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First thermal-hydraulic and thermal-mechanical analysis of a CO2-cooled solid breeding blanket for the EU-DEMO

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Helium Cooled Pebble Bed (HCPB) Breeding Blanket (BB) has been intensively studied for the EU DEMO. However, several feasibility issues remain for a HCPB-class DEMO reactor, namely the large diameter of the Primary Heat Transfer System pipework, the resulting large coolant inventory and large expansion volumes required after an ex-vessel loss of coolant accident, the limited operational experience with relevant size He-turbomachinery and the large circulating power, among other. Due to the larger density of CO2, the use of this gas as primary coolant for DEMO can lead to key advantageous features, mitigating most of the issues posed for He-cooling and resulting in a higher net efficiency than that of HCPB, as reported in a previous study. Therefore, a CO2-cooled Pebble Bed (CCPB) has been proposed as an alternative coolant to He for the EU-DEMO. After identifying that CO2 will have a negligible influence on the neutronic performance, making the CCPB's TBR almost equal to the HCPB's one (TBR ≈ 1.15), a full first set of thermo-hydraulic and thermo-mechanical analyses with the commercial code of ANSYS CFX are reported here. The analyses are based on the newly proposed design of breeding zone (BZ) in the enhanced HCPB fuel-pin concept for the EU-DEMO. Such pin-type fuel elements have been already used in liquid metal fast reactors since the 1960s. The paper will show that, despite the lower heat transfer capability of CO2 with respect to He, the fuel-pin design breeding zone improves the thermo-hydraulic performance, meeting the materials' temperature requirements. For the thermal-mechanical analysis, the structural behavior under normal operation has been assessed according to the available codes and standards (RCC-MRx). The results show that the CCPB can satisfy the basic thermal and mechanical blanket requirements and that CO2 is a realistic option as primary coolant for gas-cooled fusion reactors.

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