Neutronic analyses for the optimization of the advanced HCPB breeder blanket design for DEMO

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Within the Power Plant Physics and Technology (PPPT) programme of EUROfusion, a major development effort is devoted to the conceptual design of a fusion power demonstration reactor (DEMO) which has the capability to breed Tritium for self-sufficiency. Several design concepts, such as the HCPB, HCLL, WCLL and the DCLL, are considered as viable options for a breeding blanket in the considered DEMO. This DEMO is assumed to be suitable for the accommodation of any blanket type out of the four concepts. For the neutronics analyses, a generic DEMO model is thus set-up which serves as common basis for the integration of blankets of the considered four concepts.

The generic geometry model, based on a CAD model, is then refined for particle transport simulations using the MCNP code. The generation of the HCPB DEMO geometry model is performed in the following way. The generic CAD model with voided blanket space is used for the arrangement of the HCPB blanket boxes without interior structure around the plasma. The configuration of each module is adjusted to the specific position in the reactor and follows the given first wall contour. This model is converted to a MCNP geometry model by making use of the CAD to MCNP geometry conversion tool MCad. The empty space of the blanket modules is then filled with the internal structures representing a detailed HCPB design by making use of the repeated structure feature of the MCNP code. Such an approach satisfies quality assurance requirements, since it guarantees consistency of the CAD and the analysis model.

This work gives an overview of the neutronic analyses to support and optimize the advanced HCPB blanket concept for DEMO. Full scale 3D Monte Carlo particle transport simulations were performed to this end with the MCNP5 code employing a very detailed HCPB DEMO torus sector model with reflecting boundary surfaces.

Optimization of the tritium breeding performance was performed to determine the blanket configuration satisfying tritium self-sufficiency requirement. Different geometry configurations and material arrangements suggest by safety considerations were investigated and implemented in the final blanket design. Various integral and differential nuclear responses necessary for the reactor design and safety analyses were provided on 2D and 3D maps.