Effect of Microstructure on the Critical Thermal Shock Temperature Difference of UO_2-5wt%CeO_2 Pellets

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1. Introduction

The properties of UO_2 and $(U,Pu)O_2$ ceramic oxide nuclear fuel pellets are largely dependent on the density and microstructural characteristics which affect the performance of fuel in reactors. Since the microstructure of nuclear fuel pellets is related to the behavior of fission gas release due to the change of the thermo-mechanical properties by neutron irradiation [1-3], investigations of these properties has widely been carried out during the last several decades. Fuel behavior against thermal stress can be one important property that can give estimations not only for the behavior of the fuels in service operational condition but also for the thermo-mechanical properties of the fuel materials[4], which are affected by material characteristics such as density and microstructure. This paper describes the results of the analyses of the behavior of UO_2-5wt%CeO_2 with different micro-structures, simulating $(U,Pu)O_2$ fuel, against thermal stress by measuring critical thermal shock temperature difference ΔT_C.

2. Methods and Results

2.1 Specimen preparation

UO_2-5wt%CeO_2 pellet specimens with different microstructures were prepared with a Turbula mixer by admixing different dopants (0.05 and 0.1wt% of Li_2O, Al_2O_3 and Cr_2O_3) to the UO_2-5wt%CeO_2 powder mixture, which had been previously homogenized by the improved attrition mill[5]. The powder mixtures containing different dopants were then cold-pressed into green pellets in a cylindrical form with a compaction pressure of 300 MPa. The green pellets were sintered at 1700°C for 4hs in a reducing atmosphere (93%N_2+ 7%H_2) with a final dimension of approximately 8.3mm in diameter and 9.0mm in height. The grain structure and average grain size were evaluated on chemically etched surfaces of the specimens with a H_2O-HNO_3 etching solution and the average grain size was measured by the Linear Intercept method.

2.2 The critical thermal shock temperature difference (ΔT_C) measurement.

The critical thermal shock temperature difference ΔT_C (or thermal shock resistance R) was measured in the range between 80 and 200°C on the specimens which were maintained at the selected temperatures for 30min and then dropped into a water bath at room temperature. The temperature difference was determined which corresponded to an abrupt decrease in fracture strength[6].

2.3 Microstructural characteristics

UO_2-5wt%CeO_2 pellets with different micro structures prepared by adding 0.05 and 1.0wt% of Li_2O, Al_2O_3 and Cr_2O_3 to UO_2-5wt%CeO_2 powder give the range of sintered density between 95.5and 96.8%T.D and the grain sizes between 28 and 37㎛.

2.4 Microstructure and thermo-mechanical properties

The critical thermal shock temperature difference, ΔTc , is an important parameter for thermal stress and thermo-mechanical properties[7]. **Fig. 1** shows the critical thermal shock temperature difference (ΔT_C) of the UO_2-5wt%CeO_2 pellets with the addition of 0.05 and 0.1wt% Li_2O. It is shown that the ΔTc of Li_2O doped UO_2-5wt%CeO_2 pellet (ΔT_C = 70 °C) decreased compared with the UO_2-5wt%CeO_2 pellets (ΔT_C = 150 °C) and the addition of Li_2O decreases the thermal shock resistance, R of UO_2-5wt%CeO_2 pellets.

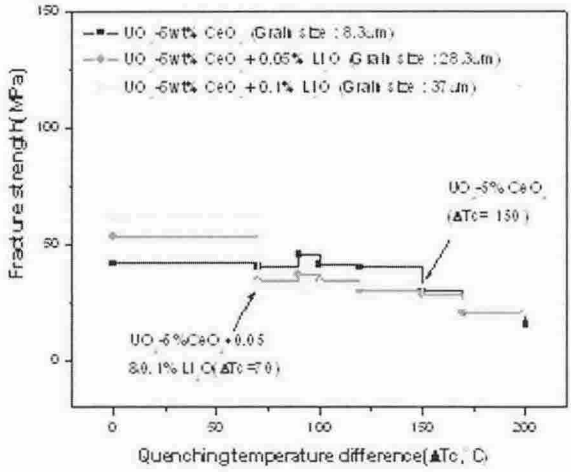

Fig 1. Critical temperature difference (ΔT_C) of the UO_2-5wt%CeO_2 pellets with the addition of 0.05 & 0.1 wt % Li_2O

The critical thermal shock temperature difference (ΔT_C) of the Al_2O_3-doped and Cr_2O_3-doped UO_2-5wt%CeO_2 pellets increased compared with that of undoped UO_2-5wt%CeO_2 pellets. In **Fig. 2 and 3,** it is

shown that the ΔT_C of the UO_2-5wt%CeO_2 pellets with the addition of Al_2O_3 and 0.05wt%Cr_2O_3 (ΔT_C=170 °C) were slightly higher than UO_2-5wt%CeO_2 pellets (ΔT_C =150 °C).

In these results, the ΔT_C in the Li_2O doped UO_2-5wt%CeO_2 pellet decreased compared with that of the undoped UO_2-5wt%CeO_2 whereas that for the Al_2O_3 doped or Cr_2O_3 doped UO_2-5wt%CeO_2 increased to a less extent, irrespective of grain size.

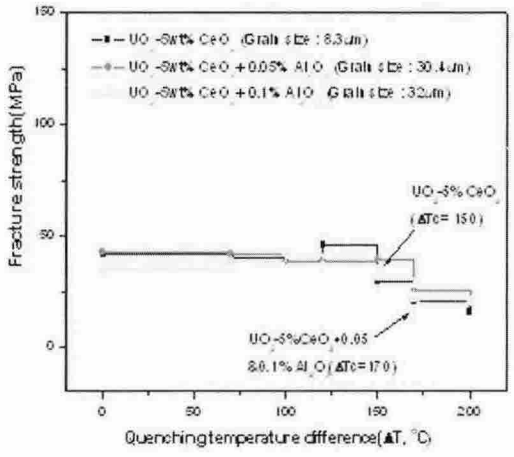

Fig. 2. Critical temperature difference (ΔT_C) of the UO_2-5wt%CeO_2 pellets with the addition of 0.05 & 0.1 wt % Al_2O_3.

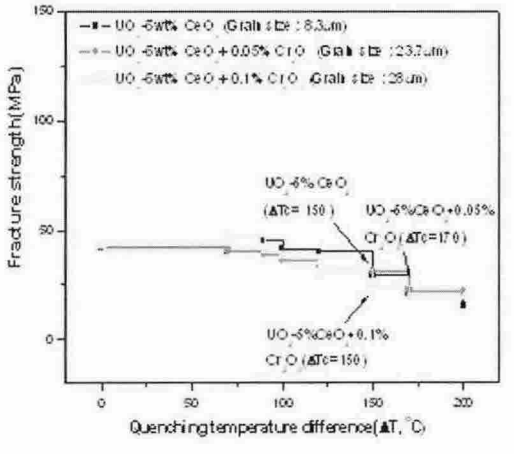

Fig. 3. Critical temperature difference (ΔT_C) of the UO_2-5wt%CeO_2 pellets with the addition of 0.05 & 0.1 wt % Cr_2O_3.

3. Conclusion

The critical thermal shock temperature difference (ΔT_C) was measured for UO_2-5wt%CeO_2 pellets with different microstructures made by use of different dopants (0.05 and 0.1wt% of Li_2O, Al_2O_3 and Cr_2O_3).

UO_2-5wt%CeO_2 pellets with addition of dopants (Li_2O, Al_2O_3 and Cr_2O_3) give the range of sintered density between 95.5 and 96.8% and the grain size between 28 and 37㎛. The ΔT_C in the Li_2O doped UO_2-5wt%CeO_2 pellet decreased compared with that of the undoped UO_2-5wt%CeO_2 one, whereas that for Al_2O_3 -doped or Cr_2O_3-doped UO_2-5wt%CeO_2 increased to a less extent, irrespective of grain size.

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