The role of the separatrix in establishing boundaries for operational regimes on Alcator C-Mod based on a model for interchange-drift-Alfvén turbulence

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This work validates a model describing operational boundaries based on separatrix plasma parameters (SepOS) with data from Alcator C-Mod. The SepOS model is based on interchange-drift-Alfven turbulence theory and was developed and first tested using ASDEX Upgrade (AUG) data [1]. The model defines three primary boundaries for tokamak operation: the L-H transition, the L-mode density limit, and the ideal MHD limit. In contrast with AUG, C-Mod has a smaller major radius, $R_0 \sim 0.68$ m, and operates at higher toroidal magnetic field, B_t, up to 8T, achieving higher electron density, $n_e \sim 10^{20} m^{-3}$. Model validation makes use of high-resolution edge Thomson Scattering (ETS) measurements of electron density, n_e, and electron temperature, T_e, as well as their gradient scale lengths. Following the same approach as on AUG, measurements from ETS allow for consistent identification of the separatrix position. This is done by estimating T_e at the separatrix, assuming Spitzer-Härm conductivity and that the heat flux width is proportional to the T_e gradient scale length, i.e. $\lambda_q = 2/7\lambda_{T_e}$. For the typical C-Mod shape in the favorable ∇B-drift direction, and in the typical operating $B_t = 5.4$ T, plasma current, $I_p = 0.8$ MA, the C-Mod separatrix conditions correlate well with the operational boundaries proposed by the SepOS model. Movement in the operational space is investigated through a recently-proposed collisionality-like turbulence control parameter, α_t. Particle transport, characterized by an effective diffusion coefficient D_{eff}, increases with α_t in both L- and H-modes as they approach the boundary for the density limit and H-L back-transition, respectively. This coefficient is inferred from neutral atomic emissivity and ETS measurements and is seen to increase with α_t at the separatrix across the steep gradient region, up to 5 mm inside the separatrix. Discharges in the unfavorable drift direction are also examined, and the L-H criterion is found to require the introduction of a proportionality constant into the stabilizing term, as proposed in a recent study on AUG [2]. I-modes are observed to fall on the L-mode side of the L-H boundary and are only observed below a minimum value of α_t. Together, C-Mod and AUG approach the parameter space in (R_0, B_t) in which SPARC will operate. The current work lends credibility to the validity of evaluating projections for access and avoidance of particular regimes and limits based on SepOS-based projections for SPARC, as well as other high power density and/or large sized devices, such as ITER.

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[1] T. Eich et al 2021 Nucl. Fusion 61 086017
[2] O. Grover et al 2024 Nucl. Fusion 64 056020

Suggested Topic: 3 "Density and radiation operational limits to H-mode sustainment"