Sintering Characteristics of Simulated DUPIC Fuel

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A new fuel cycle, called Direct Use of spent PWR fuel In CANDU reactors (DUPIC), has received renewed interest recently as PWR to CANDU synergistic fuel recycling option[1]. Taking advantage of the Korean nuclear reactor strategy of having both light water reactors (PWR) and heavy water reactors (CANDU) for electricity generation, the DUPIC concept as a alternative nuclear fuel cycle has been suggested. The spent PWR fuel can be burned again in CANDU reactors by direct refabrication of CANDU-compatible DUPIC fuel which is fabricated by only mechanical and thermal processes without the separation of any sensitive nuclear materials, even fission products. The remnant fissile content in the spent PWR fuel is high enough to be reused in CANDU reactors[2]. It can serve as one of the solutions for spent fuel management, while improving the utilization of uranium resources in a proliferation resistant way.

Simulated DUPIC fuel provides a convenient way to investigate the DUPIC fuel properties and behaviour such as thermal conductivity, thermal expansion, fission gas release, leaching, and so on without the complications of handling radioactive materials.

In this study, the effects of the variables on sintering of simulated DUPIC fuel to simulate DUPIC fuel are described. Mainly, the effects of compaction pressure, sintering temperature and time on the density of pellet are described. The experimental is performed with compaction pressure of 100 MPa~400 MPa, sintering temperature between 1900 K and 2050 K and sintering time of 4 hr, 8 hr and 24 hr.

The apparent density of wet milled powder was 1.34 g/cm^3 and increased to 2.34 g/cm^3 after crushing in tubular mixer. The particle size of raw material was 3.28 μm and its of wet milled powder and crushed powder in the tubular mixer were 0.45 and 0.37 μm, respectively.

The green density of simulated fuel due to the variation of compaction pressure was proportional to the one third power of compaction pressure was fitted by following equation:

$$\rho_g = 3.18 + 8.35 P^{1/3} \tag{1}$$

where ρ_g and P represent the green density and compaction pressure, respectively.

The sintered density of simulated fuel with compaction pressure and soaking time varied from 90.5 to 99.6 % of theoretical density. Figure 1 represents the grain size of sintered pellet with variation of sintering temperature and soaking time. The grain size with soaking time at each temperature was fitted by following equation:

$$d = 1.086 + 0.568 t^{0.4} \text{ at } T = 1943 \text{ K} \tag{2}$$
$$d = 1.852 + 0.587 t^{0.4} \text{ at } T = 2003 \text{ K} \tag{3}$$
$$d = 2.325 + 0.857 t^{0.4} \text{ at } T = 2053 \text{ K} \tag{4}$$

where d and t are the grain size and soaking time.

In general, the grain growth with the temperature and soaking time can be expressed as following equation [3]:

$$d^n - d_0^n = C_1 \exp\left(-\frac{Q}{RT}\right) \cdot \Delta t \qquad (5)$$

where d are the grain size, d_0 is the initial grain size, Q is the activation energy, R is the gas constant and n and C_1 are constants.

For UO_2, it is well known that n is 2~5 and Q is 240~620 kJ/mol [3-5]. We decided that n was 2.5 which was used in the fuel performance evaluation code. Figure 2 represents the Arrhenius plot of grain growth rate versus reciprocal absolute temperature. From the figure we found that the activation energy and the constant C_1 of grain growth were 287.97 kJ/mol and 3.05×10^7.
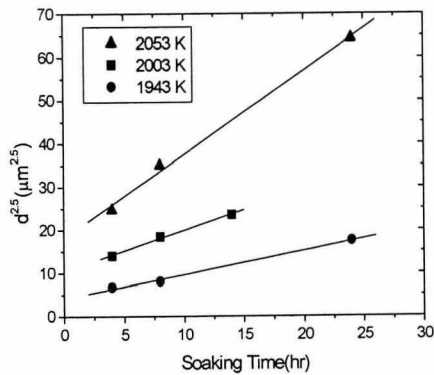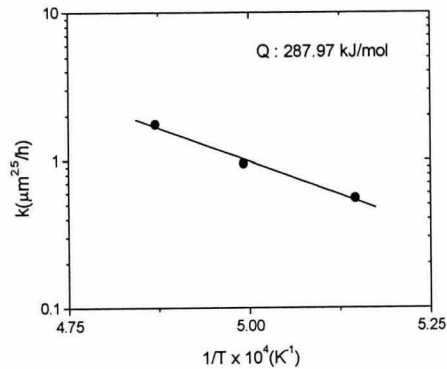

Fig. 1. Grain size with soaking time.

Fig. 2. Arrhenius plot, log k versus reciprocal absolute temperature.

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