§5. Neutronics Investigation of Self-cooled Liquid Blanket Systems for Modified FFHR2 Design

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The original design of the FFHR2 [1] adopted self-cooled Flibe blanket system of 90 cm in thickness with a structural material of ferritic steel, JLF-1, and solid beryllium neutron multiplier. Recently, modified FFHR2 design with increased blanket space of 120 cm has been proposed to improve the radiation shielding performance [2]. This modification of the dimensions provides the possibility for other types of simple and attractive self-cooled liquid blanket systems without using solid neutron multiplier. The concept of liquid lithium cooled blanket system with a structural material of vanadium alloy has been studied for the preferable compatibility, mechanical property at high temperature and high efficiency operation at up to ~700 °C. Coolant of Flibe also could be used with vanadium alloy for high temperature operation by REDOX control with MoF_6 or WF_6. In the present study, the compatibility of tritium self-sufficiency and neutron shielding ability of the lithium and Flibe self-cooled blanket systems without solid neutron multiplier was investigated for application to the modified FFHR2 design.

Neutronics calculation was performed with the MCNP-4C Monte Carlo code and JENDL 3.2 nuclear data library. Local tritium breeding ratio (local TBR) and fast neutron flux at outside of radiation shield were calculated for the simple geometry shown in Fig. 1. The torus was fully covered with the uniform tritium breeding channels and radiation shield. The breeding channels consisted of lithium or Flibe coolant (~83 vol.%) and a structural material of V-4Cr-4Ti (~17 vol.%). To enhance the tritium production, the ratio of ^{6}Li in both of lithium and Flibe coolant was enriched to 35 %. Radiations were shielded with a layer of JLF-1 (~70 vol.%) and B_4C (~30 vol.%) to avoid critical damage on super-conducting magnets. For the compatibility of tritium self-sufficiency and neutron shielding, the local TBR of >~1.3 and fast neutron flux (>0.1 MeV) of <1.0 x 10^{10} n/cm^2/s at outside of the radiation shield should be satisfied simultaneously. The balance of thickness for the breeding channels and radiation shield was examined under the constant total thickness of 120 cm and the neutron wall load of 1.5 MW/m^2.

Figure 2 shows the achievable local TBR and neutron shielding performance by the present calculation. In the lithium blanket system, the local TBR increased with the thickness of the breeding channels exceeding 1.3. In parallel, the fast neutron flux at outside of the radiation shield also increased and exceeded 1.0 x 10^{10} n/cm^2/s. Therefore, the thickness of the lithium breeding channels was decided to ~55 cm due to the limitation of the shielding ability. In contrast, the fast neutron flux for the Flibe blanket system never exceeded the limitation of 1.0 x 10^{10} n/cm^2/s even for much thicker breeding channels, i.e. much thinner radiation shield. This indicated that the Flibe coolant itself has superior shielding ability compared with the lithium coolant. However, the local TBR weakly increased with the thickness of the breeding channels. Since the increase of the local TBR was within ~1 % for thicker channels and close to 1.3, the thickness of the breeding channels was decided to 60 cm. The TBR and shielding ability of the two blanket systems may be improved further with design efforts.

The present results of neutronics investigation indicated that both of the lithium and Flibe self-cooled blanket systems without solid neutron multiplier are feasible concept enhancing the performance of the FFHR. The FFHR design with these two blanket systems are designated as FFHR-LV and FFHR-FV [3]. Further neutronics investigation will be carried out focusing on three-dimensional effect of the helical blanket structure.

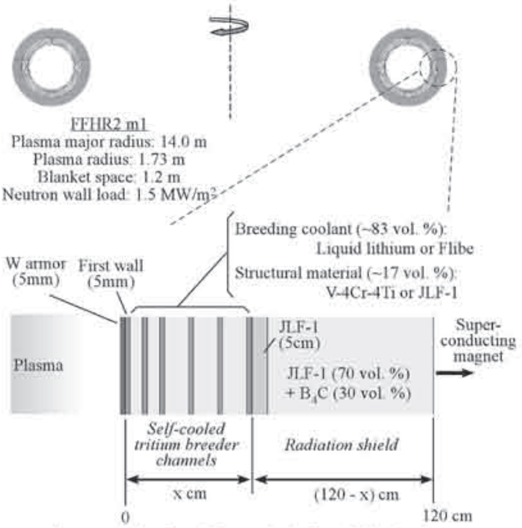

Fig. 1. Geometric model of self-cooled liquid blanket system for nuclear calculation.

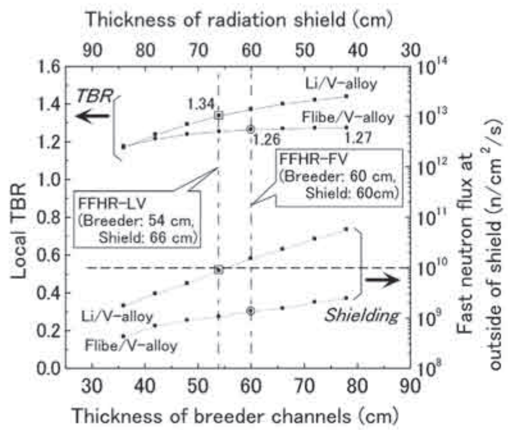

Fig. 2. Local TBR and neutron shielding performance calculated for the lithium and Flibe blanket systems with ^{6}Li enrichment to 35 %

References
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[3] T. Tanaka *et al.*, Fusion Science and Technology, 47(2005)530-534.