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Impact of the plasma response in three-dimensional edge plasma transport modelling for RMP ELM control scenarios at ITER[1]

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The constrains used in magneto-hydrodynamic (MHD) modeling of the plasma response to external resonant magnetic perturbation (RMP) fields have a profound impact on the three-dimensional (3-D) shape of the plasma boundary induced by RMP fields. In this contribution, the consequences of the plasma response on the actual 3D boundary structure and transport during RMP application at ITER are investigated. The 3D fluid plasma and kinetic neutral transport code EMC3-Eirene is used for edge transport modeling. Plasma response modeling is conducted with the M3D-C1 code using a single fluid, non-linear and a two fluid, linear MHD constrain. These approaches are compared to results with an ideal MHD like plasma response. A 3D plasma boundary is formed for all cases consisting of magnetic finger structures at the X-point intersecting the divertor surface in a helical footprint pattern. The width of the helical footprint pattern is largely reduced compared to vacuum magnetic fields when using the ideal MHD like screening model. This yields increasing peak heat fluxes in contrast to a beneficial heat flux spreading seen with vacuum fields. The particle pump out as well as loss of thermal energy is reduced by a factor of two compared to vacuum fields. In contrast, the impact of the plasma response obtained from both MHD constrains in M3D-C1 is nearly negligible at the plasma boundary and only a small modification of the magnetic footprint topology is detected. Accordingly, heat and particle fluxes on the target plates as well as the edge transport characteristics are comparable to the vacuum solution. This span of modeling results with different plasma response models highlights the importance of thoroughly validating both, plasma response and 3D edge transport models for a robust extrapolation towards ITER.

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Comparison of Measurements of Profile Stiffness in HSX to Nonlinear Gyrokinetic Calculations

Tokamaks and stellarators have observed significant differences in profile stiffness, defined as the ratio of the transient thermal diffusivity obtained from heat pulse propagation to the diffusivity obtained from steady-state power balance. Typically, stellarators have measured stiffness values below 2 and tokamaks have observed stiffness greater than 4. In this paper we present the first results on stiffness measurements in the quasihelically symmetric experiment HSX in which the neoclassical transport is comparable to that in a tokamak and turbulent transport dominates throughout the plasma. Electron Cyclotron Emission (ECE) is used to measure the local electron temperature perturbation from modulating the ECRH system on HSX. Spectral analysis of the ECE data yields a profile of the perturbed amplitude and a resulting transient electron thermal diffusivity that is close to the steady-state diffusivity. This evidence of a lack of stiffness in HSX agrees with the scaling of the steady-state heat flux with temperature gradient. The experimental data is compared to gyrokinetic calculations using the GENE code with two kinetic species. Linear calculations demonstrate that the Trapped Electron Mode (TEM) is the dominant long-wavelength microturbulence instability with growth rates that scale linearly with electron temperature gradient. Nonlinear gyrokinetic flux tube simulations indicate that the TEM contributes significantly to the saturated heat fluxes in HSX, shifting the transport-carrying wavenumbers to larger values than in typical Ion Temperature Gradient (ITG) turbulence. A set of nonlinear simulations are being executed, examining the saturated nonlinear heat flux as a function of the electron temperature gradient, to obtain a stiffness value from the simulations to compare with experimental results.