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A fluid modeling perspective on the tokamak power scrape-off width using SOLPS-ITER[1]

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SOLPS-ITER, a 2D fluid code, is used to conduct the first fluid modeling study of the physics behind the power scrape-off width (λ_q). When drift physics are activated in the code, λ_q is insensitive to changes in toroidal magnetic field (B_t), as predicted by the 0D heuristic drift (HD) model developed by Goldston. Using the HD model, which quantitatively agrees with regression analysis of a multi-tokamak database, λ_q in ITER is projected to be 1 mm instead of the previously assumed 4 mm, magnifying the challenge of maintaining the peak divertor target heat flux below the technological limit. These simulations, which use DIII-D H-mode experimental conditions as input, and reproduce the observed high-recycling, attached outer target plasma, allow insights into the scrape-off layer (SOL) physics that set λ_q. Independence of λ_q with respect to B_t suggests that SOLPS-ITER captures basic HD physics: the effect of B_t on the particle dwell time ($\sim B_t$) cancels with the effect on drift speed ($\sim 1/B_t$), fixing the SOL plasma density width, and dictating λ_q. Scaling with plasma current (I_p), however, is much weaker than the roughly $1/I_p$ dependence predicted by the HD model. Simulated net cross-separatrix particle flux due to magnetic drifts exceeds the anomalous particle transport, and a Pfirsch-Schluter-like SOL flow pattern is established. Up-down ion pressure asymmetry enables the net magnetic drift flux. Drifts establish in-out temperature asymmetry, and an associated thermoelectric current carries significant heat flux to the outer target. The density fall-off length in the SOL is similar to the electron temperature fall-off length, as observed experimentally. Finally, opportunities and challenges foreseen in ongoing work to extrapolate SOLPS-ITER and the HD model to ITER and future machines will be discussed.

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