Tritium Self-Sufficiency and Neutron Shielding Performance of Liquid Li Self-Cooled Helical Reactor

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The concept of a liquid Li self-cooled reactor has various attractive aspects such as high thermal conductivity, simple blanket structure, no irradiation damage to the breeder material etc. Moreover, one of the unique features is possibility of tritium self-sufficiency without beryllium neutron multiplier. The Force Free Helical Reactor conceptual design (FFHR-2) has been carried out with a self-cooled Flibe blanket system [1]. One of the issues of the Flibe concept is the compatibility between the tritium self-sufficiency and the performance of neutron shielding for super-conducting magnets within the limited blanket dimension. The purpose of the present study is to investigate the tritium-sufficiency and the shielding performance of the FFHR-2 with a liquid Li self-cooled blanket system.

The FFHR-2 has the major radius of 10.0 m and the average plasma radius of 1.2 m. Neutron wall load of 1.5 MW/m^2 is considered in the design. For the Flibe blanket with the total thickness of 90 cm, the local TBR of ~1.4 is expected. The fast neutron flux at outside of the shield is estimated to be 6.3 x 10^{10} $n/cm^2/s$.

Neutron transport calculation for the FFHR-2 with a liquid Li self-cooled blanket system was performed using MCNP-4C code and JENDL-3.2 nuclear data library. V-4Cr-4Ti alloy was employed as a structural material for liquid Li breeding channels. Main component for a reflector and a shield was low activation ferritic steel, JLF-1.

In the concept without beryllium multiplier, the blanket region of ~50 cm from the first wall was filled with liquid Li channels. The tritium production was enhanced by enrichment of ^6Li to 25 % for reducing the thickness of the liquid Li layers and improving the shielding performance. A 15cm layer of JLF-1 and a 38cm layer of JLF-1 (70%) + B_4C (30%) were placed as a reflector and a shield. The total thickness of the blanket was assumed to be ~105 cm, which is within the allowable dimension of the FFHR-2. The estimated local TBR and fast neutron flux at outside of the shield were ~1.4 and 5.6 x 10^{10} $n/cm^2/s$.

The thickness of the liquid Li breeding layers could be drastically reduced by introducing Be multiplier. While the total thickness of the liquid Li channels was decreased to 23 cm, the local TBR of ~1.4 was retained by installing a Be layer of 5 cm and enrichment of ^6Li to 40 %. The fast neutron flux at outside of the shield was estimated to be 9.7 x 10^9 $n/cm^2/s$, i.e. ~1/5 of the Li/V blanket system without Be multiplier, with a 20 cm layer of JLF-1 and a 57 cm layer of JLF-1 (70%) + B_4C (30%).

From the results of the calculation, it is confirmed that the compatibility between the tritium self-sufficiency and the neutron shielding performance within the limited blanket dimension for the Li/V blanket system could be comparable to that of the Flibe blanket system. Further improvement in the shielding performance is likely to be possible for the Li/V blanket system by introducing Be neutron multiplier.

[1] A. Sagara *et al.*, Fusion Engineering and Design 49-50 (2000) 661-666.