The Japanese government made an international commitment not to possess excess amount of plutonium (Pu) in its utilization plan. A high temperature gas-cooled reactor (HTGR) has inherent safety features; hence, the concept of the Pu-burner HTGR was proposed to safely reduce the amount of recovered Pu.

The minimum unit of the HTGR fuel is coated fuel particle (CFP) with a diameter of approximately 1 mm. Fissile materials and fission products are contained in each CFP. The CFP used in the High Temperature Engineering Test Reactor (HTTR), which is a HTGR test reactor constructed in Oarai Research and Development Institute in Japan, employs a UO$_2$ fuel kernel coated with four-layered coating layers (Fig.6-6). In the Pu-burner HTGR concept, the CFP, whose fuel kernel consists of inert matrix fuel, is employed. The inert matrix fuel should be chemically stable and should be hard to reprocess (Fig.6-7). The nuclear proliferation resistance of the CFP with inert matrix fuel kernel should be high. In this study, yttria-stabilized zirconia (YSZ) containing PuO$_2$ (PuO$_2$–YSZ) was employed as the fuel kernel.

The Nuclear Fuel Industries, Ltd. took charge of the development of fabrication technology of the PuO$_2$–YSZ kernel and fabricated the simulated PuO$_2$–YSZ kernels. We observed the microstructure of a fabricated simulated PuO$_2$–YSZ kernel as a part of the inspections.

Cerium (Ce) was used as the material simulating Pu. The chemical properties of Ce imitate those of Pu. A solution was prepared by dissolving Ce, Y, and Zr nitrate powders in water. The prepared solution was dropped into ammonia water to form gelated particles. These gelated particles were then sintered to form the CeO$_2$–YSZ kernels.

We observed the center region of the fabricated CeO$_2$–YSZ kernel and found that the crystal grains were densely distributed (Fig.6-8). This result indicates the possibility that the fabrication method of the fuel kernel similar to that described above is proper. If the crystal grains are not densely distributed, the fuel kernel may not contain enough Pu.

This study includes the results of the “Development of Security and Safety Fuel for Plutonium Burner HTGR” performed under the Innovative Nuclear Research and Development Program by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan.

(Jun Aihara)

Reference

Fig.6-6 Fuel of the High Temperature Engineering Test Reactor (HTTR) in Japan Atomic Energy Agency

A UO$_2$ fuel kernel was coated with four-layered coating layers to form a coated fuel particle (CFP) with a diameter of approximately 1 mm. Compacts were put into a graphite sleeve to form a fuel rod.

Fig.6-7 Structure of the CFP with (chemically) inert matrix fuel and its nuclear proliferation resistance

The yttria-stabilized zirconia (YSZ) used in this CFP as the inert matrix is chemically stable and insoluble in acid and alkali. YSZ makes the fuel difficult to reprocess and increases the nuclear proliferation resistance of fuel.

Fig.6-8 Microstructure of the center region of the CeO$_2$–YSZ kernel (scanning transmission electron microscopic bright-field image)

There are hardly spaces between crystal grains. If the crystal grains are not densely distributed, the fuel kernel may not contain enough Pu.