§13. Investigation of Neutronics Performances of Flinak/Pb Breeder Blanket

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In designs of tritium breeder blankets, beryllium (Be) has been adopted as an attractive neutron multiplier for the low threshold energy of the (n,2n) reaction, high atomic density and low cross section of the neutron capture. A Be neutron multiplier has also been adopted in the liquid Flibe cooled blanket studied in NIFS and enables an achievement of the superior tritium fuel breeding performance, i.e. TBR of 1.23 without ^{6}Li enrichment, with the thinner blanket thickness of 32 cm [1]. However, a supply of a massive amount of Be for fusion reactors might be uncertain due to the limited natural resource and the toxic property. The second candidate for a neutron multiplier in fusion blanket designs is lead (Pb) as adopted in the Li-Pb cooled blanket concept. In the present study, neutronics performances of the combination of a Flinak coolant, whose preferable safety properties as a molten salt would be expected, and a Pb neutron multiplier have been examined to investigate a feasibility of a Be free breeding blanket.

Neutronics performances of a tritium breeding ratio (TBR) and fast neutron shielding have been examined by using the Monte-Carlo neutron transport calculation code MCNP-5 and nuclear data library JENDL-3.3. Simple torus geometry was assumed in the calculation as shown in Fig.1. The structural material is JLF-1 (reduced activation ferritic/martensitic (RAFM) steel). The thickness of the first coolant channel has been set to 2 cm for cooling of the first wall. A Pb neutron multiplier layer is placed in the second layer with the thickness of 10 cm. Flinak coolant layers are placed at the back side of the Pb layer and the total thickness of the breeding layer is 54 cm. A shielding performance of the Flibe/Pb blanket system has been calculated with the 66 cm thick radiation shield of JLF-1 (70 vol.%) + B_4C (30 vol.%).

Figure 2 shows an effect of a ^{6}Li enrichment on the local TBR. Without the enrichment, the local TBR was 0.92. The value increases monotonically with the enrichment ratio and reaches 1.28 at 90 %. While a higher TBR would be achieved by a further optimization effort, the value indicates that the Flibe/Pb blanket could be a candidate of a blanket concept. When the thickness of the Pb layer was changed from 10 cm to 15 cm, the local TBR still increased to 1.33.

The distribution of the fast neutrons of >0.1 MeV in the blanket is shown in Fig. 3. The neutron wall loading of 1.5 MW/m^2 was assumed in the calculation. The neutron flux is attenuated to 1.0 x 10^{10} n/cm^2/s, which is the design target to prevent severe irradiation damage on the superconducting magnet system, with the 110 cm thick blanket (breeder blanket and shielding blanket). The total thickness of the blanket could be reduced by using more effective radiation shielding materials [2] and optimization of breeding layer.

An influence of radioactivity of Pb on the reactor operation and safety is being studied at present. In contrast to the Li-Pb blanket concept, the Flinak/Pb blanket concept does not need to circulate the Pb multiplier to the outside of a reactor for a tritium fuel recovery. This would be an advantage from the view point of safety.

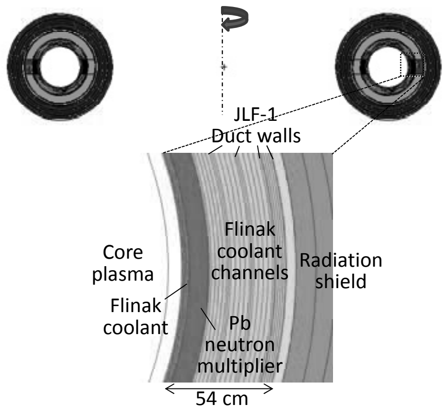

Fig.1 Calculation geometry for investigation of neutronics performances of Flinak/Pb blanket system.

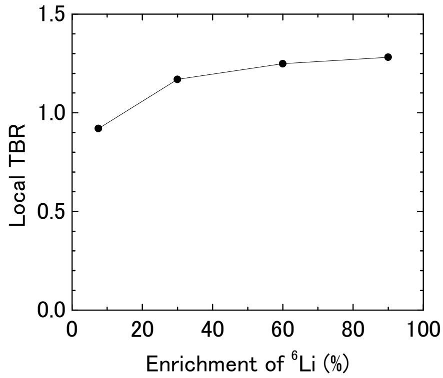

Fig.2 Relation between ratio of ^{6}Li enrichment and local TBR in Flinak/Pb blanket

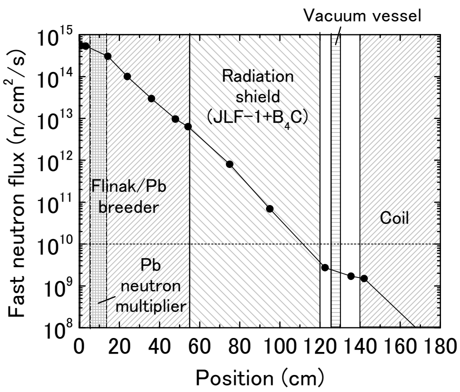

Fig.3 Attenuation of fast neutron flux in Flinak/Pb blanket and JLF-1+B_4C radiation shield for neutron wall loading of 1.5 MW/m^2.

1) Sagara, A. et al.: Fusion Engineering and design **83** (2008) 1690-1695.

2) Tanaka, T. et al.: NIFS annual report April 2009-March 2010 (2010) 282.