

Editorial

# Special Issue on “Breeding Blanket: Design, Technology and Performance”

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A prerequisite for establishing fusion power as one of the sources for low-carbon electricity generation is the demonstration of the capability of future fusion power plants in achieving tritium self-sufficiency and its capability of efficiently producing electricity; both these functions are related to breeding blanket systems, a key component in the transition from ITER to the first generation of nuclear reactors. The future demonstration of fusion power plants should be the first to show the possibility of delivering several hundred megawatts of electrical energy in net and operate in a closed fuel cycle by using a breeding blanket system. With ITER construction moving forward, DEMO projects are transitioning from a preconceptual to conceptual phase, moving towards the beginning of an engineering phase in about ten years.

New material developments and novel manufacturing processes have made their way into blanket design, raising the hopes for more cost-effective designs that still benefit from the high cooling capabilities of complex structures. The presence of the test blanket modules (TBMs) program in ITER has also brought about a paradigm change with respect to the way breeding blanket concepts are developed and nuclear licensing, with quality and qualification requirements now being an important part of the process.

This topical collection aims to provide an overview of the current status of breeding blanket designs as well as the main related technological aspects.

A total of six papers were published in this Special Issue, mainly addressing various aspects of the design studies for the European DEMO Breeding Blanket. In one of the papers, Arena et al. [1] presents the rationale behind the design choices for the Water-Cooled Lithium Lead (WCLL) blanket concept as well as its main characteristics at the end of the pre-conceptual design phase. Using a holistic approach that simultaneously takes into consideration the influence of neutronics, thermal-hydraulics, thermo-mechanics, and magneto-hydro-dynamics, the resulting WCLL layout is compliant with the imposed requirements in terms of integration, tritium self-sufficiency, cooling capabilities, and mechanical stress limits. The paper concludes with a summary of the main achievements reached during the pre-conceptual design phase, and some remaining open issues are presented.

While remaining in the area of WCLL design, Utili et al. [2] moves the discussion towards the qualification of novel manufacturing technologies presenting the preliminary design of an experiment dealing with a more general issue of the fusion breeding blanket, namely tritium permeations from the breeding zones into the blanket cooling circuit that also acts as a Primary Heat Transfer System (PHTS) for a DEMO plant. In this paper, the authors introduce the preliminary engineering design of a WCLL Breeding Blanket mock-up to thoroughly investigate the permeation of hydrogen isotopes from the breeder zone into the PHTS water pipes in the presence of an alumina coating acting as an anti-permeation and corrosion barrier. The paper also includes a hydrogen isotope transport analysis of the mock-up, taking in account the planned testing conditions as well as specific elements coming from the mock-up integration in the TRIEX-II experimental facility.



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Rieth et al. [3] provide an interesting overview of recent activities concerning the fabrication processes and their impacts on the properties of the EUROFER97 steel, which has been selected as the DEMO breeding blanket's structural material. The paper discusses various fabrication routes with a focus on their robustness and applicability in normal industrial processes. The most relevant results of the recent studies on heat treatment, fusion welding, machining, and solid-state bonding of EUROFER97 are included in the paper. As part of a new design strategy, Rieth et al. [3] applied the results of previously mentioned studies in the fabrication of a blanket first-wall mock-up that features a layer of nanostructured oxide dispersion strengthened (ODS) EUROFER97 steel. The mock-up tested in the Helium Loop Karlsruhe (HELOKA) facility under high heat-flux loading conditions using cooling parameters characteristic for the Helium-Cooled Pebble Bed (HCPB) blanket shows an absence of critical defects or recognizable damage despite the fact that the surface's temperature reached levels around 650 °C for several operating hours and was subject to about one hundred loading cycles.

The new studies on material and fabrication processes presented in [3] indicate that, from a materials point of view, there is hope in extending operating limits of the temperature range towards higher values. Despite these encouraging developments, the high surface loading conditions at the blanket first wall would always result in a quick temperature increase in cases of abnormal or accidental conditions. Predicting, with sufficient accuracy, the evolution of the first wall's surface temperature under such fast transients is of outmost importance for DEMO safety studies. Ghidersa et al. [4] present one of the first experiments looking into the behavior of a blanket first wall under a loss of flow accident (LOFA) scenario in an HCPB first wall as well as the subsequent use of the experimental data for calibrating and validating a thermal-hydraulic model of the mock-up. Together with the papers of Angelucci et al. [5] and Gonfiotti et al. [6], it creates a relevant theoretical and practical framework that can be used in further studies concerning incidental transients in real-plant scenarios as part of DEMO plant fusion safety activities. Using a novel software [6], the Best-Estimate Model Calibration and Prediction through Experimental Data Assimilation methodology was applied to thermal-hydraulic models developed with the system codes RELAP5-3D [4] and MELCOR 1.8.6 [5]. This resulted in calibrated models that incorporate, in a consistent manner, the data acquired during the LOFA experimental campaign and showed strengths and weaknesses of the aforementioned codes when dealing with phenomena characterizing LOFA transients.

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