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Development and integration study of fusion-fission hybrid systems into nuclear power fuel cycle

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The improvement of nuclear power thermal reactors, the development and creation of fast reactors accompanied with the transition to a closed nuclear fuel cycle are being carried out at present time. In this regard, it is important to develop technologies for the management of spent nuclear fuel and radioactive waste, as well as the development of fusion and "fusion-fission" hybrid systems. The combination of nuclear fusion and fission reactions in one design makes it possible to achieve fundamentally new characteristics and parameters of the nuclear energy system.
Further development of fusion-fission hybrid facility based on superconducting tokamak DEMO-FNS [1-3] continues in Russia for integrated commissioning of steady-state and nuclear fusion technologies at the power level up to 40 MW for fusion and 400 MW for fission reactions. As a part of this state program, the hybrid fusion-fission system based on the superconducting tokamak DEMO-FNS is ongoing in Russia. The general views of the DEMO-FNS facility and its vacuum vessel are shown in Fig. 1.

Fig.1 The general view of the DEMO-FNS facility and vacuum vessel

The DEMO-FNS facility uses a conventional tokamak design with a fusion power of up to 40 MW as a neutron source. The project aims at achieving the stationary operation of the facility with the neutron wall load of ~ 0.2 MW/m2 and the neutron fluence over the life cycle of ~ 2 MW•year/m2, with the subcritical transmutation zone and the tritium production zone surfaces of ~ 100 m2. This is sufficient for testing materials and components in the spectrum of DT thermonuclear neutrons, as well as for energy production, transmutation technology, production of fission fuel nuclides and tritium. Previous design options were presented at the FEC-2016 and FEC-2018 conferences [2, 3]. Results of the engineering design activity of NRC Kurchatov institute and collaborators performed in 2019-2020 are presented in this report.
The objectives of the 2019 project were focused on developing new simulation tools and plasma scenarios, improving the characteristics of the tokamak enabling systems, implementing upgraded and new systems in the ongoing design. Those are the first wall, vacuum vessel, divertor, core, blanket - tritium production, injection of neutral atoms, fueling and pumping, heat transfer, remote handling in an integrated device. Analysis of the integration of hybrid systems in Russia's nuclear power industry was started.
The physical models of the Goldstone and Nagayama lithium-vapor divertor were used to evaluate the possibilities of using lithium technology to provide the stable operation of the installation. The main problem of this solution is related to the very high temperature of the external surface in it (> 700 ℃), which requires certain structural materials, such as Mo and coolants, such as He increasing the dimensions of this divertor option.
The study of the primary damage under various damage energies and temperatures by the molecular dynamics method was carried out for bcc metals Fe and V, which form the basis of improved materials for hybrid facilities. The possible physical mechanisms underlying the observed features of the obtained energy and temperature dependences of the number of Frenkel pairs and cluster size distributions are determined and will be presented.
The main goal of the activity in 2019 was to study technical solutions that lead to the integration of tokamak systems and hybrid systems, including active transmutation cores, a tritium blanket and a remote handling system. This report presents the technical requirements that determine the current design structure of the hybrid blanket and coolants. Steady state heating and current drive is maintained in tokamak by the NBI system with 6 injectors, 5 of which operate in 2 hour-cycle with sequential recuperation and one may be used for repair and maintenance procedures. Total power of 500 keV deuterium beams is 30 MW. Optimization of beam transport ducts using beam transport code allowed reduction of their cross section to 0.4⊠0.8 m2 . These upgraded design parameters will be presented and considered in the report.
The possibility of using supercritical CO2 as a coolant for active cores, the tritium blanket, the first wall and the divertor was evaluated. This coolant is more attractive compared to the water coolant due to its allowable pressure range (~ 75 bar) and temperature (up to ~ 500℃), low neutron activation, keeping of the hard neutron spectrum and better compatibility with lithium technologies.
The analysis of the interaction of the DEMO-FNS facility and further industrial options with the nuclear fuel cycle of nuclear energy is carried out. Such a facility could provide the burning of minor actinides accumulated

by Russian nuclear energy fuel cycle during the operation of nuclear power plants in the future. Returning spent fuel to a closed fuel cycle after enrichment in a hybrid industrial facility will reduce the number of nuclear fuel storage facilities and generated radiotoxicity.
The objectives of the research in 2020 are:
• improvement of electronic models and codes for evaluating plasma-physical parameters and the DEMO-FNS tokamak scenario;
• development of models for evaluating the modification of the properties of structural and functional materials in the fission-fission neutrons environment, choice of materials proof;
• development of a neutron-physical model of a hybrid blanket, including an active core with minor actinides and a zones of tritium and fuel nuclides breeding;
• development of requirements to structural and functional materials, test stations, test conditions and prototypes.
References
1. B.V. Kuteev, E.A. Azizov, P.N. Alexeev, V.V. Ignatiev, S.A. Subbotin and V.F. Tsibulskiy // Development of DEMO-FNS tokamak for fusion and hybrid technologies. Nucl. Fusion 55 (2015) 073035 (8pp) p.1-8.
2. B.V. Kuteev, Yu.S. Shpanski and DEMO-FNS Team // Status of DEMO-FNS development / Nucl. Fusion, 57 (2017) aa6dcb.
3. Yu.S. Shpanski and DEMO-FNS Team // Progress in the design of the DEMO-FNS hybrid facility / Nucl. Fusion, 59 (2019) ab14a8.

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