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Design and Multi-physical Performance Analysis of the WCCB and COOL Blankets for CFETR

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The water-cooled ceramic breeder (WCCB) blanket has been developing as a near-term solid blanket candidate for the Chinese Fusion Engineering Testing Reactor (CFETR). Meanwhile, the supercritical CO2 cOoled Lithium-Lead (COOL) blanket has been proposed as an advanced candidate in recent years. This presentation reports the overall design and performance analysis for both WCCB and COOL blankets.
The WCCB blanket features a mixed pebble bed of Li2TiO3 and Be12Ti as the tritium breeder and neutron multiplier, and a pressurized water of 15.5 MPa as the coolant. The feasibility of the WCCB blanket design is evaluated from the aspects of neutronics, thermo-hydraulics, thermal-mechanics, tritium breeding and nuclear safety. 3D neutronics analysis shows TBR is 1.123 when considering the port effect and contribution from divertor blankets, and the blanket can provide enough shielding capacity. Thermo-mechanical analysis indicates that the WCCB blanket are compliant with the material temperatures and stress limit. Safety analysis for typical blanket module #3 proves that temperature and pressure vary in allowable ranges under steady, transient, LOFA and in-vessel LOCA condition. Tritium transport analysis of typical blanket module #3 provided the amount of tritium inventory and permeation. Tritium permeation into coolant is necessary to be extracted by coolant purification system and reduced by tritium permeation barrier.
The COOL blanket is a typical dual coolant liquid blanket, namely PbLi of 460-600℃ for cooling breeding zones and supercritical CO2 at 350–400 ℃ for cooling FW and structures. Addition-ally, the electrically and thermally insulating SiCf/SiC composites are utilized as Flow Channel Inserts (FCIs) to isolate the high-temperature corrosive PbLi and mitigate the magnetohydrodynamic (MHD) effect. Similarly, comprehensive analyses concerning neutronics, thermomechanics, thermal hydraulics, MHD, and safety demonstrate the blanket concept's feasibility. A 3D neutronic analysis shows that the current design can achieve a global TBR of 1.166 in case of port effects and divertor blankets. In addi-tion, thermal hydraulic analysis indicates the thermally insulating FCI is necessary to prevent the struc-tural overheating. Furthermore, thermomechanical analyses for typical blanket slices present allowable temperature and stress on structures even under the PbLi outlet of 700 ℃. Moreover, MHD analysis proves utilizing electrically insulating FCIs in the PbLi inlet channel decreases the pressure drop dra-matically from 0.75 MPa to 0.09 MPa.
In order to test the breeding blanket technology, both WCCB and COOL Test Blanket Modules (TBM) will be manufactured and configured in two middle ports of the Burning Plasma Experimental Superconducting Tokamak (BEST), a DT operating fusion device constructed in the next five years. Design and test plan of both TBMs will be briefly introduced in the end.

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