6–3 Improving the Fuel Safety of High Temperature Gas-Cooled Reactors during Severe Oxidation Accident

–Fabrication of Oxidation-Resistant Fuel Elements for Oxygen Ingress Accidents–

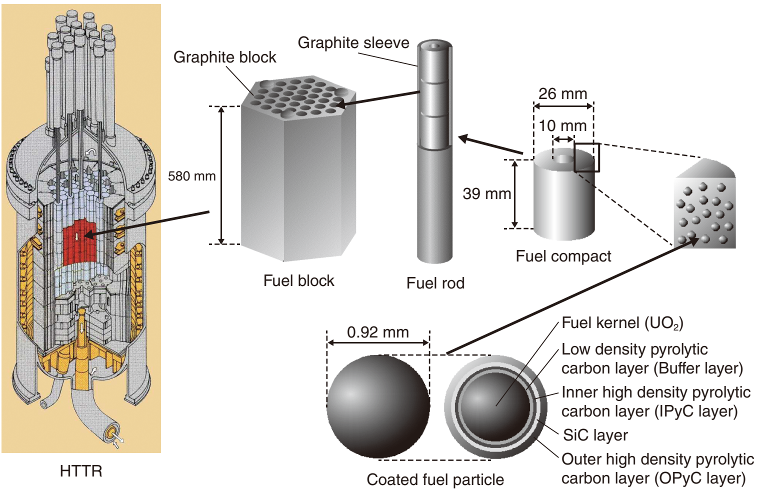

Fig.6-6 Fuel used in HTTR [*1]
A UO_2 fuel kernel is coated with ceramics layers to form a coated fuel particle (CFP) approximately 1 mm in diameter. A mixture of CFPs, graphite powder, and resin is sintered to form a fuel compact. Fuel compacts are put into a graphite sleeve to form a fuel rod. Fuel rods are put into holes of graphite block to form fuel block.

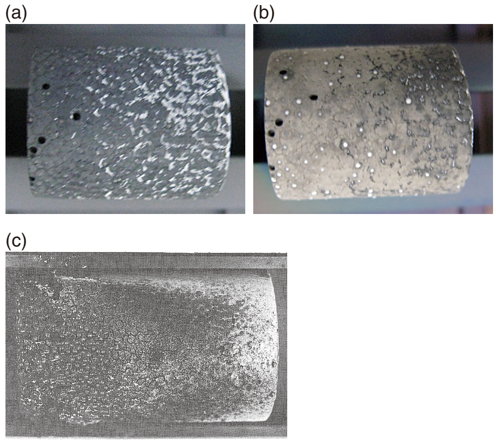

Fig.6-7 Simulated and actual fuel compact
(a) Simulated fuel compact before oxidation.
(b) Simulated fuel compact after oxidation in He including 20% O_2 at 1673 K for 10 h.
(c) Fuel compact after oxidation in air at 1673 K for 2 h. [*2]

High Temperature Gas-cooled Reactors (HTGRs) are safe next-generation reactors with cores that will not melt. Further safety improvements of the HGTR relies on improve the oxidation resistance of the fuel for the severe oxygen ingress into the core, because almost volume of the cores of the HTGRs consist of graphite (solid C, but not diamond). The graphite is oxidized into CO or CO_2 in the oxidation atmosphere at high temperatures.

A small sphere containing fissile materials is coated with layers of ceramics to form a coated fuel particle (CFP) approximately 1 mm in diameter, as shown in Fig.6-6, which are then used in HTGRs. A mixture of CFPs and starting materials of binding material is sintered to form a fuel element. The fuel elements for the High Temperature Engineering Test Reactor (HTTR) of the Japan Atomic Energy Agency (JAEA) are called fuel compacts, of which the binding material is graphite. The binding material is then oxidized into CO or CO_2 gas in an oxidation atmosphere at high temperatures. Then the binding material can finally vanish completely in oxidation atmosphere at high temperatures.

An oxidation-resistant fuel element using a binding material of SiC and graphite was developed via collaboration between JAEA and Nuclear Fuel Industries, Ltd. (NFI). SiC is oxidized into a solid oxide, not a gaseous oxide, and does not vanish under high temperature and high oxygen partial pressure. In this study, a simulated fuel element (a simulated fuel compact) with binding material of SiC and graphite was fabricated and an oxidation test was carried out using the simulated fuel compact to investigate whether the oxidation resistance of the fabricated simulated fuel compact is better than that of the fuel compact with graphite binding material or not.

Simulated CFPs (alumina particles) and binding material (Si powder, graphite powder and resin) were molded and sintered into a simulated fuel compact (Fig.6-7(a)), which was then oxidized in He including 20% of O_2 at 1673 K for 10 h. The fraction of O_2 was set to be similar to air. After oxidation (Fig.6-7(b)), all simulated CFPs were kept in the simulated fuel compact. On the other hand, in a past study, a part of CFPs were loosened from a fuel compact with the graphite binding material by the partially vanishment of the binding material after oxidation in air at 1673 K for 2 h (Fig.6-7(c)). Thus, it was shown that the oxidation resistance of the fabricated simulated fuel compact is better than that of the fuel compact with graphite binding material.

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[*1] Goto, M. et al., Conceptual Design of Small-Sized HTGR System (II) - Nuclear Design -, JAEA-Technology 2012-017, 2012, 29p. (in Japanese).
[*2] Kikuchi, H. et al., Air Oxidation Behavior of Fuel for the High Temperature Engineering Test Reactor (HTTR), JAERI-M 92-114, 1992, 20p. (in Japanese).

Reference
Aihara, J. et al., Development of Fabrication Technology for Oxidation-Resistant Fuel Elements for High-Temperature Gas-Cooled Reactors, Transactions of the Atomic Energy Society of Japan, vol.18, no.1, 2019, p.29–36 (in Japanese).