Load Effect in High Temperature on Dimensional Change of Annular Pellet

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1. Introduction

The typical fuel geometry of a PWR (Pressurized Water Reactor) is composed of a cylindrical uranium oxide sintered pellet with a tubular zirconium based alloy cladding. The sintered pellets are loaded in the cladding about 4 m long. And the outer surface of the cladding is cooled with flowing water coolant. There is a steep temperature gradient in the pellet, because of a low thermal conductivity of the uranium oxide. In the condition of conventional reactor operation, a centerline temperature of the pellet is about 1000~1300℃ while a surface temperature of the cladding is about 300~350℃. The in-reactor integrity and performance of the nuclear fuel can be affected by this temperature gradient.

Therefore, to uprate a power of nuclear reactor and to increase a safety margin of nuclear fuel, an additional cooling is necessary. One of the best ways is that a new fuel geometry that is of an annular shape and has both an internal and external cooling (dual cooled nuclear fuel) is applied [1].

The dual cooled fuel is being developed by KAERI (Korea Atomic Energy Research Institute), also as a part of the project, the development of a fabrication technology of an annular pellet is now in progress.

For the new fuel geometry, a fabrication method for an annular pellet must be developed [2]. Also, a comprehensive study to expect in-reactor behavior of annular pellet is required.

In this study, to investigate the load effect in high temperature on a dimensional change of a sintered pellet, a resintering test of the sintered annular and cylindrical pellet is conducted. In the resintering test, a metal cylinder weight was put on the pellet, and the dimensional change of pellet was observed.

2. Experimental

IDR-UO_2 (Integrated Dry Route) powder was granulated with a pressure of 70 MPa and a 50 mesh (aperture: 300 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. Powder mixture was compacted by using a double acting press, and sintered at 1600℃ for 2h in a flowing H_2 atmosphere (sintered density 94~95%TD).

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

The sintered pellet was resintered at 1700℃ for 24h in a flowing H_2 atmosphere. At this time, a tungsten metal cylinder is put on the sintered pellet. The weight of metal cylinder is 90 g on the annular pellet, and 60 g on the cylindrical pellet, respectively. The density and the dimension of resintered pellet were measured by using the above mentioned method.

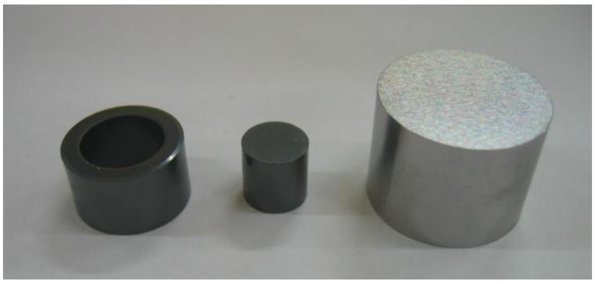

Figure 1. Specimen and tungsten metal cylinder for evaluation of load effect in high temperature.

3. Results and Discussion

Table 1. Density and volume change of specimen.

	Annular		Cylindrical	
	No load	Load	No load	Load
Sintered density (%TD)	94.95	94.96	93.93	93.89
Resintered density (%TD)	97.74	97.96	96.88	96.91
Volume change (%)	-2.785	-3.004	-2.942	-3.014

Table 1 shows the sintered and resintered pellet densities, and volume change rate. The volume change of loaded pellet is slightly higher than the one of unloaded pellet.

Figure 2 shows the change rates of measured inner diameter, outer diameter and length of the annular and cylindrical pellet. It was compared the change rate of the loaded pellet with unloaded pellet. The tendency which the change rate of length is higher than rate of inner and outer diameter was equally revealed. But it was difficult to observe the load effect on each pellet.

So, the dimensional change rates were normalized according to the volumetric change rate. Figure 3 shows the normalized dimensional change rates of each pellet. It can be said that there is not the load effect on the annular pellet. In the case of the cylindrical pellet, it seems to be affected by the load. But, because the normalized change rate of diameter and length decrease simultaneously, there is also not the load effect on the cylindrical pellet.

Finally, the diametric change rates were normalized according to the length change rate. Figure 4 shows the normalized diametric change rates of the annular and cylindrical pellet. Regardless of the pellet shape, it can be said that the diametric change rate of pellet was not affected by the load on the pellet.

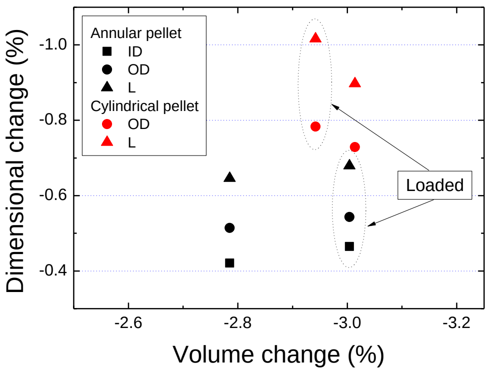

Figure 2. The change rates of measured inner diameter, outer diameter and length of the annular and cylindrical pellet.

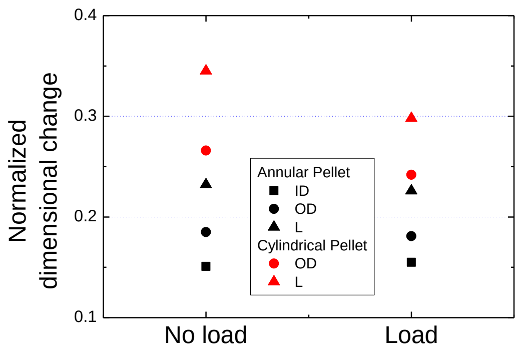

Figure 3. The dimensional change rates of the annular and cylindrical pellet that was normalized according to the volumetric change rate.

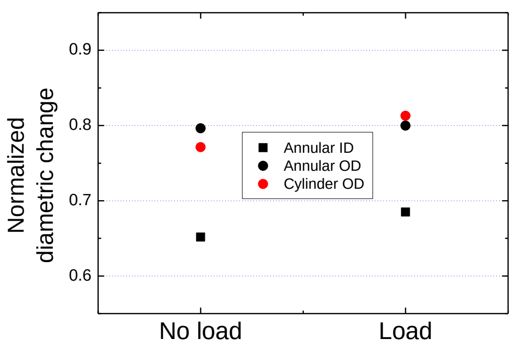

Figure 4. The diametric change rates of the annular and cylindrical pellet that was normalized according to the length change rate.

4. Conclusions

To study the load effect in high temperature on the dimensional change of annular pellet, the resintering test with load was performed.

In the load range that was used in this study, there was not the load effect on the dimensional change rate of pellet, regardless of pellet shape.

But, if applied load increases, then the load effect can be revealed. Therefore, the additional evaluation test by using the real load value which is expected under in-reactor condition is required.

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