Current design of Attachment for Test Blanket Module in Korea

Seong Dae Park[a], Suk-Kwon Kim[a], Dong Won Lee[a], Jae-Sung Yoon[a], Hyoseong Gwon[b]
[b]*Korea Atomic Energy Research Institute, Daejeon, Republic of Korea*
[b]*Korea Institute of Fusion Energy, Daejeon, Republic of Korea*
[*]*Corresponding author: sdpark@kaeri.re.kr*

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1. Introduction

The TBM is a device that will be installed in ITER to produce and transport tritium [1-3]. In general, the TBM is divided into a TBM-box part to produce tritium and remove heat, and a TBM-shield part to reduce the intensity of radiation coming out of the back of the TBM. It is necessary to connect the two, and different countries designing TBMs use different names such as mechanical joint, connecting support, attachment, etc. [4, 5]. In this study, the term attachment is used. The main purpose of the attachment is to connect the TBM-box and TBM-shield, and in order to achieve this purpose well, it is important to secure sufficient structural integrity through proper design against stresses and deformations caused by loads affecting the attachment. Currently, Korea is conducting a joint TBM design with the EU for two HCCP TBMs.

In this study, based on the attachment designs studied in the EU, we identified the characteristics of the existing designs and presented our research on the parts that need to be improved.

2. Design Characteristics

The main loads on the integrity of an attachment are thermal and EM loads. The reasons and effects of each load are described below.

2.1 Thermal load

In the multiplier and propagation materials in the TBM-box, neutron production and reactions involving tritium production occur, resulting in heat generation. All structures, including the TBM-box and the TBM-shield, also generate heat from neutron reactions. The TBM-box is kept at a relatively high temperature because it uses gaseous helium coolant to minimize the loss of neutrons. For the production and transport of tritium, a relatively high temperature of helium is used in order to be efficient [6]. The TBM-shield is maintained at a relatively low temperature compared to the TBM-box because water is used to reduce the amount and energy of neutrons escaping the back end of the TBM-set. Also, since the TBM-box and TBM-shield are made of different materials, the thermal expansion coefficient and influence of the material must be considered. The design of the attachment should reflect these temperature and material effects in the design. As the TBM-box and TBM-shield expand differently due to temperature changes, the attachment will deform, and the geometry and proper installation location should be selected to minimize stress due to deformation.

2.2 Electro-magnetic load

The TBM-set is directly exposed to electromagnetic fields to confine the plasma. Therefore, the structure of the TBM-set is subjected to the loads generated by these electromagnetic fields. The TBM-shield is made of austenitic stainless steel, which is weakly magnetic, while the TBM-box is made of ferritic RAFM steel, which is ferromagnetic. The TBM-box is subjected to loads within the magnetic field, and the attachment design must withstand deflection and torsion.

3. FEM analysis

3.1 Simplified TBM-set model & boundary conditions

Structural analyses were performed to identify characteristics of the original design by using ANSYS [7]. The TBM-set has a complex geometry and structure for internal cooling channels [8]. To check the characteristics of the attachment, the TBM-box and TBM-shield were simulated in a simple shape as shown in Figure 1. The TBM-box and TBM-shield were simulated with a blank space inside to match the weight of each part. To reflect the temperature distribution of the TBM-set formed under normal operation for the ITER D-T reaction, the heat density due to nuclear reactions occurring in the volume of the structure was reflected [9]. The cooling effect of helium and water on the walls of the internal blank space was reflected. Figure 2 shows the thermal analysis boundary conditions and the resulting temperature distribution.

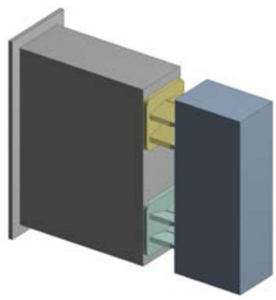

Fig. 1. Simplified TBM-set model

The EM load is the load generated by the forces on the structure within the electromagnetic field [10]. To reflect the equivalent effect of EM load, the boundary conditions were chosen to apply a constant force in the direction of the plasma facing surface of the TBM-box.

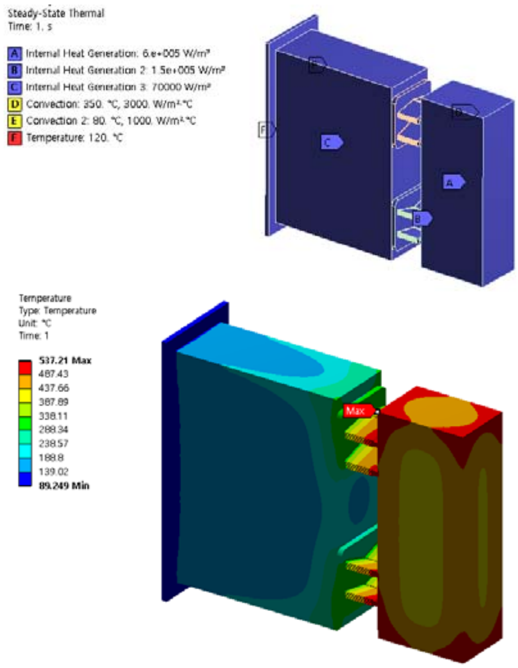

Fig. 2. Boundary condition & temperature distribution

3.2 Original design model

Figure 3 shows the original design of the attachment. In order to reduce the thermal load, thin plates were placed orthogonally to the center of the faces mounted on the TBM-box and TBM-shield to minimize the generation of stress concentration areas when the structure expands due to thermal expansion. By using multiple thin plates rather than a single thick plate, the concentrated stresses were distributed. To prevent torsion of the TBM-box due to EM load, four support points were designed to be formed.

Figure 4 shows the results of the structural analysis for the original design. High stresses occur at the connections between groups of thin plates. As the volume expands radially around the center of the attachment surface, these connections limit the expansion, resulting in a concentration of stresses.

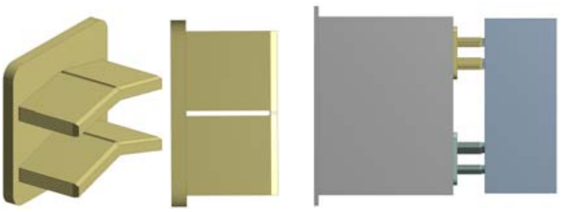

Fig. 3. Original attachment model and location in TBM-set

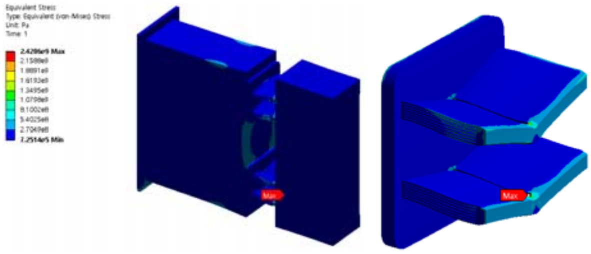

Fig. 4. Stress distribution in TBM-set

3.2 Modified design model

Figure 5 shows an improved model of the geometry where stress concentrations occurred in the original design. By removing the geometry of the area connecting the plate groups in the original design, it was shown that the high stresses formed at the attachment were removed as shown in Fig. 6.

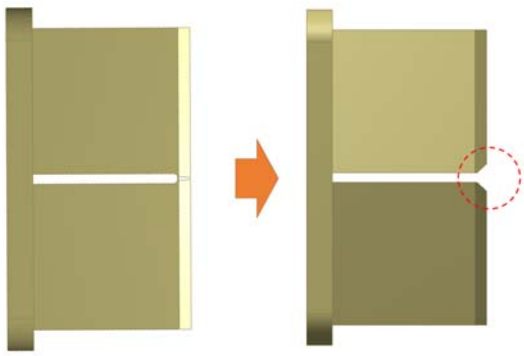

Fig. 5. Modified attachment model

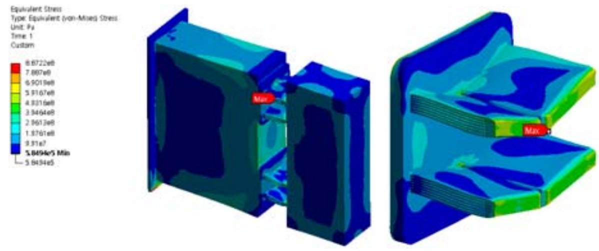

Fig. 6. Stress distribution in TBM-set with modified model

4. Further work

Under the joint Korean-EU TBM design, Korea is responsible for the design of the attachment of the TBM-set. Through the structural analysis of the existing EU-designed attachment, the main points of design and structural characteristics were identified. Based on these findings, an improved geometry model was presented. Research will continue to be conducted on the model to mitigate stress and consider manufacturability.

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