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Current Structural Design of Side Wall in KO HCCR TBM for ITER

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1. Introduction

To accomplish the test and validation of the tritium self-sufficiency and a heat transfer extraction during ITER operation, the KO HCCR TBM (Korean Helium Cooled Ceramic Reflector Test Blanket Module) has been developed considering the unique concept of using a graphite reflector [1, 2].

The TBM consists of four sub-modules and one Back Manifold (BM), and each sub-module is composed of a First Wall (FW), Breeding Zone (BZ), Side Wall (SW), and BZ (Breeding Zone) box, which contains beryllium (Be), lithium (Li), and graphite pebbles, as shown in Fig. 1. Among them, SW has functions as a manifold for the cooling flow distribution from FW cooling channels to BZ, and it should sustain the internal coolant pressure.

In this study, the structural design of the SW was performed according to the RCC-MR design code [3] to confirm the design requirement for ITER.

2. Preliminary analysis of the initial SW design

The cooling flow scheme and temperature distribution in the TBM based on a thermal hydraulic analysis were determined prior to the structural design [2]. The SW is used for the cooling manifold from the FW to the BZ, and from the BZ to the BM. To avoid a deformation from the inner pressure, the various design options were investigated using ANSYS [4].

As a structural material, RAFM (Reduced Activated Ferritic Martensitic) steel has been developed in Korea; it is called ARAA (Advanced Reduced Activated Alloy). In this study, the basic physical properties of Gr-92 were used owing to their similarity [5] for the structural design in the SW.

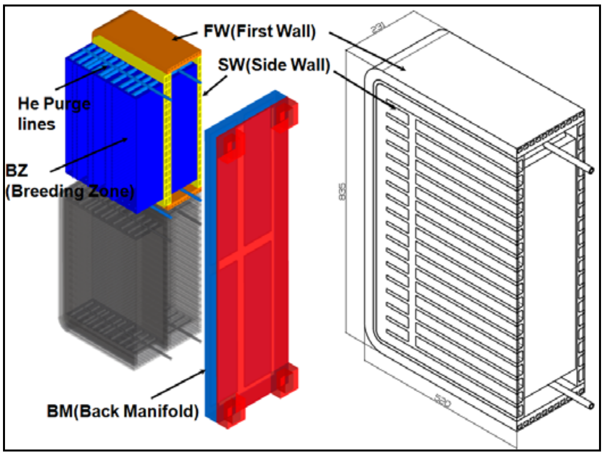


Fig. 1 Configuration of KO HCCR TBM

Figure 2 shows Tresca stress distribution in the simple SW, which did not consider the manifold and applied only internal pressure. The maximum stress is 4447 MPa and an over deformation occurs in the center region. It could be noted that the SW should sustain the inner pressure and have a uniform cooling distribution function from the FW channels to the BZ.

3. Design optimization of the SW

Table 1 shows the structural design progress of the SW, and the following material properties considered: Poisson's ratio (ν) was 0.3, Young's modulus (E) was 152 GPa, the yield strength (σ_{ys}) was 380 MPa, and an allowable stress (S_m) was 132 MPa at 520 ^{o}C.

Case 01 consists of five grids with six partitions in the SW. The maximum stress was 1187 MPa, and an over deformation occurred between grids. Case 02-01 consists of eight grids with nine partitions, and the maximum stress was 713 MPa, and Case 02-02 consists of eight grids with nine partitions, the same as Case 02-01, but an additional grid was considered in the inlet flow region. The maximum stress was 458 MPa, which it was lower than Case 02-01.

Case 03-01 consists of sixteen grids with seventeen partitions, and the maximum stress was 328 MPa. Case 03-02 consists of sixteen grids with seventeen partitions, the same as Case 03-01, but an additional grid was considered in the inlet flow region. The maximum stress provided 132 MPa which was the lowest value.

Figure 3 shows Tresca stress distribution considered for a fillet radius (R=2) in sixteen grids to avoid the stress concentration in the right angle region in Case 03-01. The maximum stress occurred in the upper inlet flow region, and the value of which was 173 MPa, and the stress in the center region in the SW was 125 MPa.

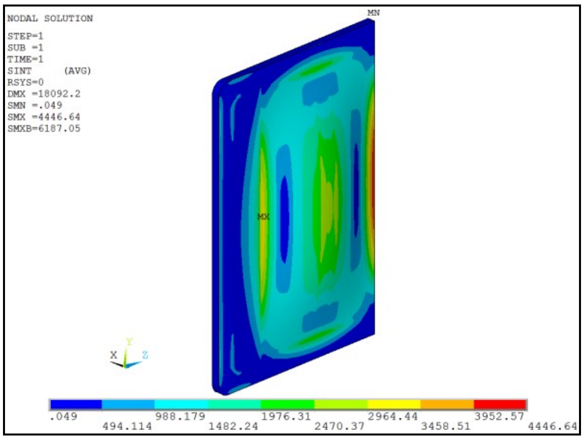


Fig. 2 Tresca stress distribution in the simple SW

Table 1 Structural design progress of SW

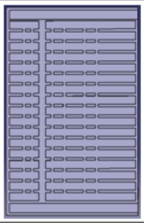
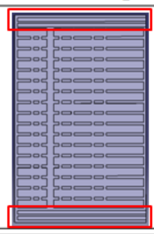
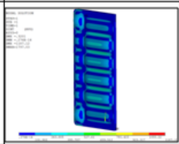
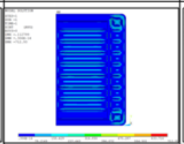
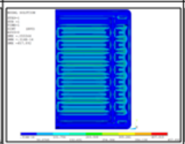
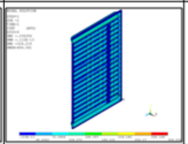
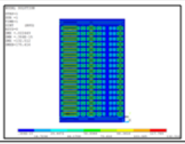
Iteration Cases	Case01	Case02-01	Case02-02	Case03-01	Case03-02
Remarks	5 grid / 6 partition	8 grids / 9 partition	8 grids / 9 partition (Additional grid)	16 grids / 17 partition	16 grids / 17 partition (Additional grids in inlet flow region)
Modeling					
Analysis results					
Max. Tresca stress (MPa)	1187	713	458	324	132

Figure 4 shows a stress analysis from the maximum point in the inner surface to the channel region through PATH in Case 03-01 considering the fillet radius. The general primary membrane stress (P_m) was 46.98 MPa and the sum of the primary membrane stress (P_L) and bending stress (P_b) was 129.2 MPa, which is less than $1.5S_m$. The stress analysis results satisfied the design requirements of the RCC-MR codes.

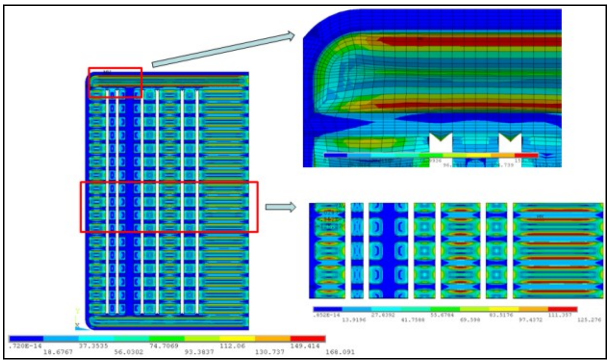


Fig. 3 Tresca stress distribution in Case 03-01 considering the fillet radius (R=2) in 16 grids

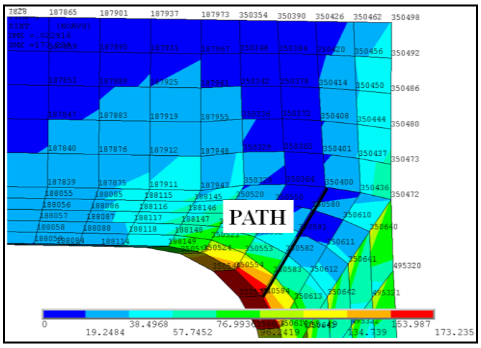


Fig. 4 Stress analysis trough PATH considering the inner pressure (10 MPa) in Case 03-01 for the fillet radius

4. Conclusion

To satisfy the KO HCCR TBM design requirements, structural analyses were performed for the preliminary SW design in the TBM. A design channel pressure of 10MPa was considered in the structural design progress of the SW. The stress breakdown was evaluated through PATH in SW. It was concluded that the results satisfy the design requirements in the RCC-MR codes for the ITER.

Acknowledgments

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References

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[3] RCC-MR Code, Section 1-Subsection B: Class 1 Components, AFCEN, French, 2007.

[4] ANSYS User Manual, ANSYS-Mechanical, 2012.

[5] The T92/P92 book, Vallourec & Mannesmann Tubes, 2000.