Foreword

Selected papers from the 23rd Topical Meeting on the Technology of Fusion Energy (TOFE 2018)

Fusion Neutronics and Tungsten

Guest Editor

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The Technology of Fusion Energy (TOFE) meeting series provides a platform for discussions and knowledge exchange for researchers working in many very exciting areas, among them being fusion neutronics. In the frame of TOFE 2018 technical program, we have succeeded in gathering worldwide neutronics specialists to present a great variety of cutting-edge neutronics results of different fusion concepts, with one common characteristic—all of them are neutron sources: large deuterium-deuterium (DD) and deuterium-tritium (DT) tokamaks, inertial fusion devices, hybrid fusion-fission reactors, and small-size DD generators. In this foreword, I want to convey briefly the content of these fusion neutronics papers, highlighting their interesting points with the hope that this brief review will not spoil your joy of discovery when reading the full papers in this special issue of *Fusion Science and Technology*. In addition beyond the fusion neutronics papers, we include in this special issue eight papers on the topic of tungsten for fusion systems.

The fusion neutronics section opens with an overview by Zucchetti et al. of neutronics scoping studies of high-field compact tokamaks denoted as "experimental fusion devices." The design line of presenting in the overview high-field compact tokamaks includes the following fusion machines: Ignitor, ALCATOR, SPARC, and ARC. The calculation results of neutron damage and several shielding characteristics are presented using the MCNP transport code and the FISPACT-II activation code. This paper emphasizes the design preferences of Ignitor, sharing with SPARC and ARC some design concepts, showing the convenience of this design line as well as progress in technological fields such as new magnet superconductors and innovative structural materials. A general-purpose macroscopic model, set up by some of the authors in previous studies, has been used to estimate the radiation damage to selected machine components. Solutions to solve the problem of radiation damage to the toroidal and poloidal field coil materials have been explored in this overview.

Bohm et al. provide initial neutronics investigation of liquid-metal plasma-facing component (LM-PFC) concepts, ensuring that radiation limits are met and that system performance meets expectations. The authors explore the LM-PFC concepts in the newly developed 3-D neutronics model on the Fusion Energy Systems Study Fusion Nuclear Science Facility (FESS-FNSF), which is a DT tokamak of 518 MW fusion power. The LM-PFC FNSF design was analyzed using the DAG-MCNP5 transport code. Among the four liquid-metal first wall (FW) candidates studied in this paper (PbLi, Li, Sn, and SnLi), the Li FW design is the best candidate from a neutronics perspective.

Rolison et al. present neutronics calculations for a rather exotic and hypothetical version of a fusion reactor based on the repetitively pulsed concept of plasma-jet-driven magneto-inertial fusion (PJMIF). The 14-MeV neutron source is formed in this concept by injection of hypersonic plasma jets that form both the DT plasma target and a high-Z spherically imploding plasma liner to compress the target. The associated plasma physics and technological challenges force us to call this concept "hypothetical." The neutronics analysis is focused on the study of FLiBe liquid blanket parameters, with aims to provide radiation shielding with adequate attenuation of neutron flux and to demonstrate achievable tritium breeding ratios. The neutron fluxes, tritium production, neutron damage, and nuclear heating have been calculated with MCNP6.2, while activation of the PJMIF reactor is done by the CINDER-2008 code.

The peculiar problem of fusion devices producing 14-MeV neutrons is activation of their cooling water. If a neutron spectrum is "hard" enough (i.e., if neutron energy is above 9 MeV), then the oxygen in water is activated in nuclear reactions with the generation of radioactive isotopes of nitrogen: ^{16}N (emits decay gamma radiation) and ^{17}N (emits decay neutrons). These nuclear reactions in the water of common fission reactors are negligible due to lower neutron flux and much "softer" neutron spectrum. In large tokamaks, such as the ITER 500 MW machine, much generated heat is removed by the tokamak cooling water system (TCWS) equipment, and this water becomes activated. This important topic is investigated in two connected papers by authors from Oak Ridge National Laboratory. The first paper is by Radulescu et al. and describes the MCNP models for the TCWS activation evaluations. The second paper is by Royston et al. and presents the results obtained with such MCNP models in the assessment of activation on level L3 of the ITER tokamak building due to the ITER TCWS. Both plasma neutrons and neutrons from the decay of radioactive isotope ^{17}N in the activated coolant will activate the steel of TCWS components located in the level L3 shielded region. These activated TCWS components will result in a shutdown dose rate during dwell periods after plasma pulses.

Hong and Kim studied the design of a hybrid fusion-fission reactor for waste transmutation (Hyb-WT) in a paper titled "Neutronic Analysis for Feasibility of Fusion-Driven Subcritical System with Constant Fusion Power by Online Feeding of Molten Salt Fuel." Neutronic calculations have been performed with the SERPENT2.1.29 radiation transport code. The authors focused on the evaluation of the feasibility of the hybrid Hyb-WT reactor with constant k-eff (neutron effective multiplication factor). Because the significant change of external source rate is one of the disadvantages of subcritical systems, including Hyb-WT, various feeding scenarios were proposed to make k-eff constant by using molten salt fuel. The performance changes, such as tritium breeding, energy multiplication, and transmutation, were evaluated compared to a once-through cycle. In other words, this paper is focused on the feasibility of a hybrid molten salt Hyb-WT reactor concept, instead of its design optimization.

Experimental neutronics work is presented in two papers wrapping up the fusion neutronics section of this special issue. The first paper, devoted to measurements of total neutron production rate (NPR) in a fusion inertial electrostatic confinement (IEC) device, is written by Bakr et al. and titled "Improvement of the Neutron Production Rate of IEC Fusion Device by the Fusion Reaction on the Inner Surface of the IEC Chamber." For this paper, inside the IEC chamber, two anodes made of titanium and stainless steel were used to study the effect of the anode material on the measurements of NPR. In the second experimental neutronics paper, titled "Preliminary Results of Neutron Transport in Blanket Module by MCNP with Profile Analysis Using Imaging Plate," Ogino et al. lay out the achievements of their neutronic experiments supported with calculation analyses. This is an interesting methodology using imaging plates and activation materials (dysprosium, indium, and gold) for measurements of neutron flux and its energy profile in blankets of fusion devices. It was applied in an experimental setup of polyethylene and graphite blocks as a model of the blanket module. The small-size DD discharge-type fusion device was used to irradiate the blanket module with 2.45-MeV neutrons. Activation foils and wires were placed in the assembly to measure neutron flux distributions. To compare the fluxes, the blanket module was reproduced in the MCNP model. The comparison shows that, in principle, measurements with the imaging plate method are feasible, with some restrictions described in the paper.

This neutronics section is worthwhile reading for neutronics specialists, nuclear scientists, engineers, undergraduates and postgraduates—anyone interested in recent achievements in the fusion neutronics area. It provides a contemporary look at today's challenging problems, design solutions, and the horizon of future developments in fusion neutronics science and technology!

Beyond this, we hope readers also find great interest and value in the second half of this special issue, which focuses on the fusion material tungsten. These eight papers span topics such as tungsten transport analysis, thermal and mechanical properties, elemental characterization of neutron-irradiated tungsten, irradiation of tungsten with helium ions, morphology and erosion, the effect of rhenium doping on tungsten properties, divertor damage characterization, and development of tungsten-coated graphitic foam for PFCs. We hope you enjoy this state-of-the-art fusion neutronics and tungsten research derived from abstracts presented at the TOFE 2018 meeting.

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