§8. Neutronics Investigations of FFHR2 Liquid Blanket Systems

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Neutronics investigations of the advanced liquid blanket systems in the FFHR2 design have been conducted using the 3-D neutronics calculation system developed for the helical reactor design activity.[1] In the present study, the 3-D calculation system has been improved by installing the new features such as [1] geometry definition method improved for increasing the maximum cell number, [2] simulation of the helical-shaped plasma distribution, [3] 3-D visualization of calculated results. Using the improved system, remaining issues of [1] tritium breeding ratio (TBR) evaluation for the multi-layered Spectral-shifter and Tritium breeding Blanket (STB) concept [2], [2] accurate evaluation of the peaking factor in the neutron wall loading distribution, [3] evaluation of neutron streaming and reflection in the FFHR2 reactor including the vacuum vessel, support structures, cryostat etc., [4] evaluation of neutron shielding performance for the superconducting coils, have been investigated.[3]

The TBR for the multi-layered Flibe cooled STB concept has been evaluated by simulating the multi layered structure of the carbon armor, first wall, Flibe breeder/coolant layer, Be neutron multiplier layer. Since neutron energies are attenuated by the 16 cm thick carbon armor facing to the core plasma, the TBR is significantly sensitive for the JLF-1 ferritic steel first wall. The result of the evaluation indicate that the adequate TBR of 1.05 would be achieved by reducing the first wall thickness to 5 mm. In the present FFHR2m1 design, it has been confirmed that all of four types of advanced blanket systems, i.e. Flibe+Be/JLF-1, Flibe cooled STB, Li/V-alloy, Flibe/V-alloy blankets, could achieve adequate TBRs >1.0 by the design efforts.

The neutron wall loading on the first walls has been evaluated more accurately by assuming the helically rotating plasma distribution with an elliptical cross-section. The averaged neutron wall loading of 1.5 MW/m^2 has been given in our previous neutronics investigations using a simple torus blanket model and a uniform torus plasma distribution.[4] In the present evaluation simulating the helical blanket configuration and the helical plasma distribution, the maximum neutron wall loading was 1.8 MW/m^2. The result indicates that the peaking factor of the distribution is moderated as low as 1.2 by the helical effect of the plasma distribution.

Neutron shielding performance of the blanket system of FFHR2m1 has been evaluated quantitatively with the calculation geometry including the vacuum vessel, support structures, cryostat etc. as shown in Fig. 1 (a). An example of the calculated fast neutron flux distribution is shown in Fig. 1 (b). For the original blanket configuration, [1] neutron streaming to the helical coils at the inner side of the torus, [2] neutron streaming to the poloidal coils at the outer side of the torus, [3] neutron reflection from the support structure to the back side of the helical coils, have been pointed out as the issues to be improved (Fig. 2). The shielding for the inner side of the torus (arrow (1) in Fig. 2) could be improved by modifying the length and thickness of the blanket layers. However, the neutron streaming for the poloidal coils and reflection to the helical coils (arrows (2) and (3) in Fig. 2) have been remained as the most important neutonics key issues in the present FFHR2m1 design. Attenuations of fast neutron fluxes by one order for the poloidal coils and by two orders for the helical coils are required to satisfy the design target of the fast neutron shielding < 1.0×10^{10} $n/cm^2/s$ at superconducting magnets.

Discussion of further design modification has been started to improve the shielding performance significantly.[5] Efforts on improvement of the calculation system has also been continued to simulate the maintenance port on the support structures, divertor pumping ports on the shielding layers etc. for accurate neutron transport calculation in the modified blanket geometry.

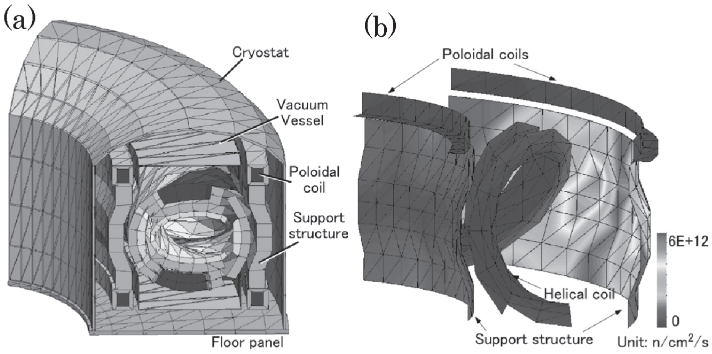

Fig. 1. (a) 3-D calculation geometry for neutronics investigations of FFHR2 liquid blanket system. (b) Example of calculated fast neutron flux distribution.

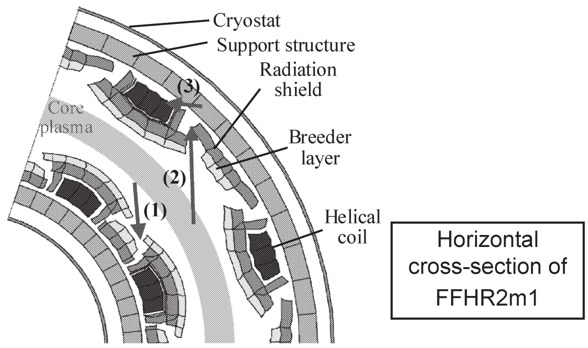

Fig. 2. Neutron streaming and reflection in FFHR2m1.

References
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5) A. Sagara *et al.*, presented at 17th ANS Topical Meeting on the Technology of Fusion Energy, Nov.13-15, 2006, Albuquerque, NM, USA.