of the distribution before CIP and after CIP. The outer and inner diameter distribution of green pellet which was made by using a usual double acting press was straightened.

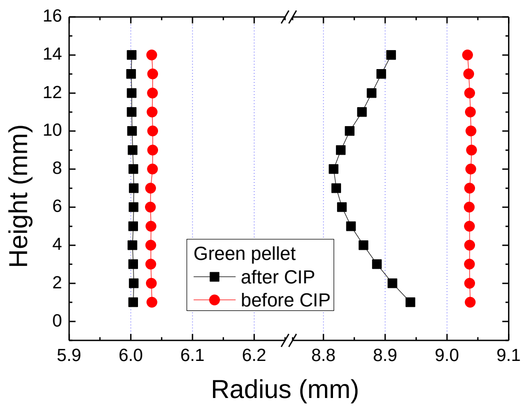

Figure 2. The measured diameter distribution of the annular green pellet before CIP and after CIP.

However, the outer diameter distribution of the green pellet which was re-pressed by using a CIP with a tungsten metal rod insertion was changed to an hourglass shape, and the inner diameter distribution was flattened due to the inserted tungsten metal rod that wasn't entirely deformed in the sintering temperature.

The density gradient in the green pellet which occurred under the usual axial pressing almost disappeared due to the re-pressing (the CIP with a metal rod insertion).

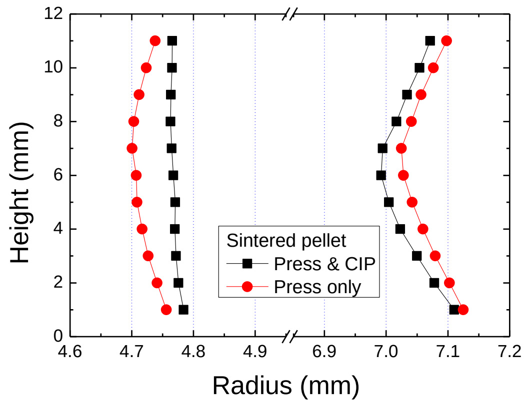

Figure 3. The measured diameter distribution of the sintered annular pellet which was fabricated by the two-step pressing method and the usual double acting pressing method.

The green pellets which were made by the two methods were sintered in the same sintering condition. Figure 3 shows the measured diameter distribution of the two sintered annular pellets. The inner diametric tolerance of the annular pellet which was fabricated by the two-step pressing was improved less than 0.015 mm, that is, there is no need to grind the inner surface of a pellet.

The fact that a grinding step of the pellet inner surface can be excluded means a lot to a fabrication of nuclear fuel pellet. It leads to reduce a loss of nuclear fuel materials, and to remarkablely raise the efficiency of mass production.

Table 1. The averaged diameter and the diametric tolerance (standard deviation) of inner and outer diameter of samples.

	Inner diameter		Outer diameter	
	Ave.	Std. dev.	Ave.	Std. dev.
Before CIP	12.068	0.003	18.074	0.003
After CIP	12.006	0.003	17.733	0.074
Sintered	9.538	0.012	14.078	0.072
Sintered (Press only)	9.443	0.034	14.133	0.062

4. Conclusions

To reduce the diametric tolerance of an annular pellet, a two-step pressing method (usual double acting pressing, CIP with metal rod insertion) was used. As a result, in the second step (CIP with metal rod), the density gradient of the annular green pellet almost disappeared. Therefore, there was a little deformation of the pellet shape during the sintering step. The inner diameter distribution of the annular pellet which was fabricated by the two-step pressing had a very low diametric tolerance, that is, there is no need to grind the inner surface of a pellet.

ACKNOWLEDGEMENT

The authors acknowledge that this work has been performed under the Nuclear Mid- and Long-term R&D Projects supported by the Ministry of Education, Science and Technology in Korea.

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