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Influence of a Tungsten Divertor on the Performance of ITER H-Mode Plasmas

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The effect of a tungsten divertor on the performance of H-mode plasmas in ITER has been investigated by combining scrape-off layer transport calculations performed with SOLPS with core transport simulations using the ASTRA code, which was coupled to the impurity transport code STRAHL. The penetration of W into the central plasma mainly depends on two mechanisms: prompt re-deposition of W to the target and the radial transport in the edge transport barrier (ETB) during and between ELMs. Within an ELM, the transport of W is strongly enhanced and concomitantly, the physical sputtering of W at the divertor target strongly increases.

Monte Carlo simulations of prompt W re-deposition, which included the effects of multiple W ionisation and electric field force on the ions in the magnetic pre-sheath, were carried out for ITER controlled ELM conditions. It was found that W re-deposition causes a significant, factor 10000, reduction in the net W erosion. The avalanche effect, where W self-sputtering could lead to a runaway process of increasing W sputtering, can be ruled out. Thus, the SOLPS simulations found that controlled ELMs conditions present very little danger of plasma contamination with sputtered W.

Between ELMs, it can be assumed that the W-transport in the ETB is due to neoclassical transport which was studied for a large range of pedestal profiles. The radial convection velocity of W was found to be outward directed for the major part of the tested profiles. This is due to a combination of high pedestal temperatures and high separatrix densities making the outward directed temperature screening term to be the predominant contribution of the convection. The high densities at the separatrix are needed to control the power exhaust and the sputtering in the divertor and the high pedestal temperatures are expected to be achieved to meet the fusion performance objectives.

Combined ASTRA+STRAHL transport simulations in presence of ELMs of varying frequencies have been carried out. Both neoclassical and ad-hoc anomalous transport models have been included to simulate the evolution of the W profile in the pedestal region. When using the sources as calculated with SOLPS, there was no influence on the total plasma radiation. Even for the most pessimistic case of no redeposition, ELM frequencies in the range 10-30 Hz lead still to tolerable W concentrations.

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