Current Status on the Korean Test Blanket Module Development for testing in the ITER

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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. Figure 1 shows the overall TBM development scheme.

In Korea, official strategy for developing the TBM is to participate to other parties' concept such as US and EU ones, in which PbLi (lead lithium eutectic), He, and FM steel were used for liquid breeder, coolant, and structural material, respectively.

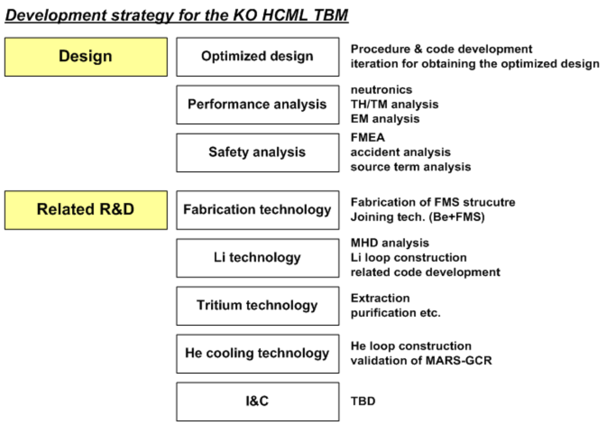

Figure 1 Plan of the KO HCML TBM development

2. Development of the design scheme and related 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. Figure 2 shows the overall codes scheme used in the TBM design and safety analysis. And more, the developed plan was included in the figure.

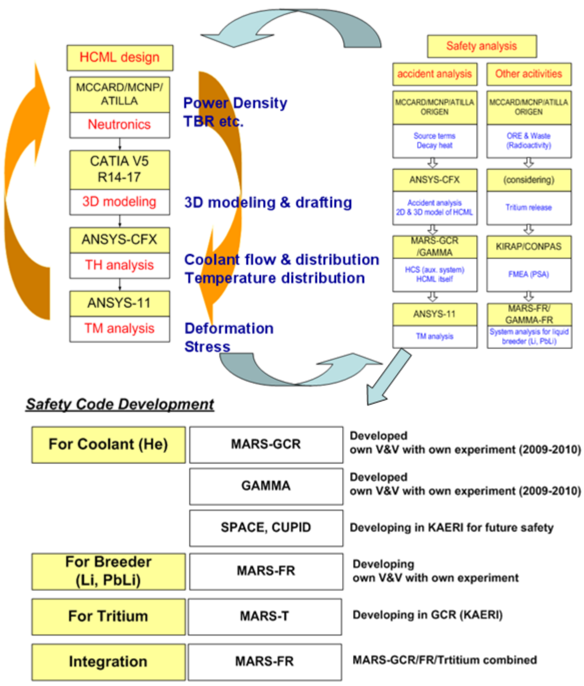

Figure 2 Plan of the design and system analysis codes development

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

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. Then, in order to evaluate the integrity of the fabricated mock-ups, they were tested at the high heat flux (HHF) test 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. Since there is no delamination or failure in the mock-ups, it could be concluded that the fabrication methods was developed successfully. Figure 3 shows the tested mock-ups for each joining.

The performance analysis for thermal-hydraulics and safety analysis for an accident by loss of a coolant for the KO TBM have been carried out with a commercial CFD code, ANSYS-11 and system codes such as MARS-GCR and GAMMA. In order to verify these codes, especially for the ANSYS-11 and GAMMA through the comparison with experimental results, a basic thermal-hydraulic test with a high pressure nitrogen gas loop up to 6 MPa pressure and 1,000 ^{o}C temperature was performed. In the experiment, a TBM FW mock-up made from the same material as the KO TBM, FM steel, was used and the test was performed under the conditions of pressures of 20 and 36 bar and flow rates of 0.75 and 0.92 kg/min. As one-side of the mock-up was heated to 230 ^{o}C, the wall temperatures were measured by installed thermocouples. Experimental results show a strong parity with the codes' ones in the test conditions. An additional test with higher pressure and temperature has been prepared for the future.

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 5 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. .

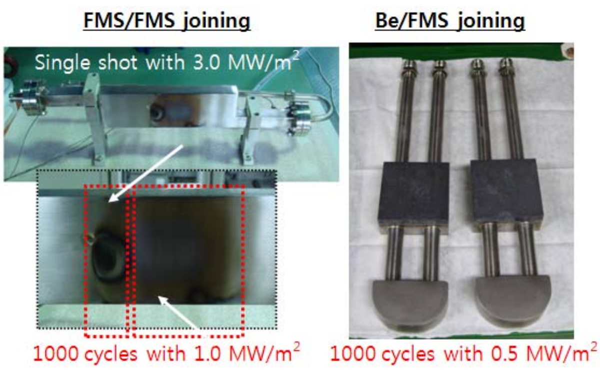

Figure 3 Fabrication technology development: FMS/FMS and Be/FMS joining

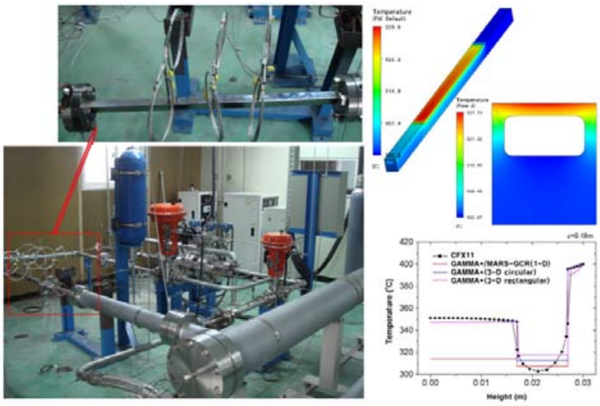

Figure 4 He cooling technology development: Gas loop and codes verification

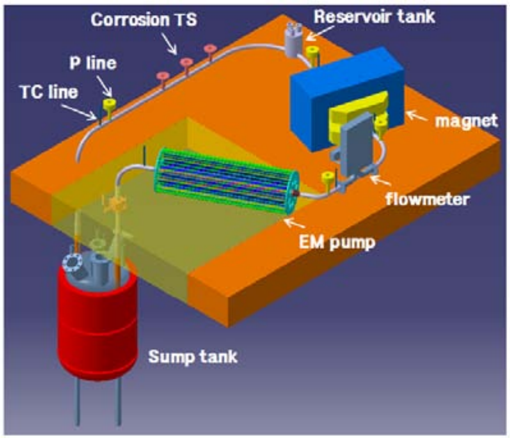

Figure 5 Liquid breeder development: PbLi loop construction and related experiments

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.

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