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Mechanical Analysis of HCCR-TBM Preliminary Design (PD) 2 Model with Various Loads

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1. Introduction

Korea has designed a helium cooled ceramic reflector (HCCR) test blanket module (TBM) including the TBM-shield, which is called the TBM-set, to be tested in ITER. This design is in progress with the preliminary design (PD) phase after the conceptual design (CD) review. The manufacturability was preferentially considered. There are 5 levels according to the integrity analysis of the full TBM-set. In the PD-1 phase, the assembly and welding were considered. In the PD-2 phase, a complementary design for the week part of PD-1 model was made.

In this work, the results of the integrity analysis and further design for PD-2 were described.

2. TBM-set geometry

The HCCR TBM-set consists of TBM and TBM-shield, as shown in Figure 1 HCCR TBM-set configuration. [1] This component is to generate the tritium from the functional materials inside the structure. The HCCR TBM-set shall be installed in the equatorial port #18 of ITER inside the Vacuum Vessel (VV) directly facing the plasma and shall be cooled by a high-temperature He coolant of 300 ºC. A low-temperature water-cooled (70 ºC) shield shall be placed behind the TBM and it shall be connected with the water-coolant system of the frame. TBM and shield shall be connected by connecting supports. The TBM is composed of four sub-modules and a common Back Manifold (BM). The associated shield is composed of the multi-box structure with internal cooling channels.

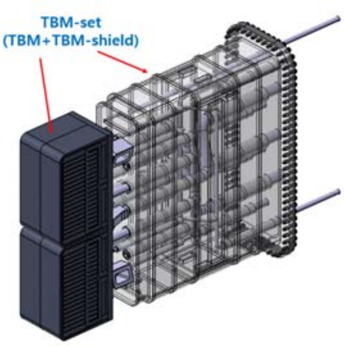
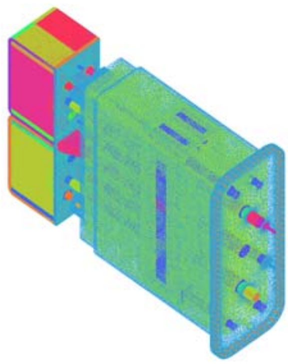


Fig. 1 HCCR TBM-set configuration

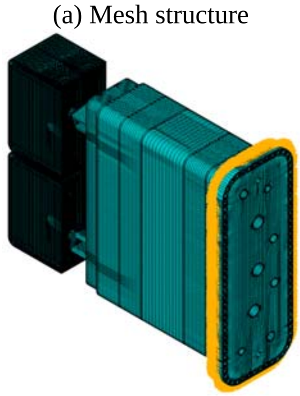
3. FEM model

Figure 2 shows TBM-set mesh model and the boundary condition. The boundary condition considers that the x-,y-, and z-axes were fixed at the end of the flange, which will be attached with the frame in the TBM Port Plug (PP). The HCCR TBM uses RAFM steel, called Advanced Reduced Activation Alloy (ARAA), recently developed by Korea [2], as a structural material. TBM-shield was made of 316L(N)-IG [3].

The loads acting on the TBM PP can be divided into five independent categories which are pressure loads, pretention load, inertial loads and thermal loads. These loads are combined according to the operation and the event condition. Load combination (LC) are 18 cases [4]. The three cases of LC was selected to assess the structural integrity of PD-2 model. It shows the three cases performed in Table 1.



(a) Mesh structure



(b) Boundary condition
Fig.2 Condition of HCCR-TBM

Table 1 Selected load combinations (LC)

Cat.	LC No.	States	# of events
I	2	Operation, Plasma-on	30,000
II	7	Operation, Plasma-on + SL-1 + MD-I	5
II	18	Seismic (SL-1) + Outgassing	5

4. Results

Figure 3 shows the von Mises stress filed of LC No.7. The location of the highest stress is the material interface between the ARAA and the 316L(N)-IG on the TBM-shield. The high stress is caused by the different thermal expansion coefficient for materials. Other stress concentrated location is the inner surface of BM. This stress is caused by the high helium pressure. The results of other cases which are LC No.2 and No.18 is similar with that of LC No.7.

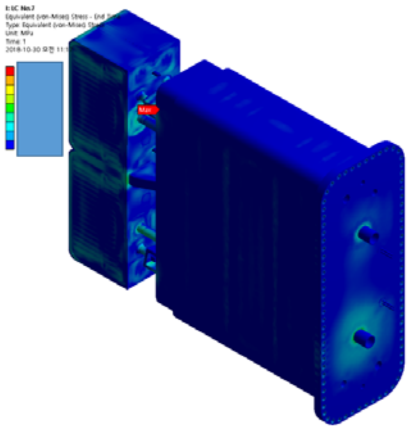
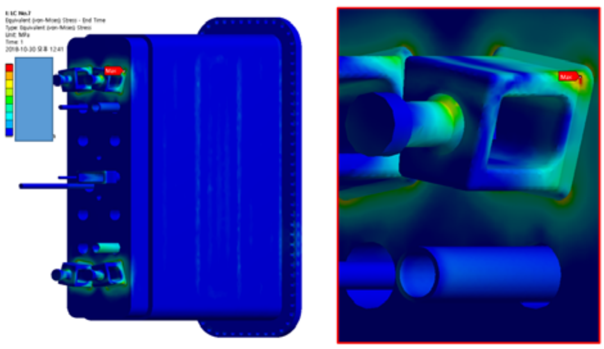
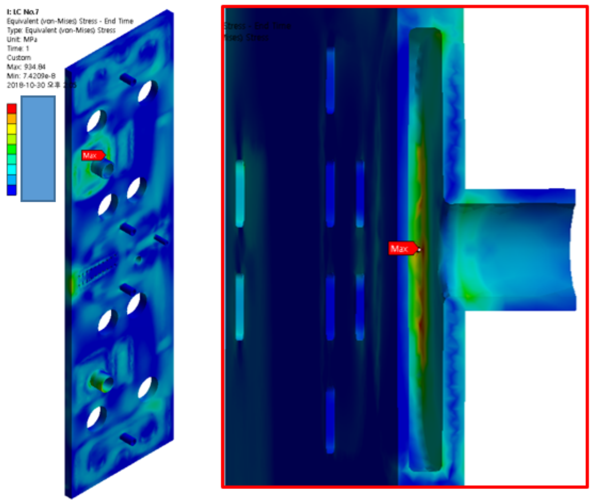


Fig. 3 Von Mises stress distribution of LC No.7



(a) High stress location on TBM-shield



(b) High stress location on TBM BM

Fig. 4 Von Mises stress distribution of LC No.7

5. Further work

The integrity analysis of PD-2 model was performed. The stress concentrated locations were confirmed. The method to reduce the stress will be investigated. The structural integrity will be evaluated according to RCC-MRx which is design code.

REFERENCES

[1] HCCR-TBS Conceptual Design Description (QQ2R5R v1.0), ITER internal document, 2014

[2] Y. B. Chun et al., "Development of Zr-containing advanced reduced-activation alloy (ARAA) as structural material for fusion reactors." Fusion Engineering and Design 109, 5 (2016).

[3] D.W. Lee et al., HCCR-TBS Material Data Summary for the Design and Analysis of CDR (QABFQ5 v1.0), 2014

[4] TBM Port Plug (TBM PP) System Load Specifications (BKXK75 v2.7), 2015