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First wall fluxes in ITER from full vessel edge-plasma simulations with SOLEDGE3X

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The physics basis for the ITER divertor largely relies on simulations performed with the SOLPS 2D edge-plasma code suite [1]. Due to technical limitations in the current version of the code, the discretization grids of these simulations can only extend radially up to the first flux surface tangent to the vacuum vessel wall. These simulations can therefore be used to evaluate heat and particle fluxes to the divertor targets, where most of the flux impacts, but give only very approximate quantities for the rest of the first wall (FW). The objective of the present work is the evaluation of fluxes and plasma conditions over the entire ITER beryllium (Be) FW, using 2D transport simulations performed with the SOLEDGE3X-EIRENE code [2], which uses a grid covering the entire vacuum vessel volume with a realistic wall geometry, as well as including self-consistent kinetic neutrals through coupling with the EIRENE code. A throughput scan is performed on cases representing plasmas which will be run in the first, non-active Pre-Fusion Operation Phase (PFPO-1) of the ITER Research Plan at 20 MW of additional heating on a magnetic equilibrium resulting from recent DINA scenario simulations with the most up-to-date ITER 2D wall contour. As expected, the highest heat and particle flux densities are found on the upper FW, in the secondary X-point region, with the heat loads far below FW panel power handling limits.

In complement, a brief investigation of the differences in the divertor atomic and molecular processes involved in high-throughput simulations on machines of similar geometries but different size is presented, using the AUG and JET devices as examples. This exercise highlights specificities of ITER regimes in the simulations versus smaller devices, in part due to a change in the ratio of the contribution of the molecular ion H_2^+ dissociation to the atom ionisation in the particle and electron energy sources near the targets.

To assess the impact on main chamber recycling of the flattening of the far-SOL density profile observed in current machines under high density, detached divertor conditions [3,4], a scan is performed in which the particle and heat diffusivity coefficients are increased in the far-SOL, mimicking turbulent filamentary transport. Both a broadening of the deposition profiles at the target and an increased particle loading on the first wall of the main chamber are found. For an order of magnitude increase in far-SOL diffusivity coefficients compared with the near-SOL values, the peak heat and particle flux densities (including contributions from plasma, neutrals and photons) on the FW in the secondary divertor region are found to increase by factors of 20 and 5 respectively, with a strong increase in plasma wall temperature from ~5 to ~30 eV.

Finally, the SOLEDGE3X simulations on the wide grid are briefly compared with equivalent cases recently produced with the SOLPS-ITER code, on the same PFPO-1 throughput scan, under the same conditions (but without an extended grid) [5] however this time using the same magnetic equilibrium (q95 = 3) as that on which the burning plasma SOLPS-4.3 database in [1] was constituted. Overall, consistent results and trends on most relevant metrics are observed on the common parts of the simulation domain.

References

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