A Study on the Sinterability of the Simulated Dry Recycling Nuclear Fuel Pellets with the Addition of Sintering Aids for 1 cycle OREOX Treated Powder

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1. Introduction

The OREOX(Oxidation and REduction of OXide fuel) process has been performed to fabricate dry recycling nuclear fuel pellets. The sinterable fuel powder was manufactured by the 3 cycles of oxidation and reduction treatment. A lot of time more than 37 hours as well as a lot of reaction gas is required to perform 3 cycles of OREOX treatment[1-4]. In this study, 1 cycle OREOX process was adopted to improve the powdering process for the simulated dry recycling nuclear fuel pellets with burnup of 35,000 MWd/tU. Simulated spent PWR fuel pellets were fabricated by using the UO_2 powder added by the simulated fission products. The simulated dry-recycling-fuel pellets were fabricated by dry recycling fuel fabrication flow including 1 cycle treated OREOX process. A small amount of dopant such as TiO_2 or Nb_2O_5[5-7] are added to increase the sinterability of the OREOX treated powder.

2. Simulated Spent PWR Fuel Pellets

Fission products were analyzed by ORIGEN-2 code based on spent PWR fuel with burnup of 35,000 MWd/tU. Simulated spent PWR fuel pellets were fabricated by the general fabrication process for UO_2 nuclear fuel mixed with the simulated fission products. The average density of the sintered pellets was 10.39 g/cm^3.

3. Simulated Dry Recycling Nuclear Fuel Pellets

The simulated spent PWR fuel pellets were treated through the one cyclic OREOX process, where the oxidation temperature was 500 °C, and the reduction temperature was 700 °C. The OREOX-treated powder was milled by a vertical attritor at the speed of 150 rpm for 15 minutes. The milled powder was mixed with zinc stearate to be suitable for compacting. Then, 0.05~0.2 wt% of dopant such as TiO_2, Nb_2O_5 are added to each prepared powder.

Green pellets were fabricated by the final compaction process with a pressure of 200 MPa. Zinc stearate was removed during heating of the green pellets for 2 hours at 800 °C in an Ar-4%H_2 atmosphere. The sintering process was performed at 1700 °C for 6 hours in an Ar-4%H_2 atmosphere.

3.1 Characteristics of Powder

Average particle size, surface area, the apparent density and the tap density of the powders were measured after the OREOX process and the milling process. For the OREOX-treated powder, average particle size was 10.1 μm. Surface area was 1.88 m^2/g. The apparent density was 1.27 g/cm^3. And the tap density was 2.45 g/cm^3. After milling process, average particle size was 0.67 μm. The apparent density was 2.02 g/ cm^3. And the tap density was 3.48 g/cm^3.

Particle size of 1 cycle OREOX treated powder was larger than that of 3 cycles OREOX treated powder. Surface area of 1 cycle OREOX treated powder was less than that of 3 cycles OREOX treated powder. That is, the sinterability of 1 cycle OREOX treated powder was worse than that of 3 cycles OREOX treated powder. A small amount of dopant such as TiO_2 or Nb_2O_5 are added to increase the sinterability of the 1 cycle OREOX treated powder.

3.2 Characteristics of Pellets

Geometric density of the green pellet ranged from 6.28 to 6.30 g/cm^3.

The sintered density of the pellets without dopant was 9.86 g/cm^3(91.5 % of T.D.), and the average grain size was 2.9 μm. Both sintered density and grain size did not meet the minimum criteria for CANDU fuel specification.

The sintered densities of the pellets doped with TiO_2 ranged from 10.40 to 10.47 g/cm^3, and the average grain size ranged from 12.9 to 15.7 μm. The densities of the pellets doped with Nb_2O_5 ranged from 10.48 to 10.51 g/cm^3, and the grain size ranged from 14.2 to 15.3 μm. Both sintered density and grain size increased dominantly by doping TiO_2 and Nb_2O_5.

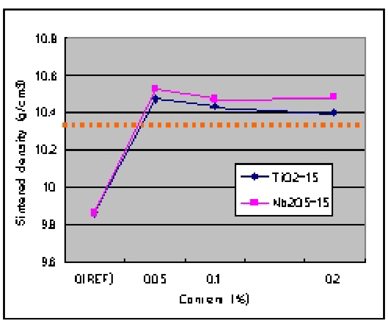

Figure 1. Density of sintered pellets.

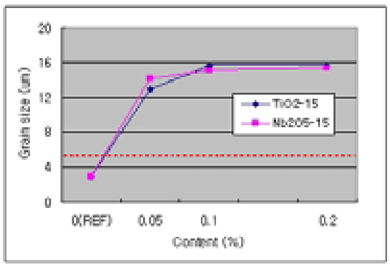

Figure 2. Grain size of sintered pellets.

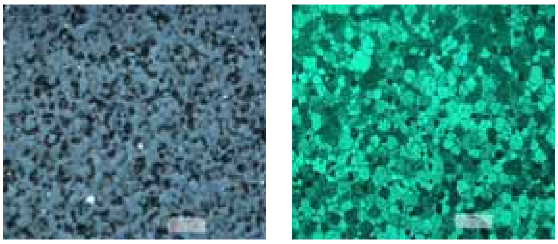
(a) Not doped (b) 0.2 wt% of Nb_2O_5

Figure 3. Microstructure of sintered pellets.

Figure 1, 2, and 3 show the result of experiment. As a result of experiment, a small amount of TiO_2 or Nb_2O_5 is effective to enhance the sinterability of the OREOX treated powder for dry recycling nuclear fuel pellets.

4. Conclusion

The simulated spent PWR fuel pellets were fabricated by using UO_2 powder added by the simulated fission products for the spent PWR fuel with burnup of 35,000 MWd/tU. The simulated dry recycling fuel pellets were fabricated by dry recycling fuel fabrication flow including 1 cycle treated OREOX process. A small amount of TiO_2 or Nb_2O_5 are added to enhance sinterability of the 1 cycle OREOX treated powder. The results are as follows.

- The sinterability of 1 cycle OREOX treated powder was not so good that both sintered density and grain size of the sintered pellets without dopant did not satisfy the criteria of CANDU fuel specification.
- The density as well as the grain size of the sintered pellets increased greatly by doping TiO_2 and Nb_2O_5.
- Consequently, a small amount addition of TiO_2 or Nb_2O_5 is effective to enhance the sinterability of 1 cycle OREOX treated powder for dry recycling nuclear fuel pellets.

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