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MULTI-SCALE NUMERICAL INVESTIGATION TO PREDICT THE IRRADIATION-INDUCED CHANGE IN ENGINEERING PROPERTIES OF FUSION REACTOR MATERIALS

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The hostile irradiation conditions in a fusion reactor induce a high rate of degradation of in-vessel components which consequently change the engineering properties of the material at different stages during its lifecycle [1]. Moreover, degradation occurs non-linearly based on the location in question relative to that of the neutron source. This is due to non-uniform irradiation energies and dose rates, and variations in temperature which consequently induce spatial and temporal variations in the evolution of the engineering properties of the material and in turn influences the overall operational performance of the tokamak. In the current work, a platform is developed based on numerical models integrating different methodologies to investigate the influence of irradiation dose and temperature dependent micro/nano structural defects on the material properties and its subsequent effect on thermo-structural behaviour of tokamak components.
To demonstrate the platform's potential, a case study is presented with a tungsten monoblock from the tokamak's divertor region. Thermal fields are obtained in the monoblock by means of finite element simulation employing the heat sources derived from Monte-Carlo based neutronics simulation [2]. Temperatures in the range of 1500^{o}C-2000^{o}C are achieved at the upper portion of the tungsten armor. Dislocation dynamics (DD) simulations [3] are performed at temperatures between 250^{o}C and 2000^{o}C on the uniaxially loaded irradiated microstructural tungsten RVE samples to analyse the line dislocation interaction with the neutron irradiated-induced defects such as dislocation loops and precipitates. DD analysis results show that for a large density of irradiated defects, yield strength is higher at low temperatures. The yield strength and stress-strain data obtained from the DD analysis are integrated within the Von-Mises plasticity model and thermo-mechanical finite element simulation results have shown that higher stress values and accumulated equivalent plastic strains are observed at tungsten armor (W)–copper (Cu) interlayer interface of the irradiated monoblock. During the cooling phase, the tungsten failure probability due to brittleness at the W-Cu interface is lower since the maximum principal stress values are very less below ductile-to-brittle transition (DBT) temperature.

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