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New progress on design and R&D for solid breeder test blanket module in China

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HIGHLIGHTS

- The new progress on design and R&D of Chinese solid breeder TBM are introduced.
- The mock-up fabrication and component tests for Chinese HCCB TBM have being developed.
- The neutron multiplier Be pebbles, tritium breeder Li_4SiO_4 pebbles, and structure material CFL-1 are being prepared.
- The fabrication of 1/3 sized mock-up is being carried-out.
- The key technology development is proceeding to the large-scale mock-up fabrication.

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ABSTRACT

ITER will be used to test tritium breeding module concepts, which will lead to the design of DEMO fusion reactor demonstrating tritium self-sufficiency and the extraction of high grade heat for electricity production. China plans to test the HCCB TBM modules during different operation phases. Related design and R&D activities for each TBM module with the auxiliary system are introduced.

The helium-cooled ceramic breeder (HCCB) test blanket module (TBM) is the primary option of the Chinese TBM program. The preliminary conceptual design of CN HCCB TBM has been completed. A modified design to reduce the RAFM material mass to 1.3 ton has been carried out based on the ITER technical requirement. Basic characteristics and main design parameters of CN HCCB TBM are introduced briefly. The mock-up fabrication and component tests for Chinese test blanket module are being developed. Recent status of the components of CN HCCB TBM and fabrication technology development are also reported. The neutron multiplier Be pebbles, tritium breeder Li_4SiO_4 pebbles, and structure material CLF-1 of ton-class are being prepared in laboratory scale. The fabrication of pebble bed container and experiment of tritium breeder pebble bed will be started soon. The fabrication technology development is proceeding as the large-scale mock-up fabrication enters into the R&D stage and demonstration tests toward TBM testing on ITER test port are being done as scheduled.

1. Introduction

ITER will be used to test tritium breeding module concepts, which will lead to the design of DEMO fusion reactor demonstrating tritium self-sufficiency and the extraction of high grade heat for electricity production. China and others parties plan to test their TBM modules during different operation phases. Related design and R&D activities for each TBM module with the auxiliary system are introduced.

The helium-cooled ceramic breeder (HCCB) test blanket module (TBM) is the primary option of the Chinese TBM program. The preliminary conceptual design of CN HCCB TBM has been completed. A modified design to reduce the RAFM material mass to 1.3 ton has been carried out based on the ITER technical requirement. Basic characteristics and main design parameters of CN HCCB TBM are introduced briefly. The mock-up fabrication and component tests for Chinese test blanket module are being developed. Recent status of the components of CN HCCB TBM and fabrication technology development are also reported. The neutron multiplier Be pebbles, tritium breeder Li_4SiO_4 pebbles, and structure material CLF-1 of ton-class are being prepared in laboratory scale. The fabrication of pebble bed container and experiment of tritium breeder pebble

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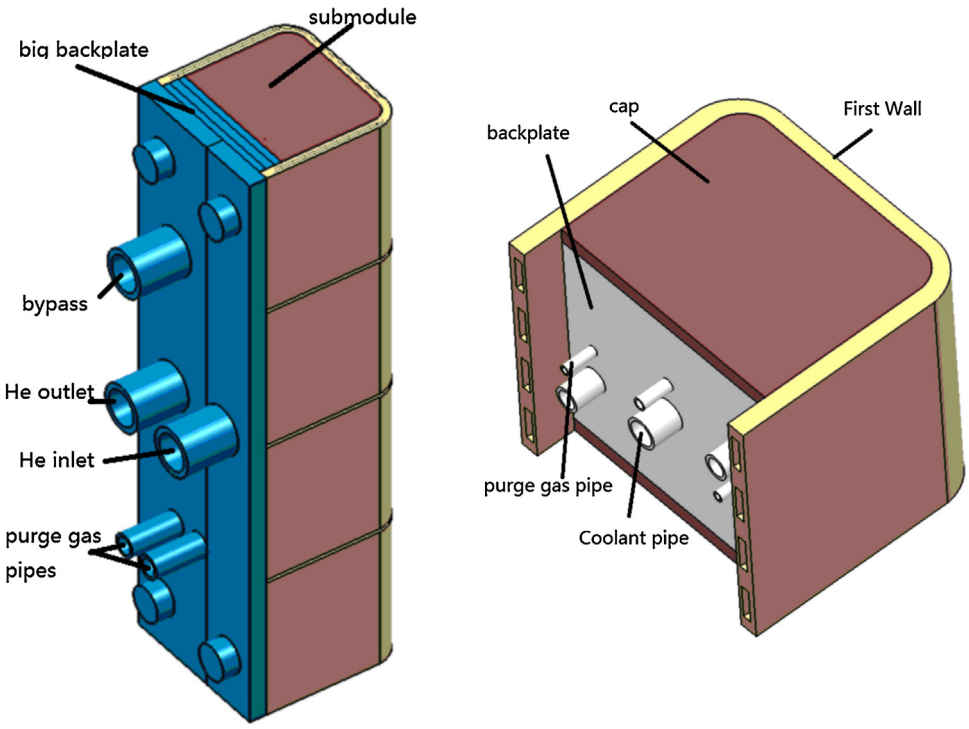

Fig. 1. Overall isometric view of the HCCB TBM and its sub-module.

bed will be started soon. The fabrication technology development is proceeding as the large-scale mock-up fabrication enters into the R&D stage and demonstration tests toward TBM testing on ITER test port are being done as scheduled.

2. Design progress

2.1. Updated design descriptions

In order to reduce the effects of magnetic field ripple, the design was updated with reduced RAFM mass. Updated CH HCCB TBM design has dimensions of 462 mm in radial direction, 1670 mm in poloidal direction, and 465 mm in toroidal direction [1,2]. The TBM consists of a big back-plate and 4 sub-modules arrayed in poloidal direction with 10 mm gap between sub-modules. All sub-modules are welded to the big back-plate. The TBM structure meets level D criteria in case of loss of primary coolant accident inside the sub-modules. There are three big pipes used for coolant helium and two small pipes for purge gas on the back-plate. The back-plate has functional cavities used to distribute and collect the coolant and purge gas. The ferritic/martensitic steel, named CLF-1, is chosen as the reference structure material. The total weight of CLF-1 is about 1.3 ton.

The sub-module shown in Fig. 1 is bounded by the First Wall (FW), two caps on top and bottom respectively, and its own back-plate. The distance between end edge of the cap and front edge of the first wall is 392 mm. In FW, one inlet is divided into two channels, and each channel is divided into 2 pipes in the plasma facing region. Therefore the cross-section dimension of the pipes in the plasma facing region is smaller that in other areas to increase flow velocity. Caps have their own internal cooling channels. The back-plate is used to supply coolants to components of the sub-module except for FW. The back plate has to accommodate three coolant pipes and three purge gas pipes (inlet in middle and 2 outlets in lateral). Three manifolds are integrated in the back-plate for the coolant and a multi cavity structure serves for the distribution of the purge flow.

In the sub-module shown in Fig. 2, there are a middle plate and two double-layer U-shaped cooling plates. These two U-shaped structures are used to hold Lithium orthosilicate as tritium breeder and outside them are beryllium pebbles used as neutron multiplier.

3-D neutronics calculation of 1×4 CN HCCB TBM incorporated into whole ITER tokamak structure has been performed by using the Monte Carlo transport code MCNP5 and the 40-degree ITER neutronics model (B-lite model, provided by ITER IO). All nuclear

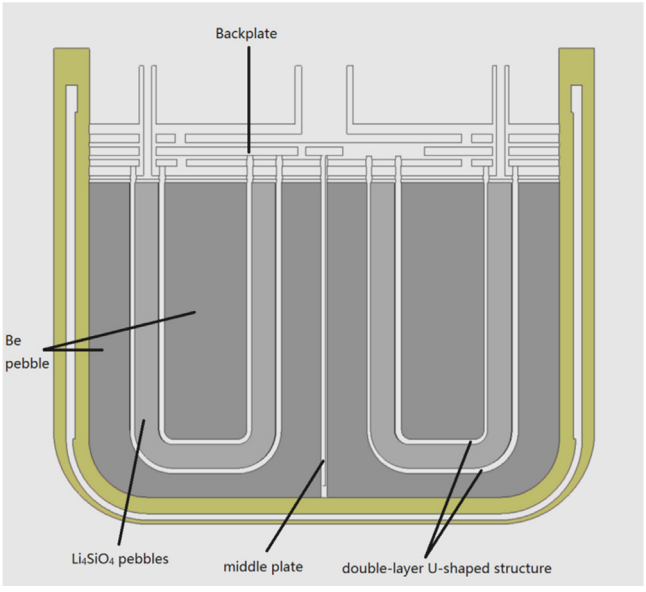

Fig. 2. Structural view of sub-module.