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| **Project Title** | **Ageing of ITER grade tungsten divertor components under tokamak plasma loading**  **related to engineering of plasma-facing materials and components manufacturing** | |
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| **Background** | Power exhaust is a crucial research area for next step fusion devices, and the design and manufacturing of the divertor, the most heavily loaded component in the device, is an engineering challenge. In particular, the first tungsten divertor in ITER will have to face unprecedented heat and particle loads and is planned to operate over ~10 years or 2000 hours of plasma time in the low duty cycle of ITER. It is therefore important to assess how the thermo-mechanical properties and the power handling capabilities of this actively cooled tungsten components will evolve after long time exposure to tokamak conditions and how this compares to high fluence plasma exposures in linear plasma devices.  Prototypes of the actively cooled tungsten ITER divertor (W monoblocks assembled on a copper heat sink) have been provided by potential ITER suppliers - including F4E candidates -for exposure in the WEST tokamak, using different material grades and manufacturing routes. The primary aim of this project is to assess ageing of these prototypes after exposure in tokamak conditions and to provide feedback for the ITER divertor series production and the expected ITER divertor lifetime. Secondly, the aging will be compared to high fluence exposures in MAGNUM-PSI and studies in electron beam facilities like JUDITH. | |
| **Objectives** | This project will be based on (a) post-mortem analysis and assessment of thermo-mechanical properties of the various prototypes exposed in WEST, to be compared with (b) pre-characterization of non exposed W monoblocks available from the production of the prototypes as well as to (c) monoblocks exposed in MAGNUM-PSI or/and e.g. JUDITH. The later exposure have partially been done before this grant.  This project will therefore provide data on the ageing behaviour of the ITER tungsten monoblocks as a function of the production route of the W material used, the component manufacturing and assembly processes and plasma exposure conditions taking into account in particular processes like cycling loading around DBTT (Ductile to Brittle Transition Temperature), W recrystallization or loading with deuterium and/or helium plasmas.  It will train the proponent in understanding the complex manufacturing route of plasma facing components for fusion, the different techniques for qualification, and in assessing the plasma-facing components performance when exposed to tokamak conditions or linear plasma and electron beam conditions. | |
| **Work programme** | The project will be organised as follow:  Activity 1: characterize each prototype in terms of : W supplier, W production routes (powder size, deformation routes, impurities, etc), targets manufacturer, W/Cu and CuCrZr/Cu bonding technology, heat treatments, machining tools and processes  Activity 2: perform characterization of unexposed W monoblocks and post-mortem analysis of divertor prototypes after their exposure in WEST. This work will allow to evaluate into more details the behaviour of each prototype under plasma exposure and to highlight the differences in ageing. Damage such as cracking, surface characterization (roughness, emissivity) as well as microstructure-related thermo-mechanical properties will be assessed.  Activity 3: participate in monoblock exposures in linear plasma MAGNUM-PSI and high heat fluxes (e.g. JUDITH) and assess damages of W monoblock proto types. Comparison with existing damage matrix for W mono blocks at high particle and power loading. Cross-comparison with damages and aging observed in WEST tokamak exposures  Activity 4: investigate the impact of materials and manufacturing parameters on the ageing response of targets under plasma exposure. In particular, the effect of impurities level and their location in the microstructure, the use of machining tools and induced stress or/and macro-damage as well as the surface roughness on the erosion, corrosion resistance and cracking will be addressed. Comparison with results from exposure in linear device or/and high heat flux facilities is foreseen.  The project will be carried out in close collaboration with the ITER Organization divertor team, as well as in a European framework, gathering a number of laboratories with expertise in analysis of fusion exposed components (WP PWIE).     |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | Months: | 1-6 | 7-12 | 13-18 | 19-24 | 25-30 | 31-36 | | *Activity 1: manufacturing history of prototypes* |  |  |  |  |  |  | | *Activity 2: post-mortem analysis of prototypes* |  |  |  |  |  |  | | *Activity 3 comparison with linear plasmas and e-beams* |  |  |  |  |  |  | | *Activity 4: impact of manufacturing on ageing response* |  |  |  |  |  |  |   *Gantt chart of high-level activities* | |
| **Competences required** before start (bullet points)   * Master degree or PhD in material engineering * Skilled in metallurgy of metals * Experience in the characterization of materials/laboratory * Excellent teamwork and communication skills, including a good level of spoken and written English | | **Competence development** during project (bullet points)   * Expertise in fusion plasma facing components design and manufacturing processes * Advanced skills in plasma-materials interactions and surface analysis * Competences for working in an international collaboration environment |
| **Facilities used** | WEST, high heat flux facility JUDITH or equivalent, linear plasma devices MAGNUM-PSI exposing actively cooled ITER grade components. Post mortem analysis set up in various EUROfusion laboratories involved. | |
| **Mobility needs** | The proponent is expected to visit the various laboratories involved in relevant surface analysis in the WPPWIE framework (max. 2 months), as well as to interact regularly with the IO divertor team (max. 2 months). | |
| **Future career prospects** Potential next career steps in fusion after this EEG traineeship | This project will allow the proponent to candidate as a lead engineer for plasma facing component design and manufacture, in response to the needs in this area of a number of existing or future fusion devices, such as JT60-SA, W7-X, DTT, ITER and DEMO. | |