1-12 Evaluation of the Mechanical Properties of the Fuel Debris

— Relationship between Fuel Debris and the Cladding Tube Components —

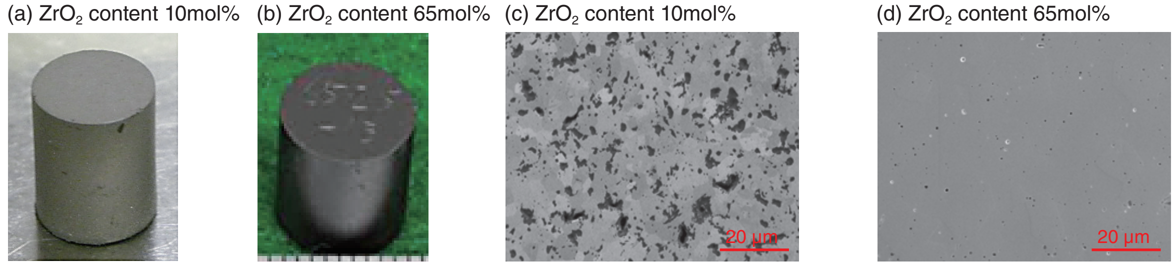

Fig.1-27 External appearance and cross section of the simulated debris

Photos (a) and (b) show the appearance of simulated debris samples with ZrO_2 contents of 10 and 65mol%, respectively. Photos (c) and (d) show the respective cross-sectional images of these samples. ZrO_2 content represents the cladding tube component. There are no defects, such as cracks in the external surface. The portion that is visible in the spotty pattern shows the grain boundary in the cross section. These grain sizes are 10–40 μm.

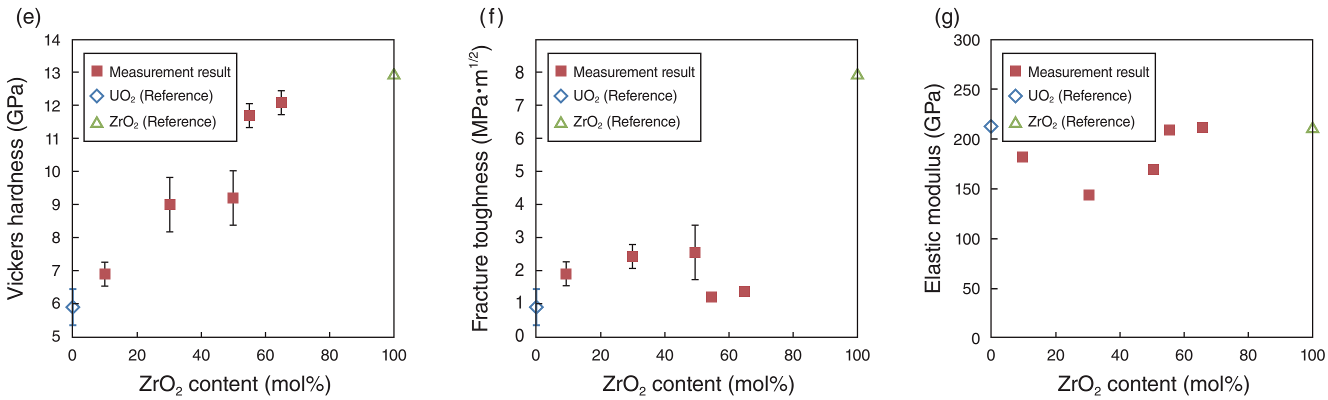

Fig.1-28 Relationship between mechanical properties and ZrO_2 content

These figures show the relationship between (e) Vickers hardness, (f) fracture toughness, and (g) elastic modulus and ZrO_2 content. In particular, ZrO_2 content affects the Vickers hardness significantly and hardness increases with ZrO_2 content.

In the decommissioning of TEPCO's Fukushima Daiichi NPS (1F), one important issue is to perform safe and steady defueling work. Before defueling in 1F, it is necessary to evaluate fuel debris for properties related to defueling procedures and technology. While defueling after the Three Mile Island Unit 2 (TMI-2) accident in the U.S., a core-boring system played an important role. Considering the working principle behind core-boring, hardness, elastic modulus, and fracture toughness were found to be important fuel debris properties that had a profound effects on the performance of the boring machine. It is speculated that uranium and zirconium oxide solid solution ($(U,Zr)O_2$) is one of the major constituents of fuel debris in 1F, according to the TMI-2 accident experience and the results of past severe accident studies. In addition, the zirconium (Zr) content of 1F fuel debris is expected to be higher than that of TMI-2 debris because the 1F boiling-water reactors (BWRs) had a high Zr rate in their constituent materials.

In this report, the mechanical properties of $(U,Zr)O_2$ made with an electric furnace are evaluated in the zirconium dioxide (ZrO_2) content range from 10mol% to 65mol% (Fig.1-27). The hardness, elastic modulus, and fracture toughness were measured by Vickers testing, the ultrasonic pulse echo method, and the indentation fracture method, respectively (Fig.1-28).

In the ZrO_2 content range under 50mol%, the Vickers hardness (e) and fracture toughness (f) of $(U,Zr)O_2$ increased, and the elastic modulus (g) decreased slightly with ZrO_2 content. In the case of 55mol% and 65mol% ZrO_2, all of those measures increased slightly with ZrO_2 content. Summarizing these results, ZrO_2 content affected the mechanical properties significantly in the case of low ZrO_2 content. Higher Zr content (exceeding 50mol%) had little effect on mechanical properties.

In the future, nonradioactive surrogate debris will be necessary for small-scale functional and large-scale mockup tests of various defueling technologies. These results are useful for selecting the material for surrogate debris.

This topic includes a part of the results of "Establishment of basic technology for decommissioning and safety of nuclear reactors for power generation" in FY 2013 that was entrusted to IRID from METI and conducted by JAEA as a member of IRID.

Reference

Hoshino, T. et al., Mechanical Properties of Fuel Debris for Defueling Toward Decommissioning, Proceedings of 23rd International Conference on Nuclear Engineering (ICONE 23), Chiba, Japan, 2015, ICONE23-2111, 6p., in DVD-ROM.