Overview of R&D activities within IFERC in support of fusion development in the context of the Broader Approach Agreement Phase II

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In DEMO R&D activities, the main milestone of subtask T1-1: tritium technology for analysis of plasma wall interaction using JET DT samples for evaluation of T inventory and T recovery is to complete T analysis of Joint European Torus-ITER like wall (JET-ILW) tiles and dusts and summarize T inventory data (so far, analysis on ILW-1 was completed in FY2022), and that of subtask T2-1: development of irradiation database and material property handbook (MPH) of blanket structural materials is to facilitate 2nd version of MPH with consideration of probability function of properties for engineering design of DEMO (so far, collection of data 1st version of MPH for breeding blanket structural materials SSTT guidelines was completed in FY2022). The progress of subtasks T1-1 and T2-1 in FY2023 are highlighted.

Introduction

The International Fusion Energy Research Centre (IFERC) is one of the three projects executed by the EU and Japan under the Broader Approach Agreement. The IFERC Project supports the other joint fusion projects (ITER, IFMIF/EVEDA, JT60-SA) and contributes to the development of the next generation of fusion devices after ITER, such as DEMO. IFERC has three lines of activity. The Computational Simulation Centre (CSC) supports the EU and JA fusion communities with super-computer resources in order to design components for present day and future machines, to interpret plasma physics data, and to model and design the future operation of ITER and DEMO. The DEMO Design and DEMO R&D activities aim to share and develop the design of the next generation of fusion devices, and to study and develop materials for these devices, towards a fusion reactor producing electricity. The ITER Remote Experimentation centre (REC) aims to develop remote participation techniques, to give access to ITER scientists to the future ITER operation results, and facilitate world-wide collaboration in the ITER exploitation

In 2020, the review of the IFERC Project Plan to orient the IFERC activities was performed following the priorities given by the Steering Committee (SC) for BA phase II; (1) to provide the support for ITER, IFMIF/EVEDA, and JT-60SA, (2) to consolidate know-how for future fusion reactors through the production of databases, inputs to engineering hand books, and review of lessons learned in the existing fusion projects. In this paper, the progress of DEMO R&D activities in BA Phase II are overviewed.

Activities on DEMO R&D

DEMO R&D tasks started as the Phase II activity in 2020 in the following 4 areas: Task 1 (T1): R&D on Tritium Technology, Task 2 (T2): Development of Structural Material for Fusion DEMO In-Vessel Components, Task 3 (T3): Neutron irradiation experiments of Breeding Functional Materials (BFMs), Task 4 (T4): Development of material corrosion database. Here, the progress of subtasks T1-1 and T2-1 are highlighted.

T1-1: Divertor titles after JET-ILW campaigns and dust collected after JET-C and JET-ILW operation were examined by a set of complementary techniques (full combustion and radiography) to determine the total, specific and area tritium activities, poloidal tritium distribution in the divertor and the presence of that isotope in individual dust particles [1]. The study was carried out on two types of samples: (a) JET-ILW divertor tiles W-coated carbon-fibre composites (W/CFCs) after ILW-1 and ILW-3 campaigns; (b) samples of dust retrieved after the operation in JET-C and then in ILW-1 and ILW-3. Tritium analyses were performed by means of radiography using a tritium imaging plate technique

(TIPT), full combustion method (FCM) and liquid scintillation counter (LSC). Figure 1 shows results obtained with TIPT for both ILW-1 and ILW-3. The images of cored samples show the tritium distribution on the titles. Larger amounts of T accumulated on the inner vertical divertor tiles than on the outer ones for both ILW-1 and ILW-3. However, the area with T is expanded downwards in the ILW-3 case. The intensity is the highest for sample 4-10 (ILW-1) located in the inner divertor inside the pumping duct. This result can be associated with the presence of tritiated carbon co-deposit, i.e., legacy after JET-C. Other differences in the T distribution on tiles 4 and 6 can be attributed to the difference positions of the typical divertor strike points in the two campaigns, as marked with green and blue lines.

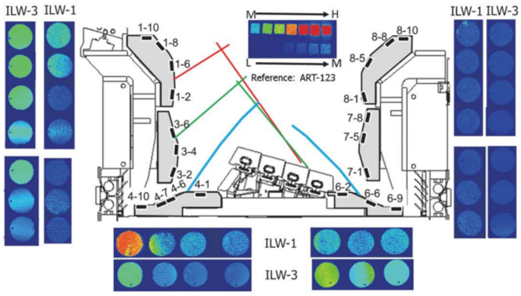

Fig.1 TIPT results of cored samples in ILW-1 and ILW-3 and for a reference T sample. Colored lines show the positions of the separatrix in three typical configurations, ILW-1 (green), ILW-3(blue). Reproduced from Fig.7 in Ref. [2].

T2-1: MPH of blanket structural materials is to facilitate 2nd version of MPH with consideration of probability function of properties for engineering design of DEMO. Bayesian method is applied to determine reference standard strength for neutron-irradiated reduced activation ferritic/martensitic steel (RAFM) F82H [3]. It is a typical RAFM steel developed in Japan, which was developed to reduce induced radioactivity by replacing Mo and Nb with W and Ta, among the main additive elements of modified 9Cr-1Mo steel. Dose dependence of tensile properties of F82H was investigated considering two prediction functions, e.g., Power and Logarithm, and two distribution models, e.g., Normal and Weibull. It is found that the 'Log-Normal' distribution gave better predictions for 0.2% proof strength and tensile strength (Figure 2). By contrast, the 'Power-Normal' and 'Power-Weibull' models gave comparable criteria for the distribution of total elongation data. It should be noted that the possibility of Bayesian inference for predicting fusion neutron irradiation effects is limited to critical neutron fluence, and beyond this threshold, it is important to obtain data from 14 MeV irradiation.

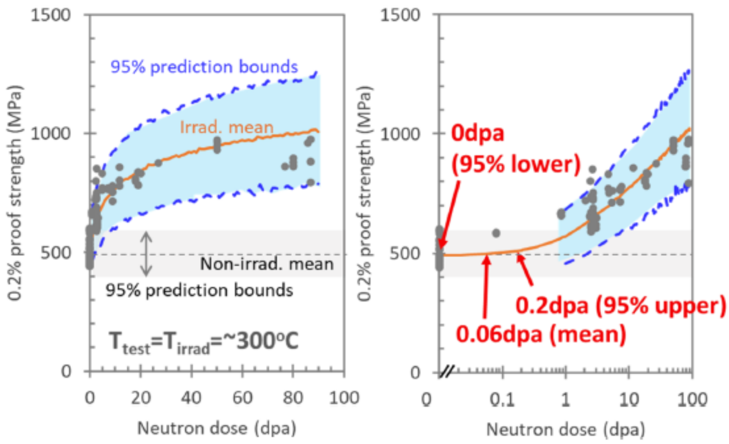

Fig.2 0.2% proof strength vs. neutron dose dependence with mean(orange) and 95% Bayesian prediction bounds(blue). Reproduced from Fig.8 in Ref. [3].

Conclusions

T1-1: Divertor titles after JET-ILW campaigns were investigated. In the divertor titles, the majority of tritium is detected in the surface region and the areal activities in the ILW divertor are in the 0.5-12 kBqcm^{-2} range. Total tritium activities show significant differences between the operation with ILW and the earlier phase with the carbon wall.

T2-1: Bayesian statistical analysis was attempted on existing irradiation data to estimate the dose dependence of statistical parameters representing changes in material property distribution due to irradiation. It is shown that the 'Log-Normal' distribution gave better predictions for 0.2% proof strength and tensile strength.

References

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[3] T. Nozawa et al. J. Nucl. Mater. 604 (2025) 155486.