Abstract

on the report of M.V. Bulavin "State of work on the project of a new neutron source at JINR" at the 58th PAC on Condensed Matter Physics

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The report presents the results of work for 2023 and work plans for 2024 on the project "New advanced neutron source at JINR" with the subproject "Research and development for the justification of the draft design of the new advanced neutron source at JINR - NEPTUNE pulsed fast reactor", implemented within the framework of a large scientific and technical research infrastructure project No. 04-4-1149-2024/2028 "Pulsed neutron source and complex of spectrometers".

1. *A model of the dynamics of a pulsed reactor and the choice of the optimal active core configuration.*

A model of the dynamics of the NEPTUNE reactor has been developed. The current version of the computer program considers the effect on reactivity of various physical processes (fuel expansion, thermoelastic cross deformations of fuel rods, friction of the medium), as well as the design of the core (various types of fixations of fuel rods and their interaction with each other). The model allows us to calculate the pulse energy and determine the parameters of stability of a periodic pulse fast reactor. In addition, the program implements the ability to enable/disable individual modules (blocks), which allows you to compare different calculation models and take into account the influence of individual physical factors.

To implement the model and carry out true calculations of reactor dynamics, it is necessary to carry out theoretical (computational) and experimental work that solves two tasks: 1) obtaining the fuel rod and environment parameters that are used in the model, 2) verification (check) of the operation of individual blocks of the model, as well as the entire model as a whole, amendments and modification of the model.

The main task of research at the RFNC-VNIITF (SC Rosatom) experimental facilities is a direct observation of the phenomenon of dynamic bending of fuel rods in a neutron field, as well as measuring the effect of energy release in fuel on the movement of fuel rod. Currently, work on the computational justification of setting up experiments simulating the main features of thermomechanical processes in the fuel rods of the NEPTUNE reactor performed under the research contract "Study of thermomechanical processes in the fuel rods of the pulsed NEPTUNE reactor. Stage 1" with RFNC-VNIITF has been completed. At the next stage, it is planned to prepare a technical specification and sign a research contract with the RFNC-VNIITF for setting up an experiment with a model fuel rod at the BARS-5M reactor in Snezhinsk. Also, at the moment, design documentation has been produced and work on the manufacture of an experimental stand for periodic heating of a model of fuel rod has begun in the FLNP JINR.

Work on choosing the optimal configuration of the NEPTUNE reactor continues. The analysis of the dynamic properties of the IBR-2M reactor was carried out and a model of thermomechanical phenomena was proposed, which makes it possible to identify critical parameters (including bending of fuel rods and fuel rod assemblies) in the power pulse, causing instability of the reactor power after a certain degree of fuel burnout. The results of this work are used to substantiate the stability of the NEPTUNE reactor in the variant of the core configuration with fuel rod assemblies (FRA).

1. *Development of fuel for a new neutron source*

Together with JSC VNIINM (SC Rosatom), a "Program for pre-reactor studies of the properties of fuel compositions for fuel rods of the NEPTUNE reactor" was agreed. The technical specification for the implementation of research and development work "Preparatory work for the development of fuel from neptunium nitride and fuel rods based on it for the NEPTUNE reactor" is also being coordinated, within which it is planned to prepare documentation for the production of 4 kg of nuclear material - neptunium-237, as well as to prepare to conduct experiments on the manufacture of a fuel tablet from neptunium nitride on the basis of JSC VNIINM.

2. *Optimization of reactor design*

Together with JSC NIKIET (SC Rosatom) work on the R&D "Computational substantiation of design solutions for the reactivity modulator and the vessel of the NEPTUNE periodic pulse reactor" is underway. Based on the results of this R&D, the degree of operability of the most loaded reactor elements will be determined and the assessment of the reasonableness of the transition to the stage of the draft design of the reactor facility of the new NEPTUNE neutron source will be given. In the New Neutron Source Department FLNF, together with JSC NIKIET, thermal calculations of the reactivity modulator are being carried out (clarified) in order to determine the maximum heating of titanium hydride in the operating mode of the NEPTUNE reactor and determine the conditions under which titanium hydride retains its properties. Work to substantiation technical solutions that create conditions that prevent possible overheating of titanium hydride: inserts made of nickel, boron carbide, thermal insulation gaskets, etc. is underway.

3. *Development of the NEPTUNE reactor reactivity modulator*

Currently, «Research on the development of manufacturing technology for titanium hydride plates for use in structural elements of the reactivity modulator of the NEPTUNE pulsed reactor» is underway. The contractor is Grankom LLC, Kulebaki, Vladimir Region. To find the optimal mode of manufacturing titanium hydride plates using the method of hot isostatic pressing, two samples with a diameter of D =40 mm and a length of L = 400 mm were made: No. 1 – with an exposure time of 2 hours at a pressing pressure of P = 105 MPa and a temperature of 922 ° C, No. 2 – with an exposure time of 2 hours at a pressing pressure of P=104 MPa and temperature T=499 °C.

At the next stage, it is planned to measure the quantity of hydrogen in both samples, including irradiation under conditions in which the dose load on the samples will be comparable to the calculated dose load on the reactivity modulator in operating mode, and compare the obtained hydrogen concentration values with the required values for the reactivity modulator of the NEPTUNE reactor (at least 3.3 ±0.2%). After obtaining a sample with the required hydrogen quantity, work to determine the mechanical properties of the compressed sample will be performed.

The final stage of manufacturing titanium hydride plates involves the manufacture of prototypes with geometric dimensions corresponding to the actual dimensions of the reactivity modulator plates.

A list of R&D projects is being developed to carry out work on creating a model of the reactivity modulator of the NEPTUNE reactor.

4. *Moderator complex*

The analysis of the efficiency of using hydrogen-containing materials as cryogenic moderators at the new NEPTUNE reactor continues. One of the main options offered for use is the aromatic hydrocarbon mesitylene in the form of solid frozen beads. Currently, the optimal configuration of such moderator has been determined: a water pre-moderator with a thickness of 4 cm and a cryogenic mesitylene beads moderator with a thickness of 3 cm.

Due to the high dose load, the operability of the beads mesitylene moderator at the NEPTUNE reactor will be provided by a fast change system of the working substance in the chamber, the concept of which is currently being worked out. The creation of a prototype cryogenic beads moderator chamber with such fast change system of working substance system is planned

on the basis of the test stand of the cryogenic moderator CM201 in the experimental hall of the IBR-2 reactor.

The work plans for the development of cryogenic moderators of the NEPTUNE reactor also include calculations to determine the optimal configuration of the chamber with a working substance based on liquid hydrogen.

5. Scientific program

Materials for scientific program are being prepared and its implementation at a new neutron source is being discussed, the composition of scientific instruments with sample environment systems and the configuration of the moderator complex is being discussed.