SIMULATION OF PLASMACHEMICAL SINTHESYS OF OXIDE AND CARBON-OXIDE COMPOSITIONS FOR DISPERSION NUCLEAR FUEL

Alyukov E., Novoselov I., Poberezhnikov A.
Supervisor: Karengin A., PhD, Associate Professor
Tomsk Polytechnic University, Russia, Tomsk, Lenin Ave, 30
E-mail: john.judo@mail.ru

Modern atomic energetics using oxide nuclear fuel (NF) in form of uranium dioxide (enriched in uranium-235) in thermal neutron reactors (TNR) has many advantages as well as disadvantages. Major disadvantages are low thermal conductivity (4.5 kJ/(m·K)), which limits specific capacity of reactor in melting temperature; frailty of ceramic fuel and possibility to fracture at high temperatures; short usage cycle (refueling every 3–5 years); impossibility to create low (10–100 MW) and extra low (up to 10 MW) capacity power generation systems; high costs on spent NF utilization; uranium-235 finite life. These factors slow down the atomic energetic development based on using TNR and lead to refusal of it in several countries.

One of the upcoming trends in atomic energetics development is creating reactor systems which use dispersion NF. In that fuel granular oxide nuclear compositions (uranium, thorium, plutonium, etc.) are placed in matrix (aluminum, molybdenum, stainless steel, etc.). Dispersion NF characterized by lack of direct contact between granules due to their regular distribution in matrix and has the following advantages: high thermal conductivity and mechanical properties; low formation of gaseous fission products; high fuel burnout (up to 120 MW·day/kg); high nuclear hardness; high durability, providing TVEL geometric stability; localization of fission products in granules; low heat reserve in fuel; low escapement of radioactive fission products in heat transfer agent circuit in case of cover failure; possibility to control the reactor online. In case of usage uranium-238, thorium-232 and plutonium-239 there is no need to apply high cost isotope enrichment and NF usage cycle could be raised to 10–15 years. Taking into account the fact that uranium-235 is limited product usage of uranium-238, thorium and plutonium as dispersion NF basis gives new prospects.

However dispersion NF has some substantial disadvantages: parasitic neutron capture by matrix material, that makes fuel neutron balance worse; necessity to apply high enriched materials, that rises risk of fuel critical mass excess. Besides, technological scheme that is used to obtain granulated oxide compositions for dispersion NF from mixed nitric solutions (MNS) based on sol-gel process that has many longtime and laborious stages [1].

Application of low temperature plasma is promising to MNS treatment. However plasma treatment of only MNS requires significant energy costs (up to 4 MW·h/t). Major advantages of plasma technology are: one-stage process; high processing speed; homogenous stoichiometrically-defined phase distribution; possibility to have an impact on particle size and particle morphology; compactness of technological equipment; low energy costs.

Article represents results in simulation of plasma treatment of MNS in form of water-salt-organic compositions (WSOC). Authors defined formulations of WSOC (MNS-acetone, MNS-ethanol) based on burning rates calculation. Such compositions have low caloric value minimum 8.4 MJ/kg and adiabatic combustion temperature minimum 1200 °C and provide lowering energy costs (to 0.1 MW·h/t) and obtaining additional thermal energy (to 2 MW·h/t). As a result authors defined operational modes providing direct plasmachemical synthesis of oxide («UO_2–PuO_2», «UO_2–ThO_2», «PuO_2–ThO_2») and carbon-oxide («UO_2–PuO_2–C», «UO_2–ThO_2–C», «PuO_2–ThO_2–C») compositions.

REFERENCES

1. Toumanov I.N., Sigailo A. V. Plasma Synthesis of Disperse Oxide Materials from Disintegrated Solutions // Materials Science and Engineering. 1991.– Vol. A140.– P. 539-548.