Development of Metal Fuel Cycle Technology for Practical Application

Background and Objective

CRIEPI has been developing an innovative fast reactor fuel cycle – metal fuel cycle – where a uranium-plutonium alloy is used as fuel (metal fuel) and metallurgical processes are adopted for reprocessing (pyroprocess) and fuel-fabrication (Fig. 1). The metal fuel cycle has many advantages: high fuel burnup capability and inherent reactor safety due to high thermal conductivity of metal fuel; high proliferation-resistance due to the inseparability of plutonium in pyroprocess technology; less environmental burden due to recovery and transmutation of long-lived minor actinides (MA: Neptunium, Americium and Curium); and high cost performance of the whole system. Global interests are focused on these distinctive features. In the United States and Asian counties such as South Korea, China and India, the metal fuel cycle is selected as the commercial candidates of fast reactor cycle. In Japan, fuel cycle utilizing oxide fuel and aqueous reprocessing has been selected as the main concept for the commercialization. The metal fuel cycle is determined to be a long term option because it has a potential to be superior to the main concept but less domestic experience. The current issues in the metal fuel cycle development are fuel irradiation tests, pyroprocessing tests with irradiated fuel, and the accumulation of demonstration data by conducting engineering-scale equipment development.

Main results

1. Irradiation tests of MA-bearing metal fuel in the fast reactor Phénix

In order to demonstrate the irradiation performance of MA -bearing metal fuel, the MA -bearing metal fuel pins (Fig. 2) were irradiated to 100,000 MWd/t burnup in the French reactor Phénix. The fuel pins irradiated to 25,000 MWd/t burnup, at which the fuel swelling is significant, were examined in collaboration with Joint Research Center - Institute for Transuranium (JRC-ITU). The examination results suggested that up to 25,000 MWd/t the irradiation performance of the MA-bearing metal fuel is equivalent to that of the MA-free metal fuel.

2. Development of engineering-scale pyroprocess equipment*

High cost performance of the pyroprocess can be attained even at a small-scale plant of a few tons per year (t/y) capacities, which is not the case with the aqueous process. A high capacity pyroprocess plant is realized by a parallel installation of the process equipment. The demonstration of an engineering-scale equipment of a few t/y capacities is, therefore, a key step toward the commercialization of the pyroprocess. For the demonstration, the main process apparatuses – reduction to metal, electrorefining, and fuel casting – equivalent to ~1 t/y capacity were designed and manufactured (Fig. 3). Repeated recycle tests with uranium will demonstrate their performances in the next year.

3. Demonstration of actinide recovery from irradiated oxide fuel by pyroprocess method

By using a pyroprocess method, uranium, plutonium and minor actinide alloys were successfully recovered from irradiated mixed oxide fuel for light water reactors (Fig. 4) in collaboration with JRC-ITU. This is the first demonstration of MA recovery, which leads to a reduction of the environmental burden of radioactive waste.

*Part of this work is the results of “Development of metal fuel cycle technology for closing FBR fuel cycle” entrusted to CRIEPI by the Ministry of Education, Culture, Sports, Science and Technology (MEXT)

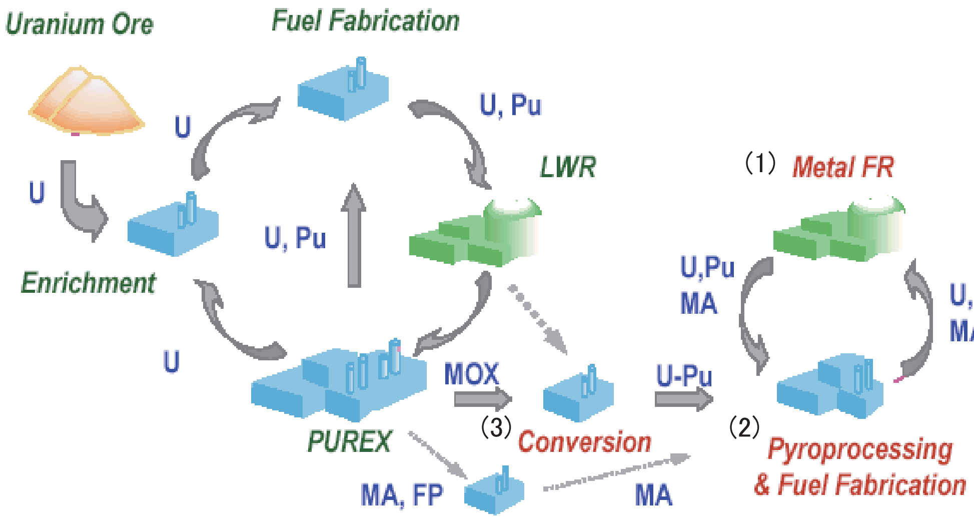

Fig. 1 Metal fuel cycle and light water reactor cycle.

Metal fuel cycle for a fast reactor is closely combined to current light water reactor cycle via pyroprocess technologies. The main results 1, 2 and 3 correspond to the technologies (1), (2) and (3) in the figure.

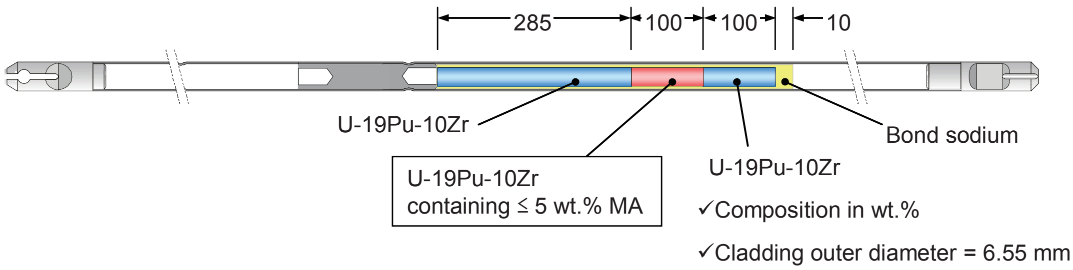

Fig. 2 MA-bearing metal fuel pin irradiated in the fast reactor Phénix.

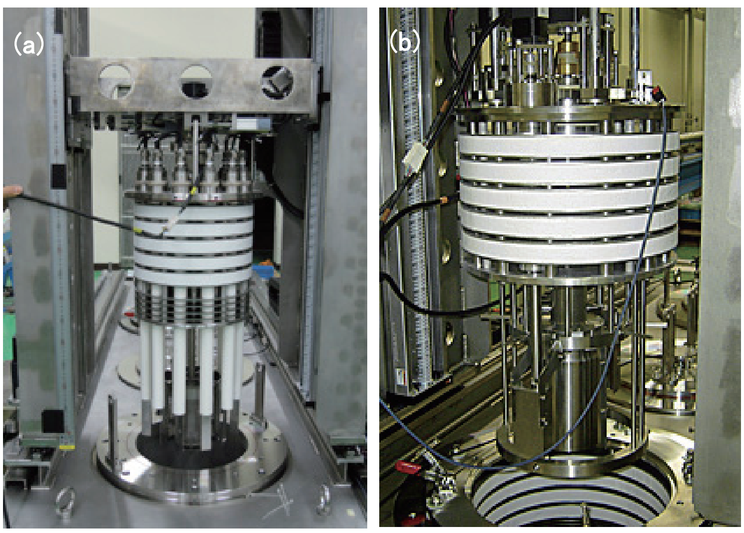

Fig. 3 Engineering-scale experimental apparatuses

(a) Electrochemical reduction apparatus for conversion of oxide fuel to metals, (b) Electrorefining apparatus for recovery of uranium from reduced metals.

These apparatuses enable us to demonstrate the throughput and reliability of the pyroprocess at a larger scale toward realization of the engineering-scale pyroprocess tests with irradiated fuel.

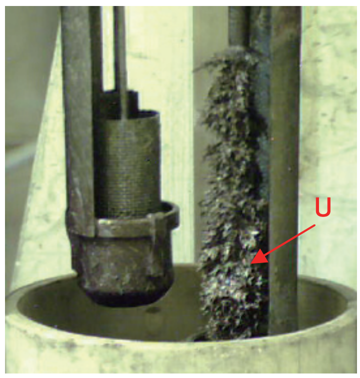

Fig. 4 Uranium metal recovered from irradiated oxide fuel.

Uranium metal showing characteristic dendritic morphology was recovered onto the iron rod on the right hand from the reduced oxide fuel in the crucible on the left hand.