§15. Investigation of Issues in Neutronics Evaluations for Advanced Liquid Blanket Systems

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The purpose of the present study is to investigate issues in neutronics evaluations for the Flibe-cooled and Li-cooled blanket systems. Benchmark experiments at the FNS (Fusion Neutornics Source) facility of JAEA have been also considered to verify the accuracy of the evaluations performed with neutron transport calculation system. Most of the benchmark experiments with the DT neutron source have been focused on a single material or features of solid breeder blanket systems. A proposal of the benchmark featuring the advanced liquid blanket systems has been discussed especially on the basis of the blanket design for the helical-type reactor FFHR2.

The neutronics performances of the advanced blanket systems in the FFHR2 have been evaluated with 3-D neutron transport calculations on the helical configuration. The results of the evaluations indicated that both of the Flibe-cooled and Li-cooled blanket systems would achieve sufficient tritium breeding and shielding performance. As to the benchmark for the Flibe breeder/coolant, it is difficult to obtain the sufficient amount of Flibe for the experiment at present. In contrast, Li breeder/coolant consists of the single element and the FNS facility stores a large number of small solid Li blocks for benchmark experiments. The blocks are canned in thin stainless steel cases. Therefore, investigation of the benchmark experiment has been started for verification of the neutronics performance in the Li-cooled blanket system.

Figures 1 (a) and (b) show the structure of the Li/Vanadium-alloy blanket system and the distribution of tritium production rate (TPR) in the Li breeding layer calculated with the neutron transport code MCNP-4C and the nuclear data library JENDL-3.2, respectively. Results for the geometries without the vanadium-alloy structures and the shielding layer are also plotted to examine their impact on the tritium production. Comparison of the TPRs indicates that the vanadium-alloy structures significantly enhance the tritium production around the first wall through the (n, 2n) reaction. The shielding layer also enhances the tritium production at backside through the reflection of neutrons. In the benchmark experiment on the tritium breeding of the Li-cooled blanket system, the neutron transport in the vanadium-alloy structures including the (n, 2n) reaction and its impact on the tritium production are important factors to be verified in addition to those in the Li breeding layer and the shielding layer.

Based on the investigation described above, benchmark experiments at the FNS facility have been planned for the verification of the neutron transport and tritium production in the Li-cooled blanket system, a mock-up constructed with solid Li and vanadium blocks as shown in Fig. 2. Measurement methods and procedures for the verification have been discussed. The experiment is planned to start with activation detectors and to expand to tritium production measurement with Li_2TiO_3 pellets, neutron spectrum measurement with scintillation detectors etc. The neutron shielding performance of the Li-cooled blanket system is also an important factor to be verified with the mock-up.

As to activation properties of the materials for the advanced liquid blanket systems, which are important from the safety aspect, DT neutron irradiations have been performed on foils of teflon (for fluorine in Flibe), vanadium-alloy NIFS-HEAT2 (Structural material) and metal erbium (Er_2O_3 electrical insulator) in this year. The accuracy of activation calculation system has been evaluated for eight radioactive nuclides by comparison with the radioactivities obtained from gamma-ray measurements after the irradiations. The activation experiment is also planned using the Li mock-up.

Data analysis after the experiments and feedback to the blanket design activity will be discussed in this collaborative study. Investigation of neutronics issues in the Flibe-cooled blanket system also has been continued in parallel for improvement of the blanket design and the future benchmark experiment.

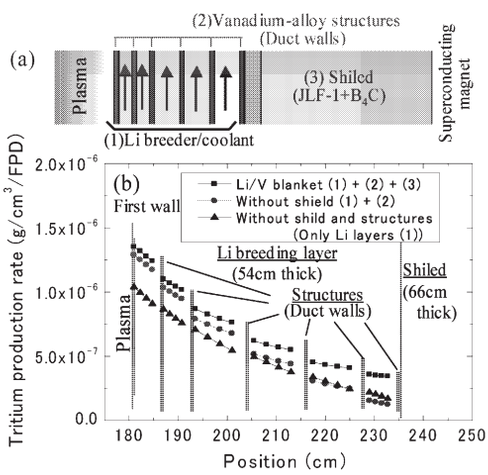

Fig. 1. (a) Structure of Li/V-alloy blanket system. (b) Contribution of structures and shielding layer on tritium production rate.

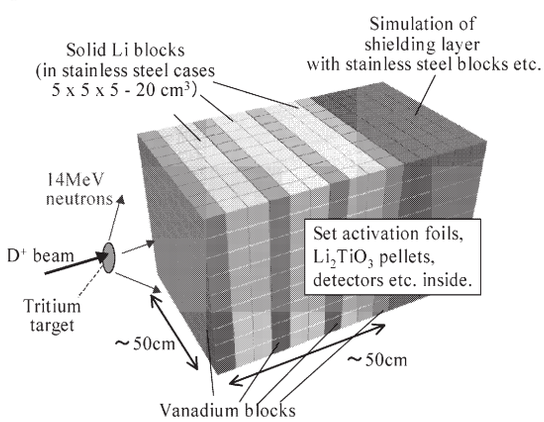

Fig. 2. Tentative drawing of Li mock-up for benchmark experiment for Li-cooled blanket system.