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Progress in the theoretical description and the experimental characterization of tungsten transport in tokamaks

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The validation of current models to predict the transport of a heavy impurity like tungsten in tokamaks is confronted with challenges from both the theoretical and experimental standpoints. Both neoclassical and turbulent transport mechanisms are involved, and have to take into account the impact of poloidal asymmetries, produced by both centrifugal effects and temperature anisotropies caused by auxiliary heating. These can significantly modify the neoclassical transport, affecting both its amplitude and the strength of the temperature screening. The size of turbulent impurity transport strongly depends on the ratio of the electron to the ion heat flux and is maximized when this ratio slightly exceeds unity. Moreover, in these conditions, subdominant modes can non-negligibly impact the transport, and lead to turbulent convections which are in opposite direction with respect to the predictions based on the most unstable linear mode only. Theory validation benefits of experiments which are dedicated to testing detailed predictions. However, experiments on heavy impurity transport face limitations on the possibility of diagnosing the impurity density, the accessible domains of plasma parameters and the available heating systems in each device. Experiments have been performed in ASDEX Upgrade to investigate the impact of central wave heating in the avoidance of W accumulation in H-mode plasmas with dominant neutral beam injection heating. Experiments show that ion cyclotron and electron cyclotron heating have similar effects on the W behavior when similar power density profiles are produced with the two wave heating systems, consistent with dominant electron heating produced by ICRH in the H minority scheme in ASDEX Upgrade. Theory-based modelling is performed by combining the GKW and NEO codes, and conditions under which the role of H-minority becomes significant are highlighted. These results are compared with companion experimental and modelling research performed at JET. Finally the implications of the experimental and theoretical results on the prediction of the tungsten behavior in ITER and a future reactor are presented. General parametric dependencies of confinement with increasing size of the device support the favorable expectation for impurities that in a reactor the impact of neoclassical transport is reduced with respect to present tokamaks.

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