Progress on the Korean Test Blanket Module Development for testing in the ITER

Dong Won Lee [a*], Eo Hwak Lee [a], Suk Kwon Kim [a], Jae Sung Yoon [a], Seung Jae Lee [a], Dong Ju Seo [a], Seungyon Cho [b]

[a]*Korea Atomic Energy Research Institute, Daedeokdaero 1045, Yuseong-gu, Daejeon, 305-600, Republic of Korea*
[b]*National Fusion Research Institute, Deokjin-dong, Yuseong-gu, Daejeon, Republic of Korea*
[*]*Corresponding author:dwlee@kaeri.re.kr*

1. Introduction

Korea has proposed and designed a Helium Cooled Molten Lithium (HCML) Test Blanket Module (TBM) to be tested in the International Thermonuclear Experimental Reactor (ITER) [1-4]. Ferrite Martensitic (FM) steel is used as the structural material and helium (He) is used as a coolant to cool the first wall (FW) and breeding zone. Liquid lithium (Li) is circulated for a tritium breeding, not for a cooling purpose.

Main purpose for developing the TBM is to develop the design technology for DEMO and fusion reactor and it should be proved through the experiment in the ITER with TBM. Therefore, we have developed the design scheme and related codes including the safety analysis for obtain the license to be tested in the ITER. In order to develop and install at the ITER, several technologies were developed in parallel; fabrication, breeder, He cooling, tritium extraction and so on. The past progress was introduced in the former meeting [5]. In the present paper, the current progress was introduced after that meeting.

2. Development of the design scheme and codes

For design of the TBM itself, 3D CAD was developed with CATIA V5 and thermal-hydraulic /mechanical performance was evaluated with ANSYS codes; -CFX and -mechanical classic version. In neutronic analysis, MCCARD and MCNP were used and ATILLA code has been prepared for 3D analysis. In accident analysis, decay heat and activation materials were obtained through MCCARD and MCNP codes. Transient performance after accident was evaluated with ANSYS and MARS-GCR (Multi-dimensional Analysis of Reactor Safety for Gas Cooled Reactor) and GAMMA (GAs Multi-component Mixture Analysis) codes for TBM temperature and coolant behavior, respectively. For liquid breeder, the safety analysis was not performed because the related codes such as MARS-FR and GAMMA-FR developments were not completed yet.

Among them, CFD and GAMMA codes were verified up to 30 bar of pressure and 2.5 kg/min of mass flow rate with the experimental data by 6 MPa nitrogen loop. Both code show a good agreement with the experimental results, as shown in Fig [6]. 1. Currently, new 9 MPa He loop has been prepared and it will be used for these verification with the high pressure and mass flow rate conditions.

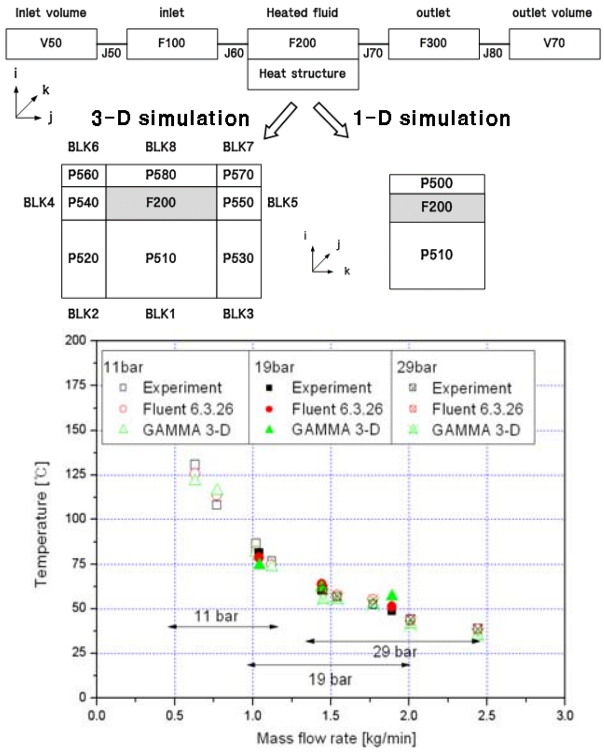

Fig. 1 Nodalization of the GAMMA input and its comparison with the experimental data

3. Development of the key technologies for developing the KO TBM

3.1 Fabrication technology development

The FW is an important component which faces the plasma directly and therefore, it is subjected to high heat and neutron loads. The FW is composed of a beryllium (Be) layer as a plasma facing material and FM steel as a structure material. In order to develop the fabrication technology for a TBM structure, several mock-ups, especially for the FW channels, were fabricated with a HIP (Hot Isostatic Pressing), which was developed similarly to the development of the ITER blanket FW in Korea. For joining FMS to FMS, mock-ups were fabricated with an HIP (1050 ^{o}C, 100 MPa, 2 hours). For joining Be to FMS, two mock-ups were fabricated with the same method (580 ^{o}C, 100 MPa, 2 hours) using different interlayers. All of the developed joining methods were proved through the high heat flux (HHF) test with the constructed facilities, KoHLTs (Korea Heat Load Test) under 1.0 MW/m^2 and 0.5 MW/m^2 heat fluxes of up to 1000 cycles [7].

After confirmation of the joining methods, actual FW fabrication procedure was developed. To fabricate the FW without rectangular channels by cold rolling, machining, welding, and HIP were used as shown in Fig. 2. Currently, 10 channel mock-up has been fabricated with the same procedure. It will be tested with HHF condition for its joining integrity.

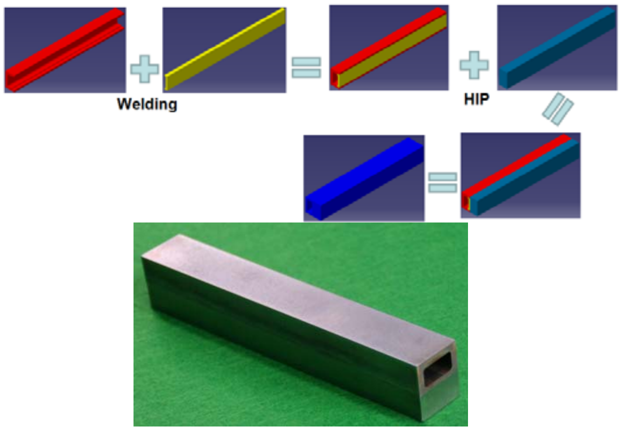

Fig. 2 Fabrication technology development: FW fabrication method verification

3.2 He cooling technology development

A new He loop has been constructed in KAERI, in which the design pressure and temperature were 9 MPa and 500 ^{o}C, respectively. With this loop, high temperature and high pressure He will be supplied to the mock-up, which installed in the graphite heating system, KoHLT. The test conditions will be 8 MPa pressure, 300 ^{o}C inlet temperature and 0.5 kg/s flow rate, which are the same conditions of the KO TBM FW. One-side of the mock-up was heated with constant heat flux, 0.5 MW/m^2. The conceptual design of the loop is shown in Fig. 3.

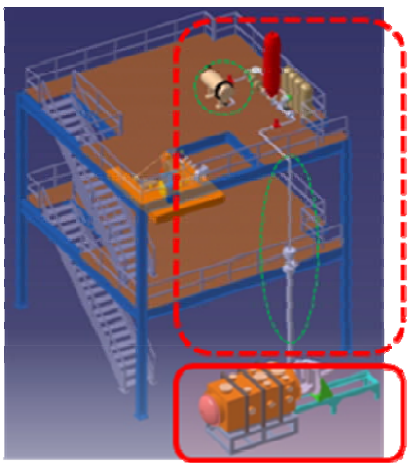
Fig. 3 Design of the He supplying system

3.3 Liquid breeder technology development

In order to develop the liquid breeder technology, the analysis methods of its behavior under electro-magnetic field (MHD, magneto-hydrodynamics), compatibility with structural material, and key-component such as electro-magnetic pump are essential. The experimental loop with PbLi like Figure 4 was established at KAERI for performing the above essential experiments. The design parameters are as follows; over 250 ^{o}C of temperature, 0.5 MPa of pressure, up to 60 lpm of flow rate, 2 T of magnetic field in the magnet [8, 9].

Fig. 4 PbLi loop in KAERI

4. Conclusion

In order to develop the KO HCML TBM for testing in the ITER, design scheme has been developed and the related codes development and verification were performed. The key technologies were classified and developed such as fabrication, He cooling, liquid breeder and so on.

REFERENCES

[1] D.W. Lee, et. al., "Current status and R&D plan on ITER TBMs of Korea," Journal of Korean Physical Society, Vol.49, Dec. 2006, pp S340-S344.
[2] D.W. Lee, et. al., "Preliminary design of a helium cooled molten lithium test blanket module for the ITER test in Korea," Fusion Eng. Des. 82 (2007) 381-388
[3] D.W. Lee, et. al., "Helium cooled molten lithium TBM for the ITER in Korea," Fusion Sci. and Tech. 52 (2007) 844-848
[4] D.W. Lee, et. al., "Design and preliminary safety analysis of a helium cooled molten lithium test blanket module for the ITER in Korea," Fusion Eng. Des., Vol. 83 (2008) 1217-1221.
[5] D. W. Lee, et. al., "Current status on the Korean test blanket module development for testing in the ITER," *Proc. of the KNS Spring Meeting*, Yong-pyoung, Korea, May, 2010.
[6] D.W. Lee, et. al., "Thermal hydraulic test with 6 MPa nitrogen gas loop for developing the Korean He cooled test blanket" Fusion Eng. Des., **85** (2010) 2160-2164.
[7] D.W. Lee, et. al., "Fabrication and high heat flux test of the first wall mock-ups for the Korean He Cooled Test Blanket (KO HCML TBM)," Fusion Eng. Des., Vol. 84 (2009) 1164-1169.
[8] K. S. Jung, et. al., "Preliminary PbLi melting experiment for developing the PbLi loop in KAERI," *Proc. of the KNS Spring Meeting*, Yong-pyoung, Korea, May, 2010.
[9] J. S. Yoon, et. al., "Development of a liquid breeder loop for ITER TBM," *Proc. of the KNS Spring Meeting*, Yong-pyoung, Korea, May, 2010.