Finalizing the SOLPS-ITER vs. SOLPS4.3 benchmark for the ITER divertor

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Predictions for the ITER divertor operational conditions using all-metal plasma-facing components (PFC) require a careful assessment of the dissipation capabilities of extrinsically seeded low-Z impurities like neon (Ne). Previous efforts to benchmark the ITER divertor design code SOLPS4.3 [1] with the new SOLPS-ITER code [2], focused on the comparison of simulations for carbon PFCs [3]. The existing SOLPS4.3 database for ITER deuterium (D), helium (He) and Ne with a metal wall is relatively limited. It consists of a set of simulations scanning D and Ne throughput at a fixed level of power \(P_{\text{edge}}=100\) MW entering the plasma edge and a choice of anomalous transport coefficients which sets the scrape-off layer (SOL) heat flux width to \(~3.5\) mm upstream [4]. In order to extend the ITER divertor simulation database, SOLPS-ITER is now employed by the IO as the standard plasma boundary code. It provides new capabilities for additional physics to be included, such as fluid drifts and SOL currents [5].

The work reported here extends the previous benchmarking effort of [3] comprising, in part, an assessment of the numerical errors, which affect the accuracy of the results due to finite grid resolution and numerical convergence. For stability reasons, the central differencing scheme (CDS) employed in SOLPS4.3 to discretize particle and momentum fluxes is rarely used in SOLPS-ITER. With its collocated grid formulation for parallel ion flows, the hybrid scheme combining CDS and upwind discretization schemes efficiently stabilizes transients in the convective flows.

A subset of the SOLPS4.3 D/He/Ne database, scanning the Ne concentration, \(c_{\text{Ne}}\), and D\(_2\)-throughput, is reproduced with SOLPS-ITER. To demonstrate the impact of the discretization schemes, new simulations with spatially refined poloidal grids have been prepared and compared. For the ITER standard partially detached divertor scenario, SOLPS4.3 shows a moderate dependence of the total target heat flows on grid resolution. Increasing the resolution in SOLPS4.3 with the default CDS scheme leads to a saturation of the maximum heat flow \(q_{\text{pk}}\) at a higher level. SOLPS-ITER simulations on the other hand are robust and stable already at lower resolutions when employing the hybrid scheme for convective flows. Within numerical noise, SOLPS-ITER matches the SOLPS4.3 results at 4x the standard resolution. Under less detached conditions, SOLPS-ITER again finds similar results to SOLPS4.3 (e.g. an \(~1:2\) \(q_{\text{pk}}\) in-out asymmetry), with small remaining deviations in discretized convected flows caused by the susceptibility to grid resolution. This work demonstrates a high degree of agreement between SOLPS-ITER and SOLPS4.3 across the operational range covered by the existing SOLPS4.3 burning plasma database for the all-metal ITER divertor. It successfully concludes the benchmark efforts between the two codes for ITER application.


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