Gyrokinetic understanding of edge pedestal transport driven by resonant magnetic perturbations in a realistic divertor geometry

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The many kinetic side effects of RMPs complicate reliable prediction of the effectiveness of RMP ELM control in ITER. For example, plasma density is pumped out, which can lower the fusion efficiency in ITER, while the electron temperature pedestal is preserved or becomes even somewhat steeper. Gyrokinetic total-f simulations of the plasma transport driven by n=3 resonant magnetic perturbations (RMPs) in a DIII-D H-mode plasma performed with the gyrokinetic code XGC now reproduce these two experimental observations. XGC calculates neoclassical and turbulent transport self-consistently in realistic divertor geometry with gyrokinetic ions and drift-kinetic electrons, nonlinear Fokker-Planck collisions, and neutral particle recycling. The RMP field – calculated using linear extended MHD simulation with the M3D-C1 code and coupled into the electrostatic version XGC – is stochastic around the pedestal foot (ψ_N>0.98) but contains good KAM surfaces at the pedestal top and steep-slope. In the stochastic pedestal foot, neoclassical transport is enhanced and is responsible for the bulk of particle transport there. In the pedestal shoulder and slope, enhanced turbulent particle transport from trapped electron modes takes over. The increase of turbulent transport is at least partly consistent with RMP-induced weakening of the ambipolar radial electric field, and is caused by increased cross-power between the electrostatic potential and density fluctuations rather than a change in the cross-phase. The electron heat transport barrier in the steep-slope region of the pedestal is preserved. The electron heat conductivity is even completely suppressed in the steepest part of the pedestal, making the electron energy loss to be completely convective flowing out together with the density. The neoclassical component of the electron heat flux, while significantly enhanced in the outer thin stochastic layer, remains small compared to the turbulent heat flux, indicating that this thin stochastic region near the separatrix is not stochastic enough for Rechester-Rosenbluth transport theory to be applicable. The comparison between experiment and XGC simulation will be extended from DIII-D by short (~0.2 ms) gyrokinetic simulations of a KSTAR H-mode discharge with n=1 RMPs. Extension of our studies to ITER is planned.

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