Cooling Performance of TBM-shield Designed for Manufacturability

Seong Dae Park[a*], Dong Won Lee[a], Dong Jun Kim[a], Jae Sung Yoon[a], Mu-Young Ahn[b]
[a]*Korea Atomic Energy Research Institute, Republic of Korea*
[b]*National Fusion Research Institute, Republic of Korea*
[*]*Corresponding author: sdpark@kaeri.re.kr*

1. Introduction

Helium cooled ceramic reflector (HCCR) TBM-set will be installed in the equatorial port #18 of ITER inside the vacuum vessel directly facing the plasma. TBM-set refers the TBM and associated shield and connecting support, as shown in Fig. 1 [1]. Helium cooled ceramic reflector (HCCR) test blanket module (TBM) is composed of four sub-modules and a common back manifold (BM). The associated shield is a water-cooled 316L(N)-IG block with internal cooling channels. The purpose of the TBM-shield is to make the condition with the allowable neutron flux and dose rate level. There is a dose rate criterion for maintenance access used in ITER. The dose rate should be lower than 100 μSv/h [2]. To satisfy the ITER guideline for maintenance accessibility, the neutron flux during operation should be less than $3*10^6$ n/cm^{2}s. This criteria could be satisfied by placing the water and structure properly. It is confirmed in the conceptual design phase. The radially continuous layers of water and structure were configured. The main purpose of the shield is to reduce the neutron flux by absorbing the neutron in the structure. The water could act as the moderator and cool down the structure which is heated due to the reaction with the neutrons. The moderated neutrons are easily absorbed by the structure. It could meet the criteria for the minimum neutron flux by increasing the thickness of structure. The formation of inside cooling channel in the TBM-shield should be considered while maintaining the allowable temperature range.

In this work, a manufacturing process including the formation of inside cooling channel was presented. The maximum temperature of the TBM-shield was confirmed by using the CFD code, ANSYS-CFX 14.5.

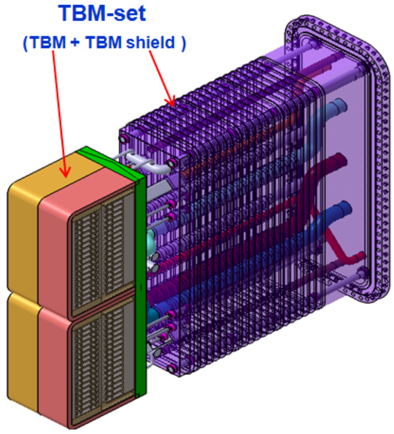

Fig. 1. HCCR-TBM-set configuration at CD phase

2. Manufacturing

Figure 2 shows the cross-sectional view of the TBM-shield proposed in the CD phase [3]. It is expected the welding of channel pipes with the shield blocks is complicated. The water with 4 MPa, 70 °C is injected into the inflow pipe. The inflow pipe has the several hole. The water could be distributed to the separated blocks through these holes. After distributed water cooled down the structure, the water is discharged into the channel of outflow. The water coolant flow scheme is described in Fig. 3. The welding was proposed in order to connect the contact region as withstand the internal pressure. The candidate welding methods are GTAW (Gas Tungsten Are Welding) and EBW (Electron Beam Welding). One block consists of several sub-blocks. All contact region should be welded to prevent the leakage of water. It is difficult because of the limited access to the welding region.

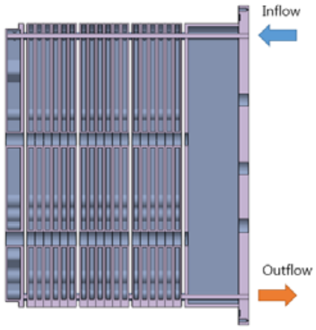

Fig. 2. Cross-section of TBM-shield at CD phase

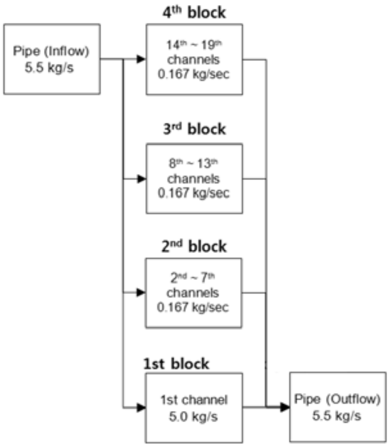

Fig. 3. Water coolant flow scheme

The design of TBM-shield was presented to remove the manufacturing difficulties as shown in Fig. 4 and 5. The shield blocks has the initially channel-shaped geometry. After assembling the shield blocks, the channel cover plate would be welded with the shield blocks to prevent the water leakage. The welding region of channel would be exposed to the outer surface. There is no access limitation in the present design of TBM-shield. Each shield block could be completely fabricated before assembling each other. The overall manufacturing process is simplified compared with the previous process of CD model.

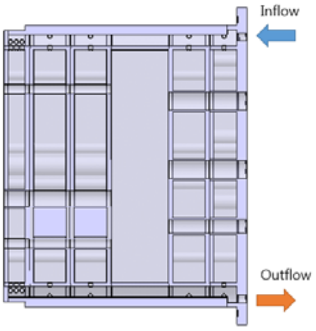

Fig. 4. Cross-section of present TBM-shield design

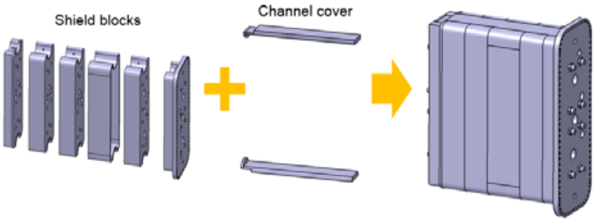

Fig. 5. Components of TBM-shield

3. Thermal analysis

For the TBM-shield, 316L(N)-IG stainless steel is considered as the structural material. At temperatures above 450 °C, stainless steels present grain boundary embrittlement and then could affect fracture properties [3]. The design requirement of 316L(N)-IG is determined as 400 °C [4]. CDF analysis was performed to check the maximum temperature in the TBM-shield structure. The water coolant was fully flooded in the channels. The condition of injected water is 5.5 kg/s flow rate and 70 °C. The structure itself was heated due to the reactions with neutrons. The heating condition and boundary was obtained from the results of neutronics analysis. The figure 6 shows the temperature distribution on the TBM-shield. The maximum temperature is 371.3 °C. The region of the highest neutron flux is in the front of the TBM-shield. The most amount of heat is generated in this region. It could be expected that the highest head region will be bottom of first block considering the distance between the coolant channel and the thermal state. This prediction is consistent with the analysis results.

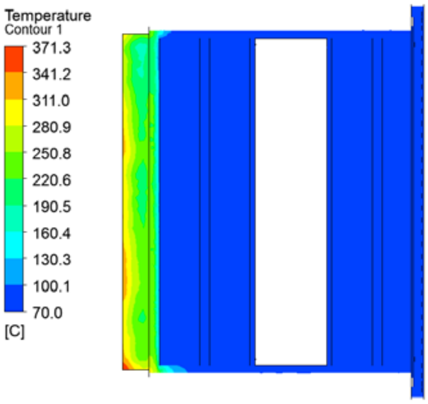

Fig. 6 Temperature distribution on the TBM-shield

4. Conclusions

Current design and thermal analysis results for the TBM-shield were presented. The geometry of the shield blocks was considerably changed. The coolant channel was exposed to the outer surface of the TBM-shield. The overall manufacturing process is simplified compared with the previous process of CD model. The maximum temperature of the structure meets the design criteria.

Acknowledgment

This work was supported by R&D Program through National Fusion Research Institute (NFRI) funded by the Ministry of Science, ICT and Future Planning of the Republic of Korea (NFRI-IN1603).

REFERENCES

[1] HCCR-TBS Conceptual Design Description (QQ2R5R v1.0), 2014
[2] HCCR-TBS CD Neutronics Analysis Report for TBM-set (QQ3KQS v1.0), 2014
[3] HCCR-TBS CD Thermal-hydraulic Analysis Report for TBM-set (QQJMTT v1.0), 2014
[4] HCCR-TBS Material data summary for the design and analysis of CDR (QABFQ5 v1.0), 2014