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Progress of KO HCCR TBM Design and Performance Analysis for ITER

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1. Introduction

One of the main engineering performance goals of the ITER is to test and validate the design concepts of the tritium breeding blankets relevant to a power producing reactor. The tests will focus on modules including a demonstration of the breeding capability that will lead to a tritium self sufficiency and extraction of heat suitable for an electricity generation. Korea has developed a Helium Cooled Molten Lithium (HCML) Test Blanket Module (TBM) and Helium Cooled Solid Breeder (HCSB) TBM to be tested in the ITER. Recently, solid-type HCSB TBM was chosen as a leading concept in the National Fusion Committee, and the other is developing as a breeding blanket for DEMO. The name of the solid type TBM was changed into a Helium Cooled Ceramic Reflector (HCCR) considering the unique concept of using the graphite reflector.

In the present study, the progress of the overall design and its performance analysis after the previous presentation were introduced according to the main components such as the First Wall (FW), Breeding Zone (BZ), Side Wall (SW), and BZ box.

2. Recall the design concept and requirements

From the proposed IO requirements in PMG-18-06 meeting (the 6th meeting on Port-18 Management Group), the followings were decided: (1) a 15 mm gap from the port frame to the TBM, and a 120 mm recession should be considered. Since port dimension is fixed, the TBM dimension was determined as follows; 1670 mm height and 462 mm width. (2) The surface heat flux from the plasma side was reduced from 0.5 to 0.35 MW/m^2.

Considering the design requirements, such as (1) KO DEMO relevancy, (2) compact size for delivery for PIE (Post Irradiation Examination), (3) adopting a graphite reflector as a unique feature of the concept, and (4) TBR > 1.4 under local assumptions. The conceptual design and basic dimension of the KO TBM were determined, as shown in Fig. 1. By changing the fabrication procedure, a SW and BZ box design was updated in this figure.

3. Updated FW design and performance analysis

From the old FW design of the HCCR TBM design, which has 15x11 rectangular U-shape FW, a mechanical analysis for an internal pressure about 9 MPa of the design pressure was performed. It shows that the Tresca stress in this channel of 60 MPa is lower than that of the allowable stress for Gr-91of 123 MPa at 500 °C, which is the reference structural material for KO TBM. However, since the reference material was changed from G-91 to Gr-92 by similarity of the composition of the developed alloy and update of the neutronic analysis results considering the local profile by the distance from the plasma surface (see chapter 4), the flow analysis was performed, and a flow scheme was made considering a 4 sub-module concept, as shown in Fig. 2. The maximum temperature of the FW does not exceed 550 °C of the design requirement. In this condition, the flow velocity in a single FW channel is about 50 m/sec, and the total mass flow rate is about 1.14 kg/sec. In this temperature, the thermal stress including the channel pressure of 10 MPa is 237 MPa, which is lower than that of the allowable stress for Gr-92of 378 MPa (3Sm) at 538 °C.

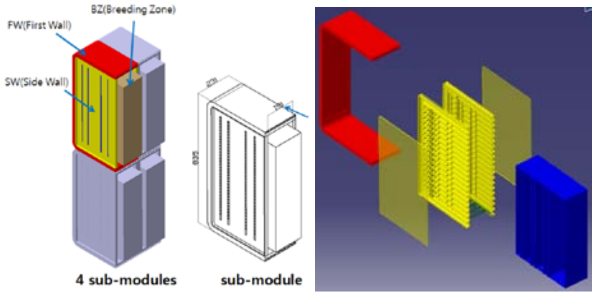

Fig. 1 Concept of KO HCCR TBM and its sub-module dimensions.

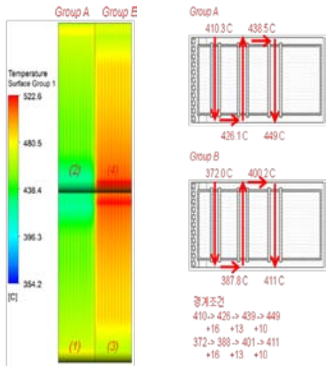

Fig. 2 Updated temperature distribution and flow scheme of the TBM FW

4. BZ design and performance analysis

To optimize the design to meet the requirements such as (a) TBR >1.4, (b) RAFM temperature < 550 °C, and (c) Li pebble temperature < 900 °C, neutronic and thermal-hydraulic analysis were performed with MCNP and ANSYS-CFX, respectively, from the base array of version 1 case06, as shown in Table I. Six cases were analyzed and the final design is chosen with case 08.1, and finally the temperature distribution was investigated with the combined with FW.

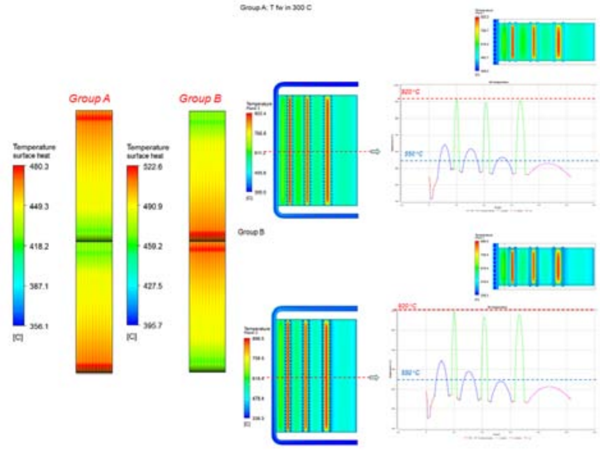

Fig. 3 Currently optimized KO HCCR TBM design and its temperature distribution (v1 case08.1).

5. SW design and performance analysis

Considering the function of the SW such as flow manifold and assembling part, a flow scheme was developed in the previous study. The basic concept for satisfying an internal pressure of 10 MPa was introduced and the flow analysis was performed as shown in Fig. 4 considering the flow scheme to the BZ cooling plate. Now, the optimum design is on-going.

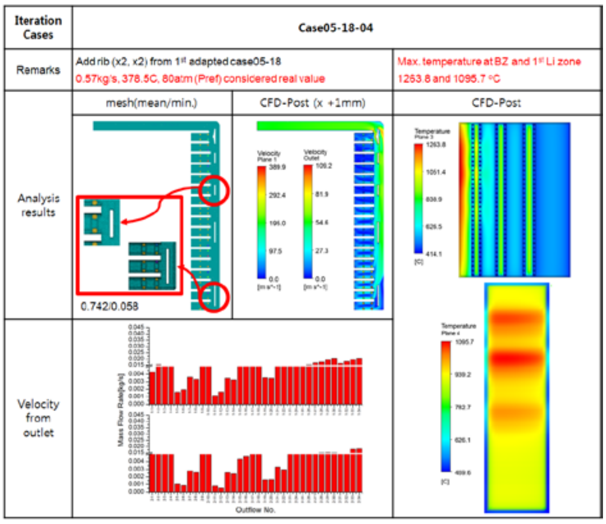

Fig. 4 SW design and its flow analysis results.

6. BZ box and He purge line design

Since the main objective of the BZ is to extract the produced tritium from each BZ layer, the He purge line should be installed inside each BZ layer with a uniform flow distribution. Basic concept of this was designed as shown in Fig. 5. The flow analysis and stress analysis were performed considering the internal pressure of 8 MPa assuming the ingress accident. The flow analysis shows that a uniform flow can be made with the current design, as shown in Fig. 6, and the stress analysis is on-going.

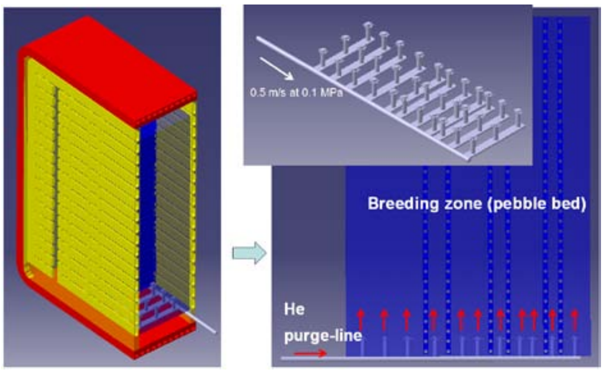

Fig. 5 He purge line design concept.

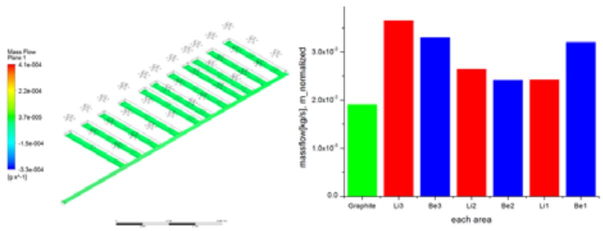

Fig. 6 Flow distribution analysis of the BZ box with current He purge line design.

7. Conclusion

To develop a Fusion Reactor, we have participated in the TBM program in the ITER. According to the recent national decision to lead a solid-type HCCR TBM, design and performance analysis for the TBM has been carried out considering the uniqueness of the KO TBM and the design requirements of the IO and KO design concept. The design has been updated, and the results are introduced in the present paper: (1) FW and BZ performance analyses were updated by updated neutron analysis results, (2) a SW design concept was proposed and its flow distribution was analyzed, and (3) a flow distribution analysis of a BZ box with a He purge line was performed. A mechanical analysis with internal pressure is on-going.

References

[1] D.W. Lee, et. al., “Current status and R&D plan on ITER TBMs of Korea,” J. Korean Phys. Soc. 49 (2006) S340-S344.

[2] D.W. Lee, et. al., “Preliminary design of a helium cooled molten lithium test blanket module for the ITER test in Korea,” Fusion Eng. Des. 82 (2007) 381-388.

[3] D.W. Lee, et. al., “Helium cooled molten lithium TBM for the ITER in Korea,” Fusion Sci. Tech. 52 (2007) 844-848.

[4] D.W. Lee, et. al., “Design and preliminary safety analysis of a helium cooled molten lithium test blanket module for the ITER in Korea,” Fusion Eng. Des. 83 (2008) 1217-1221.

[5] ANSYS CFX-11, 2007, User Manual, ANSYS-CFX.