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Design status of the European DEMO Helium Cooled Pebble Bed breeding blanket

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Within the EUROfusion DEMO programme, the Helium Cooled Pebble Bed (HCPB) breeding blanket is being developed as a reactor-relevant breeding blanket for the European DEMO. The reference design of this concept employs pressurized helium (8 MPa) as the coolant, a lithium-ceramic pebble bed as the tritium breeder, and beryllide blocks (beryllium-based alloys) as neutron multipliers. Tritium extraction employs a helium purge gas with 100 Pa of hydrogen (partial pressure) at 8 MPa, enhancing tritium recovery through the formation of hydrogen isotopes. This configuration achieves a tritium breeding ratio (TBR) of 1.17—exceeding the TBR design target of 1.15 for tritium self-sufficiency—alongside high reliability and low tritium permeation. However, the use of beryllium poses challenges for commercial deployment due to its global supply constraints, toxicity, and limited reserves. To ensure a cost-effective and economically viable solution, alternative neutron multipliers such as lead (Pb) or Pb-based alloys are being explored.
In terms of manufacturing, the conventional approach for fabricating the first wall involves hot isostatic pressing (HIP) or Electrical Discharge Machining (EDM) to create cooling channels, followed by bending the wall into a U-shape. However, the feasibility of scaling this method to produce an 18-meter-long first wall at the DEMO scale remains uncertain. Alternative manufacturing techniques, such as casting and forging, are currently being investigated as promising solutions. Consequently, modifications to the HCPB architecture are also being explored. This work presents the design progress of the evolved helium-cooled pebble bed breeding blanket concept, emphasizing design simplification and cost-effective material selection, along with its nuclear, thermal-hydraulic, and thermo-mechanical performance assessments.

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