Progress on solid breeder TBM at SWIP


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A R T I C L E   I N F O

Article history:
Available online 15 September 2010

Keywords:
ITER
Test blanket module
Helium-cooled solid breeder blanket
HCSB TBM

A B S T R A C T

Current progress on the design and R&D of Chinese helium-cooled solid breeder test blanket module, CN HCSB TBM is presented. The updated design on structural, neutronics, thermal-hydraulics and safety analysis has been completed. In order to accommodate the HCSB TBM ancillary system, the design and necessary R&Ds corresponding sub-systems have been developed. Current status on the development of function materials, structure material and the helium test loop are also presented. The Chinese low-activation ferritic/martensitic steels CLF-1, which is the structural material for the HCSB TBM is being manufactured by industry. The neutron multiplier Be and tritium breeder Li₄SiO₄ pebbles are being prepared in laboratory scale.

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1. Introduction

ITER will be used to test tritium breeding module concepts, which will lead to the design of DEMO fusion reactor design demonstrating tritium self-sufficiency and the extraction of high grade heat for electricity production. The helium-cooled/solid tritium breeder (HCSB) with the pebble bed concept was selected as Chinese test blanket module (TBM) design. Dimensions of HCSB TBM occupying half of the ITER test port is shown in Fig. 1. Previous configuration of the HCSB TBM with the $3 \times 6$ modularized sub-module (SM) arrangement has been replaced by the $2 \times 6$ modularized SM arrangement [1]. The new configuration will better satisfy the ITER TBM design requirements [2]. Corresponding design optimization on structural, neutronics, and detailed performance analyses has been performed. Furthermore, in order to reduce the impacts of the RAFM steel material impact on the magnetic field ripple, the last design has been modified to minimize the mass of RAFM steel.

Updated structure design based on originally design that is shown in Figs. 1 and 2 has been performed. Progress on module configuration, analysis on structure, neutronics, thermal hydraulic, thermal mechanical, EM assessment on induced field ripple are presented. Necessary R&Ds on the low-activated CLF-1 steel, neutron multiplier Be pebbles, and the tritium breeding materials Li₄SiO₄ pebbles are moving towards industrial production level.

2. Modification design

Main design modification of HCSB TBM is focused on the structure and configuration of breeding zone of the sub-module. In the former design, the backside of the blanket module is the back-plate forming the flow plenum and distributors. The stiffening grid plate is welded into the box; and each grid plate is cooled by helium flowing with internal channels that are fed from the back. Breeding sub-modules (shown in Fig. 2) are separated by the grid plates. Each sub-module has its own independent cooling and tritium purge gas circuits. Tritium breeder and neutron multiplier are separated by the cooling channel of the sub-module.

The structure design of the sub-module has been modified based on the neutronics results from a 3-D MCNP global model. The modified configuration of the HCSB TBM is shown in Fig. 3a. Main modifications of new modular design include: (1) The TBM is composed of two materials; RAFM steel is used for the FW, caps, grid and sub-modules section, and 316 stainless steel is used for the back-plate and support-plate. (2) The total radial length of the TBM is retained at 670 mm, but the radial dimension of the U-shape FW and breeder sub-modules were decreased to 350 mm and 320 mm, respectively. Subsequently, the total mass of the RAFM steel in TBM is reduced to 720 kg. The explored view of the TBM module is shown in Fig. 3b. (3) The width of the CP is decreased by 5 mm while keeping the area of the cross-section of the helium gas channel. (4) Arrangement of pebble beds in sub-module is changed from the former transverse direction to the current vertical direction, which has the advantages of simplifying the helium cooling loop, improving the neutronics performance. The corresponding RAFM steel of the sub-module is reduced. Schematic of the sub-module is shown...