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Neutronic And Thermo-Mechanical Analysis in Support of The Design of The Water-Cooled Lead Ceramic Breeder Breeding Blanket Concept for The EU DEMO

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The design of the breeding blanket (BB) system represents one of the biggest challenges towards the accomplishment of the conceptual design of the DEMO fusion reactor, due to its pivotal role in the machine operations. In this regard, novel BB concepts have been recently emerging in Europe with the aim of developing BB configurations capable of surmounting the major criticalities emerged so far from the dedicated BB R&D programme carried out within the EUROfusion consortium. In this context, the present work focuses on the Water-cooled Lead Ceramic Breeder (WLCB) BB concept. It foresees sub-cooled pressurized water as coolant, solid lead as neutron multiplier and the well-known ceramic breeder in form of pebble bed as breeding material. The ongoing studies aims at demonstrating that such a combination of functional materials will allow maximizing the tritium breeding while keeping high efficiency in heat removal and structural performances compliant with the provisions of the adopted code&standards. Therefore, in order to attain a robust WLCB BB design, neutronic and thermo-mechanical assessments are currently ongoing at the University of Palermo, under the umbrella of EUROfusion. In particular, different WLCB BB architectures have been investigated under the nuclear, thermal and structural standpoints to compare their performances in view of the goals of the WLCB BB design activities.
From the neutronic point of view, a campaign of parametric nuclear analysis has been launched. In particular, assuming different tungsten layer thickness values, different breeder material composition and structural material for the breeding zone cassette (a dedicated structure devoted to house the breeder and the neutron multiplier), the best configuration in terms of tritium breeding ratio has been selected. Then, it has been possible to properly evaluate the impact of each selected parameter on the WLCB BB overall nuclear response.
From the thermo-mechanical standpoint, the outcomes of the afore mentioned neutronic analysis, in terms of nuclear deposited heat power density within the different structural and functional materials, have been assumed to investigate the thermal and structural behaviour of the Top Cap region of the WLCB BB Central Outboard Blanket segment. The study has allowed checking the fulfilment of the prescribed thermal requirements on the Eurofer steel maximum allowable temperature and to verify the compliance with the RCC-MRx structural design criteria. Results have allowed providing indications for the design improvements of such a singular region.
The activity herein presented has been performed adopting a numerical approach, using the MCNP code for the nuclear analysis and the Ansys Workbench calculations suite for the thermo-mechanical investigations.

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