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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 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 decided as a leading concept in National Fusion Committee and the other is developing as the breeding blanket for DEMO. The name of the solid type TBM was changed to a Helium Cooled Ceramic Reflector (HCCR) considering the unique concept of using the graphite reflector.

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

2. 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) 15 mm gap from port frame to TBM and 120 mm recession should be considered. Since port dimension is fixed, the TBM dimension is decided as follows; 1670 mm height and 462 mm width. (2) Surface heat flux from 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, (2) TBR > 1.4 under local assumptions, The conceptual design and basic dimension of the KO TBM was determined, as shown in Fig. 1.

3. FW design and performance analysis

From the old HCML TBM design, which has 20x10 rectangular U-shape FW, mechanical analysis for internal pressure about 9 MPa of design pressure was performed. It shows that the Tresca stress in this channel of 165 MPa is higher than that of the allowable stress for Gr-91of 123 MPa at 500 ^{o}C, which is the reference structural material for KO TBM. Therefore, the channel design was changed to be 15x11 and 11 channels in order to meet the requirement, in which the maximum stress was 60 MPa. According to the FW design change, the flow analysis was performed and flow scheme was made considering 4 sub-module concept, as shown in Fig. 2. The maximum temperature of the FW does not exceed 550 ^{o}C of the design requirement. In this condition, the flow velocity in single FW channel is about 50 m/sec and total mass flow rate is about 1.14 kg/sec.

4. BZ design and performance analysis

To optimize the design to meet the requirements such as (a) TBR >1.4, (b) RAFM temperature < 550 ^{o}C, and (c) Li pebble temperature < 900 ^{o}C, neutronic and thermal-hydraulic analysis were performed with MCNP and ANSYS-CFX, respectively, from the base array of case 02, as shown in Table I. Seven cases were analyzed and final design is chosen with case 06 and finally the temperature distribution was investigated with the combined with FW like case 07. Figure 3 shows the flow scheme from BZ to BW.

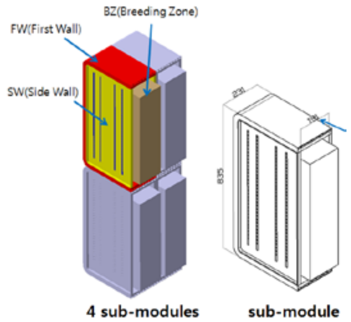


Fig. 1 Concept of KO HCCR TBM and its sub-module dimensions.

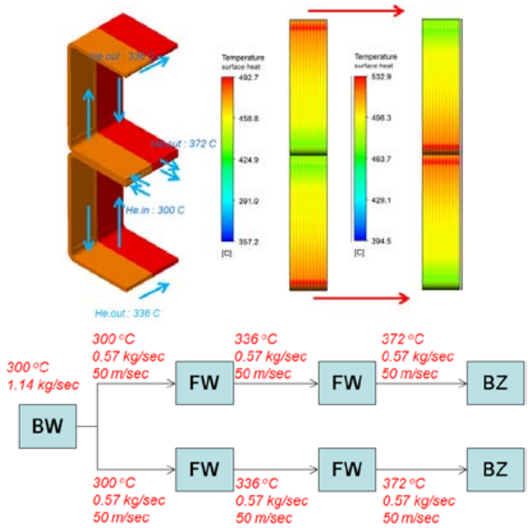
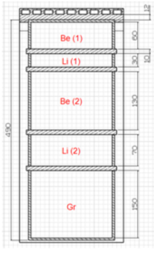
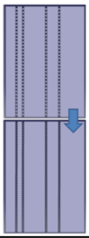
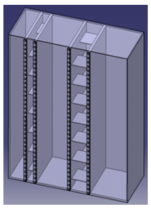
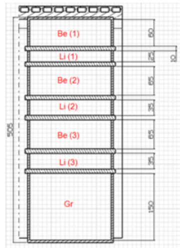
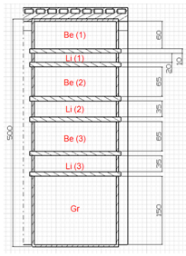
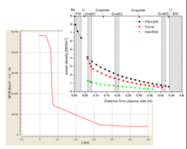
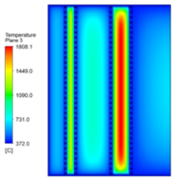
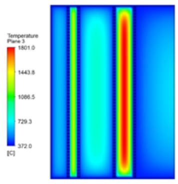
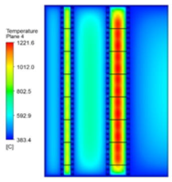
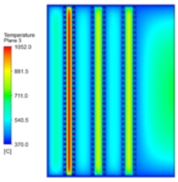
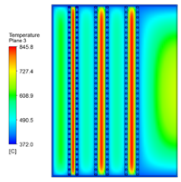
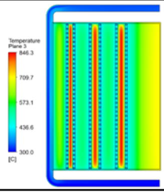


Fig. 2 Flow scheme and temperature distribution of TBM FW

Table I Iteration for the optimized KO HCCR TBM design.

Iteration Cases	Case02	Case03	Case04	Case05	Case06	Case07
Remarks	Initial design $T_{Li(2)}$ = 1808 °C >> 900 °C	Increasing No. of Coolant holes (34 -> 54) $T_{Li(2)}$: no change	Insert cooling pins in Li zone $T_{Li(2)}$ =1222 °C >> 900 °C	Add Li(3) for preserving TBR, Li(1) ~ 25 mm $T_{Li(2)}$ =1052 °C >> 900 °C	Reducing Li(1) ~ 20 mm $T_{Li(2)}$ =846 °C < 900 °C	Combined FW with Li(1) ~ 20 mm $T_{Li(2)}$ =846 °C < 900 °C
Modeling		same array case02 	same array case02 			same array case06 
Analysis results						

5. SW design and performance analysis

Considering the function of SW such as flow manifold and assembling part, flow scheme was developed as shown in Fig. 4. For cover-type SW design, mechanical analysis was performed considering 9 MPa of design pressure, but the maximum stress is over the allowable one. Now, optimum design for enduring internal pressure and flow distribution is on-going.

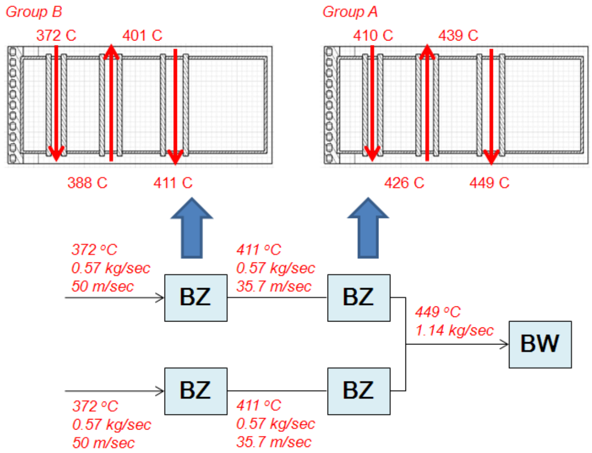


Fig. 3 Flow scheme and coolant temperature in BZ.

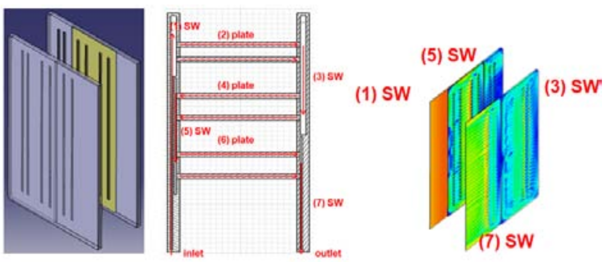


Fig. 4 Flow scheme and analysis results in SW.

6. Conclusion

In order to develop the Fusion Reactor, we have participated TBM program in the ITER. According to the recent national decision to lead solid-type HCCR TBM, design and performance analysis for TBM body has been carried out considering the uniqueness of KO TBM and design requirements by IO and KO design concept; (1) sub-module concept was used for PIE and its delivery, (2) FW design was changed to 15x11 rectangular shape and its performance was confirmed by TH/TM analysis, (3) BZ arrays was decided by neutronic and TH/TM analysis and their iteration, and (4) BZ structure and SW design is on-going considering the mechanical analysis and its functions.

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