Mechanical Analysis of Single Load for HCCR TBM-set at Preliminary Design Phase 3

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1. Introduction

The HCCR TBM shall be installed in the equatorial port #18 of ITER vacuum vessel directly facing the plasma and cooled by a high-temperature helium coolant of 300 °C. A low-temperature water-cooled (70 °C) shield shall be placed behind the TBM and connected with the water-coolant system of the frame. The TBM is composed of four submodules and a common Back Manifold (BM). A submodule is composed of First Wall (FW), Breeding Zone (BZ). The BZ comprises total seven layers, i.e., three breeder layers, three multiplier layers, and one reflector layer. Thick graphite reflector is located at the last so that its nuclear efficiency can be maximized. Between the layers, breeding zone cooling plates with cooling passage inside are located to cool down each layer in the BZ within operation temperature limit as shown in Fig. 1 [1, 2, 3, 4]. This TBM design was change from PD-2 to PD-3 at preliminary design phase. The major change for each component was shown in Fig. 2. In this work, the engineering analysis results will be introduced.

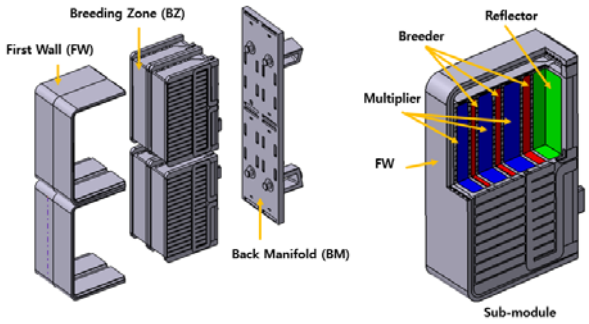


Fig. 1. Exploded and internal view of the HCCR-TBM

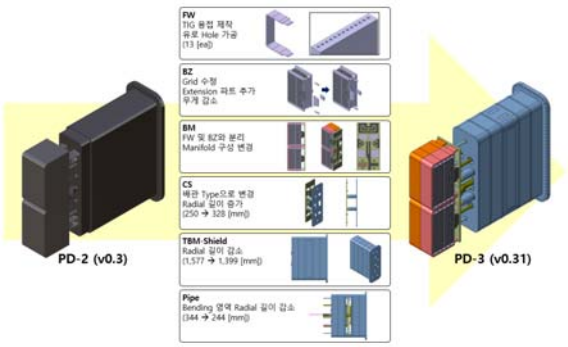


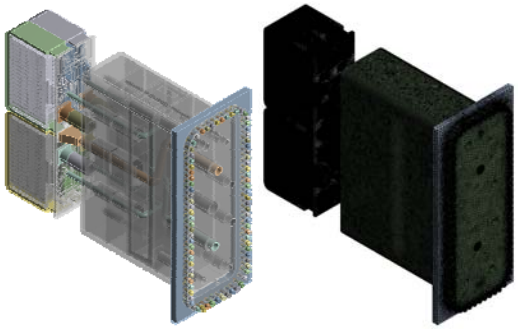
Fig. 2 Design change from PD-2 to PD-3

2. Analysis results

2.1 FEM model

Fig. 3 shows the TBM-set model for FEM analysis. Thermal-hydraulic and mechanical analysis were performed with a ANSYS-CFX. The boundary condition considers that the x-, y-, and z-axes were fixed at the end of theflange, which will be attached with the frame in the TBM Port Plug(PP). The total number of elements is about 35.110.000. The Min. and Ave. mesh quality is 0.101 and 0.807.

The material for the structure is Advanced Reduced Activation Alloy (ARAA) which is Korean Reduced Activation Ferritic Martensitic (RAFM) steel for TBM. SS316L(N)-IG is used for the structure of TBM-shield.



a. Geometry b. Meshing

Fig. 3 FEM model

2.2 Single load

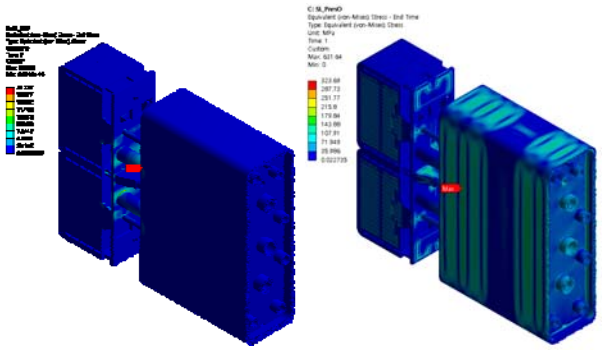
The boundary conditions for the loads applied in TBM-set is described below.

- Dead weight load: The gravity was applied in the analyses with a vertical acceleration of 1g (9.81m/s^2)
- Operation pressure load: The TBM and TBM-shield are loaded by different pressures according to operational states. The operation pressures of TBM and TBM-shield are 8 MPa and 4 MPa, respectively. The specific pressure value was set on the pressure boundaries.
- Operation thermal load: In normal operation, surface heat flux of 0.3 MW/m^2 (INT-TBM) and

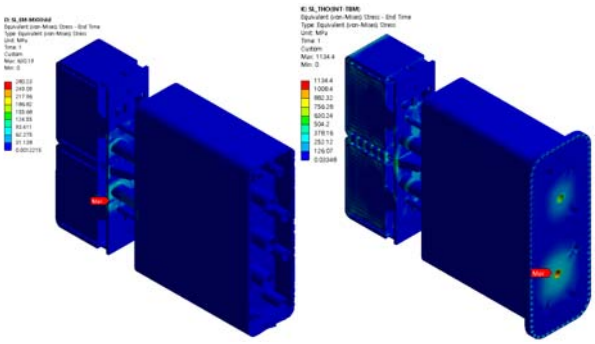
nuclear heating affects the TBM-set temperature. The only surface heat flux of 0.17 MW/m^2 is applied in EM-TBM analysis. It is noted that only INT-TBM was considered in LC analysis because it envelops the EM-TBM, which operate at ~~has~~ lower temperature condition than that of INT-TBM. Thermal-hydraulic analysis was performed to obtain the temperature distribution on the TBM-set. The temperature value on the TBM-set was mapped to perform the structural integrity analysis.

- EM load: MXWstd is the Maxwell force in the steady state of normal operation. MD-I, MD-II, and MD-IV are Lorentz force in the downward exponential 22 milliseconds, downward exponential 16 milliseconds, and the downward slow-fast condition. Cat. III scenario is not considered at present analysis because Cat. III has the same characteristics as Cat. II. The force and torque of the TBM-set according to the EM loads were mapped to perform the structural integrity analysis.

The results of the mechanical analysis for each single load were shown in Fig. 4. The assessment of the structural integrity is in progress.



(a) Dead weight (b) Pressure load



(c) Thermal load (d) EM load

Fig. 4 Von Mises stress for each single load

3. Further work

The mechanical analysis for the single load were performed with only single load acting on the HCCR TBM-set model of the PD-3 phase. Gravity, thermal load and electromagnetic load were used for structural integrity for each single load and load combinations (LCs). The structural integrity assessment will be performed based on the design criteria of RCC-MRx. When unsatisfied locations of HCCR TBM-set is identified, then geometry shape and method that can be improved the structural integrity will be suggested.

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