§6. Investigation of Tritium Self-Sufficiency for FFHR2 Design with Liquid Li Self-Cooled Blanket System

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In conceptual design of a fusion reactor, tritium self-sufficiency is one of fundamental neutronics performances determining the feasibility. It is evaluated with a tritium breeding ratio (TBR), i.e. a ratio of tritium quantity produced in a blanket to that burned in DT plasma during operation, and TBR>1 is required for DT fusion reactors as permanent power source. Tritium is produced in a blanket region by nuclear reactions of neutrons and lithium atoms contained in breeder materials such as Li_2TiO_3, Flibe, liquid Li etc. Most of reactor concepts achieve the condition of TBR>1 by enhancing tritium production rate with beryllium neutron multiplier, which is sparse material on the earth. In contrast, the liquid Li self-cooled blanket system developed in Fusion Engineering Research Center has advance and attractive possibility to achieve TBR>1 without beryllium multiplier. By neutron multiplying ability of lithium with fast neutrons, liquid Li coolant behaves also as neutron multiplier and tritium breeder. In the present study, application of the liquid Li self-cooled blanket system to the Force Free Herical Reactor conceptual design [1] (modified FFHR2 [2]) was investigated from the aspect of tritium self-sufficiency.

Neutron transport calculation for evaluation of tritium production was performed with the MCNP-4C Monte Carlo code and JENDL 3.2 nuclear data library. Fig. 1 shows the cross section of the liquid Li self-cooled blanket system. Vanadium alloy (V-4Cr-4Ti) was employed as a structural material for the liquid Li channels. In the concept without beryllium neutron multiplier, the blanket region of ~50 cm from the first wall was filled with liquid Li (natural lithium) channels. At the outside of the blanket, a 27 cm layer of JLF-1 (reduced activation ferritic steel) and a 39 cm layer of JLF-1 (70 %) + B_4C (30 %) were placed as a reflector and a shield. The total thickness between the first wall and the outside surface of the shield was possible maximum of ~120 cm according to the modified FFHR2 design. In the present calculation, the tritium self-sufficiency was investigated as a 'local TBR' for the torus fully covered with the blanket.

Fig. 2 shows the distribution of tritium production rate in the Li coolant channels of the blanket and the reflector regions. Since only fast neutrons react with ^{7}Li (92.5 % in natural lithium), the contribution of ^{7}Li to the tritium production is higher around the first wall. The adequate local TBR of 1.35 was obtained from the calculation. The value was almost same as the previous study for the original FFHR2 with Flibe blanket system. The result indicates that more than ~75 % of the torus should be covered with the blanket to achieve the TBR of >1 in more detailed reactor design considering layout of super-conducting magnet coils, ports and others. As to neutron shielding ability, which is another important neutronics performance, the fast neutron flux at the outside of the shield was 4.8 x 10^{10} n/cm^2/s. It was also comparable to that for the original FFHR2.

From the results of the present calculation, it is confirmed that the modified FFHR2 design with the liquid Li self-cooled blanket system has adequate tritium self-sufficiency to proceed on further optimization and detailed design. Optimization of shielding ability and others are in progress.

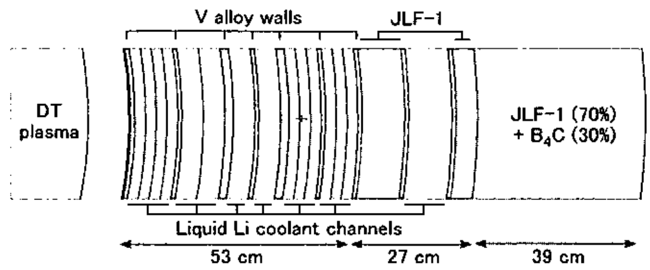

Fig. 1. Cross section of liquid Li self-cooled blanket system

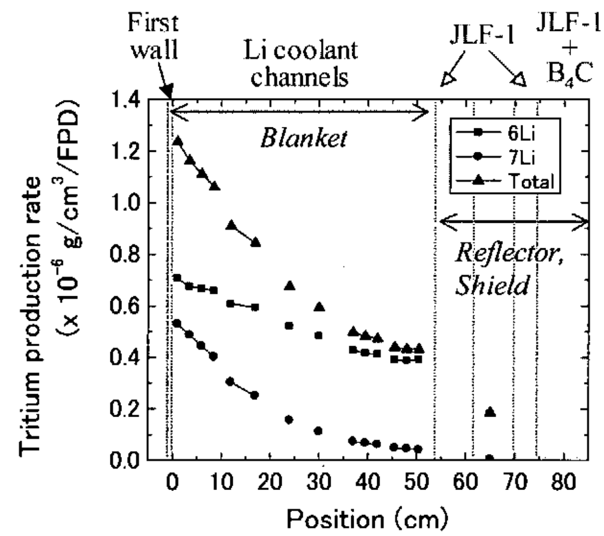

Fig. 2. Distribution of tritium production rate in outboard blanket for neutron wall load of 1.5 MW/m^2

References

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

[2] A. Sagara *et al.*, to be presented in 20th IAEA, FT/3-6 (2004).