Preliminary Design Progress of the HCCR TBM for ITER testing

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1. Introduction

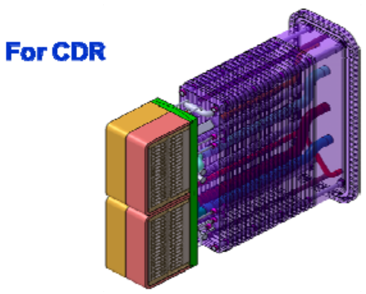
Korea has designed a helium cooled ceramic reflector (HCCR) test blanket module (TBM) including the TBM-shield, which is called the TBM-set, to be tested in ITER, a Nuclear Facility INB-174[1]. Through the conceptual design review (CDR), its design integrity was successfully demonstrated at the conceptual design level at various loads [2-6]. After CD approval, preliminary design (PD) was started and the progress is introduced in the present study. After PD review and approval, final design and then fabrication will be started.

The main purpose of PD is to design the TBM-set according to the fabrication aspect and more detailed design for interfaces with ITER machine, such as installed TBM port plug and frame. With these considering, PD of TBM-set was started. Figure 1 shows the main change of the design parameters for each TBM-set design phase; breeder material was changed Li4SiO4 to Li2TiO3 and it affects the temperature limit and enrichment of the Li-6; Graphite reflector was changed pebble type to block type and it affects the radial dimension of the TBM; as a results of the TBM-set design, the total weight was changed 5.552 tons to 5.124 tons and the limitation of RAFM steel (1.3 ton) was satisfied to be 1.163 tons.

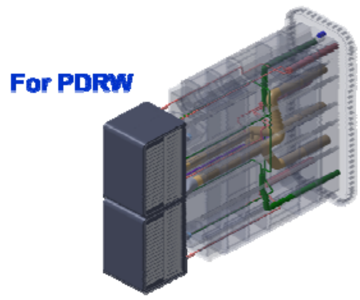
As shown in Fig. 2, the first wall (FW), breeding zone (BZ), side wall (SW), tritium extraction line, back manifold (BM), and connection pipes are being changed. Among them, the FW and BM design changes are introduced in the present study.

2. First wall design and analysis

The end of channels was designed to concentrate to ensure the welding area with BM. The number of He cooling channels is reduced from 11 to 10 to avoid the HAZ related to welding. The current FW design has the port plug to enhance the connection with BM. The temperature requirement (<550 ^{o}C) for the material strength is satisfied with modified FW design, as shown in Fig. 3.



Parameter	Values
FW heat flux	0.3 MW/m^2
Neutron wall load	0.78 MW/m^2
Thermal Power	0.98 MW
Structural material	KO-RAFM (ARAA) (< 550 °C)
Breeder	Li_4SiO_4 (< 920 °C) 40% enrichment Li-6
Multiplier	Be (< 650 °C)
Reflector	Graphite (pebble type, <1200 °C)
Size	1670(P) x 462(T) x 605(R) (mm)
Weight (TBM/FMS/shield)	5.552 tons (1.452 / 1.209 / 4.1)
Coolant	8 MPa He 1.14 kg/s (Nominal) FW (300 °C/390 °C) Breeding Zone (390 °C/500 °C)
Purge gas	He with 0.1 % H_2



Parameter	Values
FW heat flux	0.3 MW/m^2
Neutron wall load	0.78 MW/m^2
Thermal Power	0.98 MW
Structural material	KO-RAFM (ARAA) (< 550 °C)
Breeder	Li_2TiO_3 pebble (< 920 °C)** 70% enrichment Li-6
Multiplier	Be (< 650 °C)
Reflector	Graphite (block type, <1200 °C)
Size	1670(P) x 462(T) x 535(R) (mm)
Weight (TBM/FMS/shield)	5.126 tons (1.363 / 1.163 / 3.763)
Coolant	8 MPa He 1.14 kg/s (Nominal) FW (300 °C/390 °C) Breeding Zone (390 °C/500 °C)
Purge gas	He with 0.1 % H_2

Fig. 1. Main change of the TBM-set design parameters according to the design phases

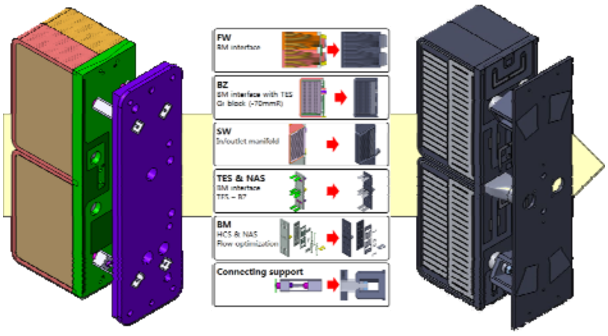


Fig. 2. Main design changes of the TBM-set in the PD phase

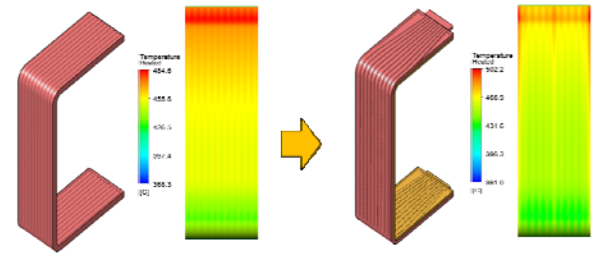


Fig. 3. FW design and analysis results

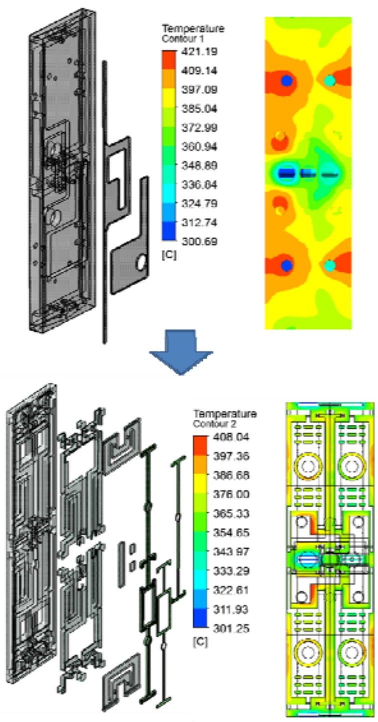


Fig. 4. BM design and analysis results

3. Back manifold design and analysis

The back manifold supports the 4 TBM sub-modules. The formation of the effective cooling channel is focused in the current BM modeling. The helium cooling channel and the TES line are embedded in BM structure. Retain the enough space between the TBM and TBM-shield. The temperature requirement (<550 ^{o}C) for the material strength is satisfied with modified BM design, as shown in Fig. 4.

4. Conclusions and future works

PD for HCCR TBM has been performed (so far v0.24) from the CD model. FW, BZ, SW, TES/NAS, BM, and connecting support design were performed through the analyses, if necessary. The manufacturability was the main concern for PD model development. Thermal hydraulic analysis will be performed to evaluate the temperature and pressure drop in TBM-set.

The structural integrity of TBM-set will be confirmed with combined various loads condition. For analysis, structure and fluid meshes were produced (64 M and 15 M elements each), as shown in Figs. 5. Thermal-hydraulic analysis is being performed with mesh sensitivity study.

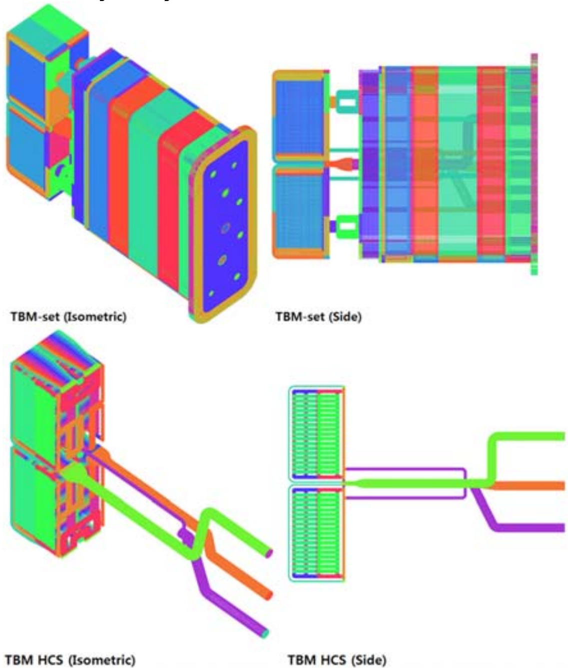


Fig. 5. Meshes for TBM-set structures and fluids

REFERENCES

[1] D. W. Lee et al, Integrated Design and Performance Analysis of the KO HCCR TBM for ITER, Fusion Eng. Des. 98-99 (2015) 1821-1824

[2] D. W. Lee et al, Thermal-hydraulic Analysis for Conceptual Design of Korean HCCR TBM-Set, IEEE T. Plasm. Sci. in press (2016)

[3] D. W. Lee et al, Thermo-Mechanical Analysis for the Conceptual Design of Korean HCCR TBM-Set, IEEE T. Plasm. Sci. in press (2016)

[4] D. W. Lee et al, Seismic Analysis for Conceptual Design of HCCR TBM-set, Fusion Eng. Des. 109-111 (2016) 232-236

[5] D. W. Lee et al, Structural Analysis by Electro-Magnetic Loads for Conceptual Design of HCCR TBM-set, Fusion Eng. Des. 109-111 (2016) 554-560

[6] D. W. Lee et al, Structural Analysis by Load Combinations for Conceptual Design of HCCR TBM-set, Fusion Eng. Des. 109-111 (2016) 237-241

[7] ANSYS-CFX 14.5, 2014, User Manual, ANSYS-CFX