§14. Study on Detailed Liquid Cooled Blanket Design Based on Neutronics Investigation

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In the design activity of a helical type DEMO reactor conducted in NIFS, the target of the blanket system design is to present realistic three-dimensional blanket drawings. The present study is focusing on neutronics investigation of tritium fuel breeding, radiation shielding, nuclear heating etc. by simulating the detailed blanket structure. The investigation is not only for the optimization of a blanket configuration from the view point of neutronics, also for aiming a combination with a thermal hydraulics design, structural design and material development to accomplish the integral blanket design.

In the fiscal year of 2010, influences of a duct wall configuration and a size of beryllium neutron multiplier pebbles on a tritium breeding performance has been investigated by neutron transport calculations using the MCNP-5 code and JENDL-3.3 library.

Figure 1 shows an example of cylindrical calculation geometry simulating duct wall configuration in a Flibe+Be/JLF-1 breeding blanket (JLF-1:reduced activation ferritic/martensitic (RAFM) steel). Previous investigation indicates that an insertion of JLF-1 walls to the Flibe(40 vol.%)+Be(60 vol.%) layer with 10 vol. % would degrade the local tritium breeding ratio (local TBR) by ~13 % [1]. However, Flibe, Be and JLF-1 were assumed to be uniformly mixed in the layer. In the present investigation simulating the duct configuration, local TBRs have been examined by changing the JLF-1 duct wall thickness and position in the Flibe+Be layer by keeping the volumetric ratio of the walls to 10 vol.% of the layer. The calculation results indicate that the impact of duct wall thickness and position on the TBRs in the Flibe+Be/JLF-1 blanket is <4 % for the Flibe without ^{6}Li enrichment and <2% for the Flibe with ^{6}Li enrichment to 40 % (Fig. 2).

An impact of the Be pebble size on the TBR has been examined by using the geometry shown in Fig. 3. In the calculation, local TBRs were calculated for the pebble size of the 3, 9 and 15 mm. A three-dimensional cubic closest packing was assumed for the pebble positions, while Fig.3 shows only the two-dimensional cross section. The TBRs for the Flibe with natural lithium were 1.22-1.23. The values for the Flibe with ^{6}Li enriched to 30 % were 1.34-1.35. These results indicate that the impact of the pebble size was almost negligible.

The above results obtained by simulating the wall configuration and pebble structure are considered to be explained by a mean free path of neutrons in the blanket. Detailed analysis of neutron behavior in the blanket component is being continued. These results also indicate that the detailed structure of the Flibe+Be/JLF-1 blankets should be proposed from the view point of the heat removal, mechanical stress etc.

In the present study, (i) advantage of three-dimensional Monte Carlo neutron transport calculations in a radiation shielding design compared with those with one or two-dimensional S_N transport calculations, (ii) method to convert three-dimensional CAD data to input data for neutronics calculation codes, (iii) evaluation of neutronics calculation accuracies using DT neutron sources have also been discussed.

The next topics to be investigated are (i) construction of a design system to connect the neutronics calculations which provide parameters of nuclear heating, irradaiton damage distribution etc. to thermal hydraulics calculations and mechanical stress calculations, (ii) investigation of effective shielding materials of B_4C, WC. ZrH_2 etc.

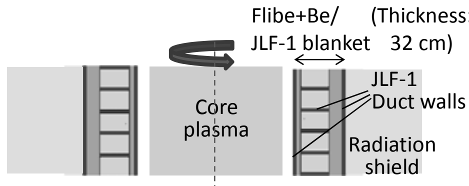

Fig.1 Cylindrical calculation geometry used in investigation of influence of duct wall configuration on local TBR of Flibe+Be/JLF-1 blanket

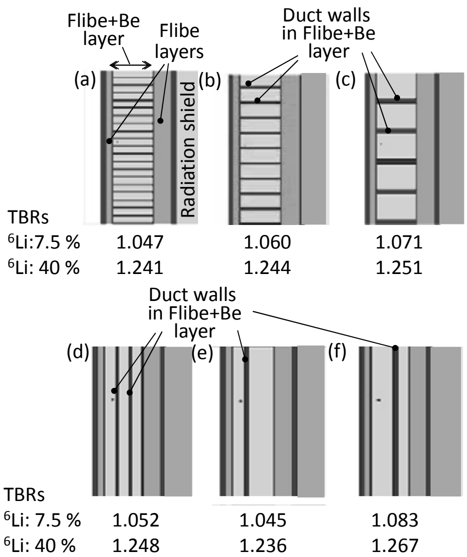

Fig.2 TBRs of Flibe+Be/JLF-1 blanket calculated for various duct wall configurations.

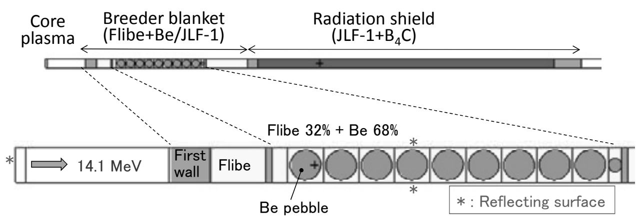

Fig.3 Calculation geometry used in investigation of influence of Be pebble size on local TBR of Flibe+Be/JLF-1 blanket

1) Tanaka, T. et al.: NIFS annual report April 2008-March 2009 (2009) 257.