Powder Treatment to Improve Microstructure of UO_2 Annular Pellet

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1. Introduction

In the nuclear industry, the economical efficiency for a nuclear fuel is one of the major issues. To increase the efficiency, the development of a 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, i.e. the nuclear fuel for a high burnup has to preserve its integrity under reactor operations.

A modification and an improvement of the 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 an external cooling (dual cooled fuel [1]).

A dual 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 of a UO_2 annular pellet is now in progress.

In developing the fabrication technology of a UO_2 pellet, an improvement of its microstructure properties is very important. The homogeneity of the pore and grain structure of a sintered pellet affects the fuel performance and integrity [2-4].

To improve the microstructure of a UO_2 annular pellet, the condition of a powder treatment must be optimized. There are many ways to treat a powder. A granulation improves a flow-ability of a powder under a compacting process. However, a granulation with an inappropriate condition can have a bad influence on the microstructure of a sintered pellet. So an optimized powder treatment with an appropriate condition is necessary. Moreover, because we needed to use a low enriched powder, if possible, an optimized condition of a powder treatment without a powder milling process is required.

In this study, to find the optimized condition of a powder treatment, the effect of a pre-compacting pressure and a granule size on the microstructure of a sintered pellet was investigated.

2. Experimental

IDR-UO_2 (Integrated Dry Route) powder was granulated with a various pressure (10, 20, 35, 70 MPa) and sieve mesh (20, 30, 50: aperture 850, 600, 300 μm). The granulated powder was mixed with a lubricant powder (zinc stearate) by using a Turbula mixer for 0.5h. Powder mixture was compacted by using a double acting press, and sintered at 1730 ºC for 4h in a flowing H_2 atmosphere.

The sintered density of the annular pellet was determined by using an immersion method, and the microstructure of the samples was observed by using an optical microscopy.

3. Results and Discussion

Table 1 show that the UO_2 powder was treated with various conditions (pre-compacting pressure and granule size). In the Figure 1, the sintered density of each sample increased with decreasing pre-compacting pressure and granule size, however these values of the density were suitable for a pellet as a nuclear fuel.

Table 1. Sample preparation with a various condition of powder treatment.

Pre-comp. pressure (MPa)	Sieve mesh	Aperture (μm)	Sintered density (%T.D.)
70	20	850	96.0
70	30	600	96.7
70	50	300	97.0
35	20	850	97.0
35	30	600	97.1
35	50	300	97.2
20	20	850	97.4
10	20	850	97.7
10	50	300	97.8

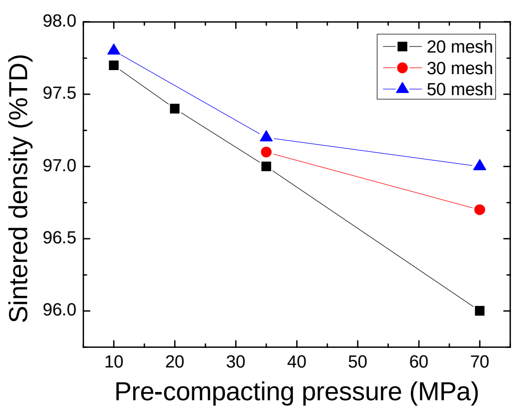

Figure 1. The sintered density increased with decreasing pre-compacting pressure and granule size.

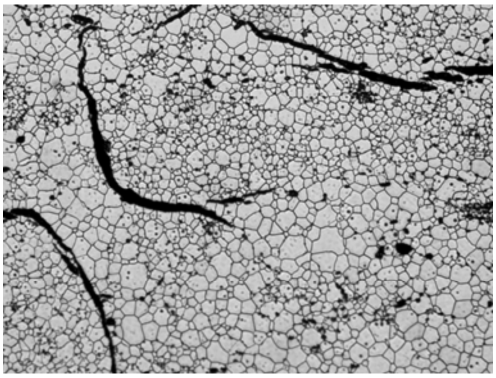

Figure 2. The bad influence of a high pre-compacting pressure and a large granule size (70 MPa and 20 mesh) on the microstructure of sintered pellet (optical microscopy, ×200).

But the sample with a high pre-compacting pressure had an inappropriate microstructure. Figure 2 shows the inhomogeneous grain structure of the sintered pellet. It reveals a difference of the grain size between the inner and outer side of a granule.

To improve the unsuitable microstructure, we intended to optimize the powder treatment condition by using a control of two variables. As a result, the microstructure of the sintered pellet was improved by decreasing the pre-compacting pressure and granule size, i.e. a homogeneous microstructure could be obtained (Figure 3 (b)). The optimized condition (10 MPa and 50 mesh) of the powder treatment was applied to fabricate the sintered annular pellet for the HANARO irradiation test.

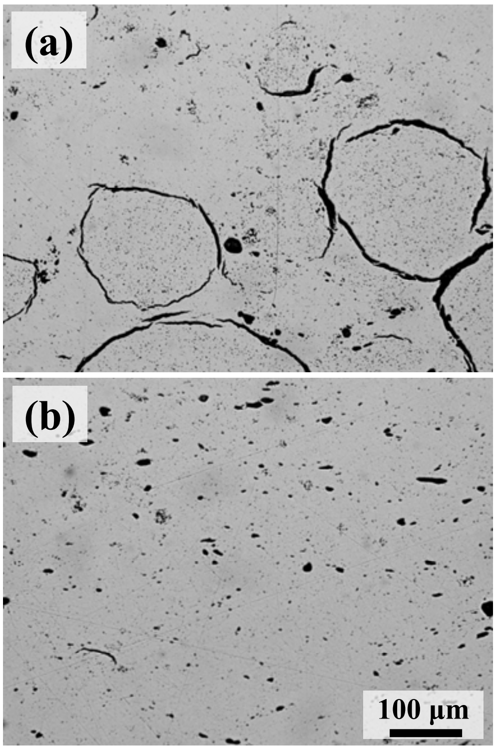

Figure 3. The pore structure of the sintered pellet (×100): (a) 70 MPa and 20 mesh, (b) 10 MPa and 50 mesh (the optimized condition of powder treatment).

3. Conclusions

The effect of a powder treatment on a microstructure of a sintered pellet was investigated. A pre-compacting pressure and granule size were considered as variables of the powder treatment. As a result, an optimized treatment condition was obtained, and a sintered annular pellet with a suitable microstructure as a nuclear fuel was fabricated.

ACKNOWLEDGEMENT

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