NEW MATERIALS AND COATINGS FOR NUCLEAR TECHNOLOGY

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In order to eliminate severe accidents in new generation fast nuclear reactors, it is possible to use pellet fuel based on micrograins of ceramics UO_2-Pu_4O_7 (MOX) or UN-PuN (MN) and depleted (dump) uranium metal nanopowder. The technology for producing such fuel is known. It was developed for VVER in JSC "V.G. Khlopin Radium Institute" (St. Petersburg, Russia, 2011) and involves sintering of micropowder of ceramics and nanopowder of metal hydride. The nature of the emergency conditions in a reactor with MOX-U-fuel (about 20% U by weight) and MN-fuel is almost the same. First of all, emergency modes, accompanied by a failure of emergency protection (ATWS - anticipated transients without scram), and their combinations were considered. The role of the Doppler reactivity coefficient is approximately the same in different emergency conditions. As a result, optimization of the layout of the reactor with restrictions for the functional models simulating the safe termination of ATWS modes is not in conflict.

The most preferred fast reactor fuel (the ATF - Accident Tolerant Fuel) can be considered MN fuel with the addition of U nanopowder (about 20% by weight). MN-U is a high temperature fuel. Emergency behavior is similar to using metallic fuel. The role of the Doppler reactivity coefficient is the same in all emergency conditions. (When using MOX fuel, this role is different.)

To increase the safety of fast reactors, lead coolant is more preferable. The self-protection of the reactor depends on the isotopic composition of lead. By maximizing the content of the twice-magic 208Pb, the neutron balance improves. Additional opportunities are opening up for the disposal of radioactive waste and to increase the breeding ratio, including in the core (BRC). When using MOX-U or MN-U fuel, it is easily achievable BRC = 1, which eliminates large reserves of burnup reactivity: the core operates in self-supplying fuel (the operating and burning rates of fissile nuclides are the same). The use of a coolant based on 208Pb reduces the void effect of reactivity to safe values even in reactors of infinitely high power. Weak absorption of neutrons by 208Pb nuclei contributes to an increase in the lifetime of instantaneous neutrons, which is important to eliminate reactive accidents that pose a potential danger to fast reactors.

Optimization of the composition of lead coolant does not require isotope separation. The maximum content of ^{208}Pb is characteristic of lead of thorium ores (^{208}Pb is the final decay product of ^{232}Th), ^{206}Pb is characteristic of lead of uranium ores (^{206}Pb is the final decay product of ^{238}U).

The use of cladding of tungsten-coated fuel rods on both sides, deposited using low-temperature plasma spraying, can improve the reliability and safety of lead-cooled reactors without impairing (and possibly improving) the economic characteristics of nuclear power plants. The use of tungsten coatings of the claddings will reduce the rate of corrosion and erosion in liquid lead, the void effect of reactivity, will open up the possibility of using cheap lead, which is more contaminated with impurities.

It is possible to adapt new materials for other types of nuclear technology. The problem of ATF search with increased (compared to UO_2) thermal conductivity is relevant for thermal neutron reactors. It can be $UO_{2,1}$, UN, U_2N_3, U_3Si_2 fuel (with a much lower concentration of fissile nuclides) with the addition of a low enriched U nanopowder (to increase the reactor power and increase the density and thermal conductivity of the fuel) or Be (BeO).

Ceramic fuel containing depleted uranium with U nanopowder can be used in the blanket of a thermonuclear reactor. As a neutron multiplier, ^{237}Np, ^{241}Am and ^{243}Am nuclei (long-lived radioactive waste to be disposed of) are more preferable than beryllium. The cross section for their fission in the spectrum of thermonuclear neurons is approximately 10 times higher than the cross section for the (n, $2n$) reaction on ^{9}Be nuclei. At neutron energies above 6 MeV, reactions (n, $2n$) are realized on Np and Am nuclei. When using a liquid metal coolant containing lead, tungsten coatings of fuel claddings are of interest.

All the proposed innovations can be implemented within the framework of existing technologies.

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