Application of Lubricant to Minimize Axial Deviation of Annular Pellet Diameter

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1. Introduction

In the nuclear industry, the elevation of an economical efficiency for a nuclear fuel is one of the major issues. To increase the efficiency, a development of the nuclear fuel for a high burnup and extended cycle is necessary. In the development of a high performance fuel, in-reactor fuel behavior must be seriously considered. Also, a fuel fabrication and an enrichment process must be discussed [1].

A modification and an improvement of a nuclear fuel system will be also required. 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 the application of a new fuel geometry that is of an annular shape and has both an internal and external cooling [2]. From this point of view, a double cooled fuel is being developed by KAERI (Korea Atomic Energy Research Institute), and as a part of the project, the development of a fabrication process for a UO_2 annular pellet is now in progress.

In developing the fabrication technology for an annular pellet, there are various methods which can be applied to the fabrication of an annular pellet. But a die pressing method was dominantly chosen, because it is profitable for a production on a large scale.

The dimensions (inner and outer diameter) of a sintered annular pellet must be satisfied with a tolerance of <0.03 mm [3]. In the die pressing process, an inhomogeneous distribution of the density in a green pellet occurs, because the density of a compact increases with coming closer to punch-to-powder contact surface. Therefore, an axial deviation of a sintered pellet diameter due to the inhomogeneity of the green density occurs. The deviation of the outer diameter can be easily straightened by using a centerless grinding machine. However, it isn't easy for the deviation of the inner diameter to be straightened. So the technology to minimize this deviation – especially, that of a pellet inner diameter – must be developed.

To reduce a deviation of an annular pellet diameter, a minimization of a powder-to-powder or powder-to-die friction is necessary [4-6]. In this study, a lubricant (zinc stearate) which could reduce the friction was added to UO_2 powder. The axial deviation change of the pellet diameter as a function of the lubricant content was also investigated.

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 granulation improves the flow-ability of a powder under a compacting. The granulated powder was mixed with a lubricant powder (zinc stearate) by using a Turbula mixer for 0.5h. The content of the zinc stearate was varied from 0.3 to 2.0 wt%. Powder mixture was compacted with a pressure of 300 MPa, and sintered at 1730 °C 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 (outer & inner diameter, length) of the sample were measured by using a 3-dimensional measuring system (VERTEX 230, MicroVu).

3. Results and Discussion

Figure 1 shows the tolerances in diameter of each sample as a function of the lubricant content. Both the tolerance of the inner diameter and that of the outer diameter decrease with an increasing zinc stearate content. And, in the case of the 2.0 wt% zinc stearate added annular pellet, both diameters were satisfied with a tolerance of <0.03 mm, that is, there is no need to grind the surface of a pellet.

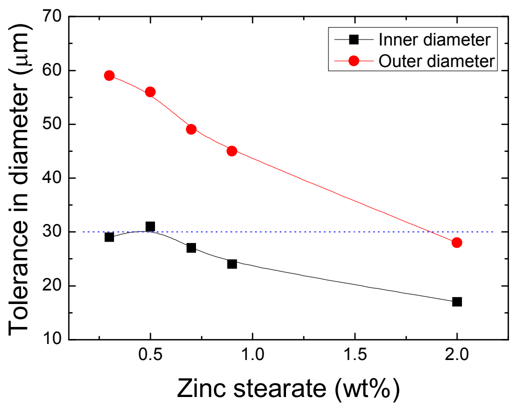

Figure 1. The axial deviation of UO_2 annular pellet diameter. It decreases with increasing zinc stearate content.

The sintered density of each sample is shown in Figure 2. There was no significant difference between the densities of the green pellets (~47 %TD). Nevertheless the sintered density does considerably decrease with an increasing zinc stearate content.

Especially, in the case of the 2.0 wt% zinc stearate added sample, its sintered density was not profitable as a nuclear fuel pellet.

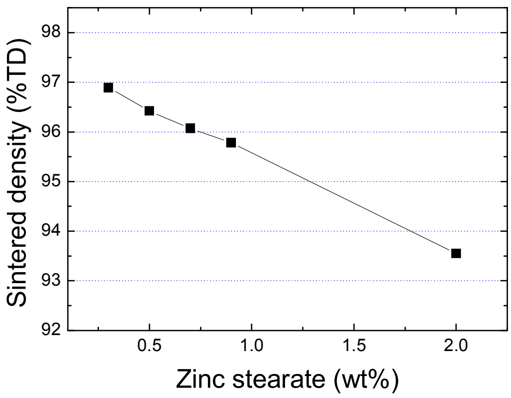

Figure 2. The density drop of annular sintered pellet with increasing zinc stearate content.

Figure 3 shows a pore structure of a sample. In Figure 3 (a), an amount of a large pore began to form in the UO_2 matrix. The amount of the large pore increases with an increasing zinc stearate content. In Figure 3 (b), pore channels form in the matrix, and the open porosity is higher.

Though the application of a lubricant is considerably helpful to improve the axial deviation of an annular pellet diameter, it has a problem where the microstructure of a sample is degraded by the added lubricant. So, an effort to improve the microstructure is necessary.

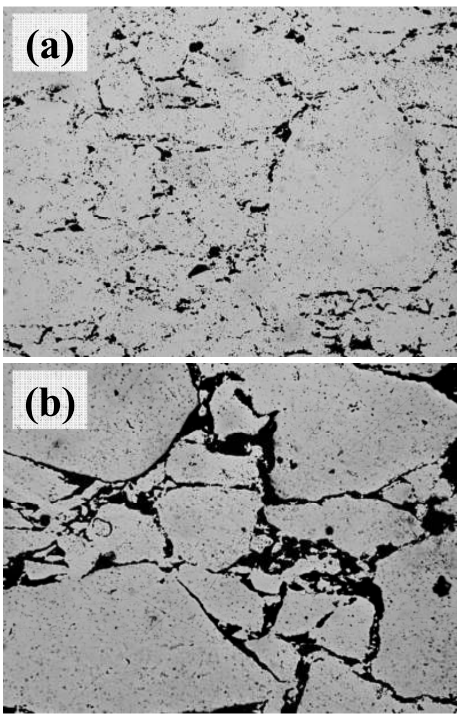

Figure 3. The optical microscopic image of the sintered pellet (×100): (a) 0.9 wt%, (b) 2.0 wt% zinc stearate.

3. Conclusions

The axial deviation change of an annular pellet diameter as a function of a lubricant content was investigated. As a result, although an improvement of the microstructure is additionally needed, the axial deviation of the pellet diameter was considerably improved.

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