Seminar

Institute for Plasma Research

Title : Neutronics Benchmark Studies for the Tritium Breeding Blankets

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Abstract:

Tritium self-sufficiency is of critical importance to future DT fusion power plants. All DT experimental devices and fusion power plants will have to breed their own tritium with lithium containing blankets due to its unavailability in the nature. Nuclear design of the breeding blankets is performed with the neutronics calculations utilizing three dimensional transport codes and cross-section data libraries. The calculated tritium breeding ratio (TBR, ratio of tritium atoms produced in the breeding blankets to that consumed in the plasma) for a given concept of blanket and first wall is uncertain due to uncertainty associated with the system definition and the inaccuracies in predicting the TBR. The latter includes the uncertainty associated with nuclear data, the geometrical modelling, and calculation methods. The calculated achievable TBR in design analyses has to be larger than the required TBR by a margin to safely take into account the uncertainties on the requirements and the uncertainties in design elements, modelling and nuclear data used in the TBR calculations. Therefore, in order to minimize the margins, high accuracy predictions of the TBR and other nuclear responses are needed, which require validated computational tools and qualified nuclear data, including reliable uncertainty estimates. The Fusion Evaluated Nuclear Data Library (FENDL) is widely used worldwide for neutronics calculations in the fusion environment because of the high fidelity of reliability and quality assurance. Despite the high fidelity, the FENDL versions are far from perfect. Integral validation of the data libraries and 3D codes used in the fusion neutronics area is an inevitable step as feedback from integral nuclear testing in a 14 MeV neutron environment leads to significant improvements to cross-section evaluations.

The present thesis investigates the nuclear responses of the candidate materials for breeding blankets of a D-T fusion reactor in the form of mock-up assemblies. The measured responses are compared with calculated values obtained from the neutron transport tools used for the nuclear design of the breeding blankets. The main focus of the thesis is to validate the neutron transport physics applied in the calculation tools (code and nuclear data) and to assess the uncertainty in tritium production rate (TPR) due to uncertainty in the relevant nuclear data. The uncertainty in the TPR can eventually be linked to the tritium breeding ratio.

India has proposed Lead-Lithium cooled Ceramic Breeder (LLCB) concept of breeding blanket for in-situ tritium breeding in its DEMO reactor. Mock-up of the LLCB breeding blanket will be tested in ITER through Test Blanket Module (TBM) program. A set of four mock-up experiments is evolved during this work to investigate the neutronics performance of materials used in the LLCB TBM. In support of LLCB TBM nuclear design, the first mock-up experimental assembly was designed and fabricated to perform measurements of the nuclear responses. In this thesis, the techniques for the measurement of TPR and neutron flux spectra are developed, characterized and employed in the experimental assemblies containing materials relevant to breeding blankets. Benchmark experiments with three kind of experimental assemblies are performed and analysed in this thesis. Two experiments are performed with lithium titanate and Lead in the LLCB TBM radial geometry. One experiment was performed with lithium aluminate breeding material. The measured responses are analysed with radiation transport code MCNP using FENDL-2.1 and 3.0 libraries. The difference between calculated and measured responses with lithium titanate and Lead assemblies is found to be in the range of 5-10% due to the nuclear data of the Lead isotopes. Current measurements are also compared with the experiments performed with pure Lead. The impact of the discrepancy in the FENDL nuclear data on the prediction of LLCB TBM breeding performance is discussed.