§11. Investigations of Radiation Shielding Performance of FFHR2 Liquid Blanket Systems

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Radiation shielding performance for protection of a superconducting magnet system is one of important issues in fusion blanket designs. Investigations of the shielding performance of liquid Flibe cooled and Li cooled advanced blanket systems proposed in the FFHR2 helical reactor design have been conducted by neutron and gamma-ray transport calculations in the present study.

Design parameters related to neutronics investigations of the FFHR2m1 design have been a neutron wall load of 1.5 MW/m^2 and blanket space of 1.2 m. Our previous investigations indicate that all types of proposed blanket systems, i.e. Flibe+Be/JLF-1, Flibe-STB, Li/V-alloy and Flibe/JLF-1, would achieve adequate neutron shielding performances for protection of the super conducting magnet system within the blanket space of 1.2m.[1] However, in the present 3-D geometry of the FFHR2m1 design, the allowable blanket space between the first wall and helical coil is ~100 cm. Neutron shielding performances of the blanket systems with the total thickness of 100 cm were investigated by Monte Carlo neutron transport calculations with a simple torus calculation model. Since the Flibe+Be/JLF-1 blanket system has a superior shielding ability, a fast neutron flux of >0.1 MeV at the magnet layer could be suppressed to the design target of $<1x10^{10}$ $n/cm^2/s$ without changing the original material compositions. The Flibe-STB and Flibe/V-alloy blanket systems could achieve the design target by changing the composition of the radiation shield of 70 vol.% JLF-1 + 30 vol.% B_4C to that of 40 vol.% JLF-1 + 60 vol.% B_4C. In the case of the Li/V-alloy blanket system, enhancement of shielding ability using WC was required to reduce the total blanket thickness to ~100 cm.[2]

Another important parameter of nuclear (neutron and gamma-ray) heating in the magnet layer was calculated for the blanket layers with total thickness of ~100 cm using the simple torus calculation model. The Nb_3Al superconducting magnet layer was simulated with a homogeneous composition of 44 vol.% SS316, 5 vol.% epoxy-resin, 15 vol.% Cu, 20 vol.% liquid He and 15 vol.% Nb_3Al. Calculated nuclear heating in the magnet layer are shown in Fig. 1. The maximum nuclear heating at the inner surface of the magnet layer was 0.1-0.2 mW/cm^3 for the Flibe cooled blanket systems. The value for the Li/V-alloy blanket system was ~0.8 mW/cm^3 and is considered to be within the technologically allowable level for cooling of the magnet system.

In our previous three-dimensional (3-D) neutronics investigations, the fast neutron flux (>0.1 MeV) at the superconducting magnet layer significantly exceeded the design target of 1.0 x 10^{10} $n/cm^2/s$ due to neutron streaming through the divertor pumping areas.[1] To improve the radiation shielding performance in the 3-D blanket geometry, Discrete Pumping with Semi-closed Shield (DPSS) concept has been proposed.[3] To evaluate the shielding performance of the DPSS concept, neutron transport calculation in the 3-D geometry was performed by closing the divertor pumping areas with the radiation shield layers as shown in Fig.2. The Flibe+Be/JLF-1 blanket system was simulated in the calculation. The maximum fast neutron flux on the helical coil surface was suppressed to ~3 x 10^{10} $n/cm^2/s$. The maximum nuclear heating for the helical coil was ~0.3 mW/cm^3 in the 3-D neutron transport calculation. The values can be suppressed considerably by further design modification, e.g. increase of the shielding layer thickness at the divertor pumping areas. It has been confirmed by the present results that the DPSS concept is significantly effective for improvement of radiation shielding performances of helical reactors.[3]

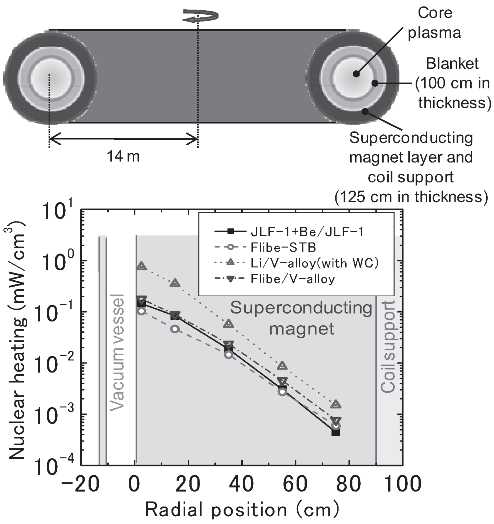

Fig. 1. Simple torus model for neutronics investigations of FFHR2 and calculated distribution of nuclear heating in the superconducting magnet layer.

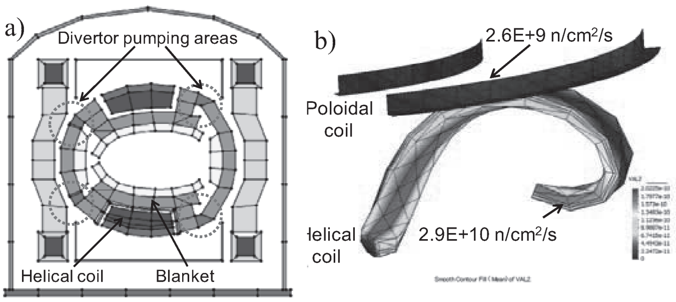

Fig. 2. a) Vertical cross section of 3-D neutron transport calculation geometry with closed divertor pumping areas for simulation of DPSS concept. b) Calculated fast neutron flux (>0.1 MeV) on superconducting magnets.

1) T. Tanaka *et al.*, Nucl. Fusion 48 (2008) 035005.
2) T. Tanaka *et al.*, presented at the fourth International Symposium on Radiation Safety and Detection Technology, July 18-20, 2007, Seoul, Korea.
3) A. Sagara *et al.*, presented at the 8th International Symposium on Fusion Nuclear Technology, Sept. 30-Oct. 5, 2007, Heidelberg, Germany.