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Seed island formation of neoclassical tearing modes via transient transport events*

C. C. Hegna
Dept. of Engineering Physics, University of Wisconsin
Madison, WI 53706-1687

Abstract

One of the crucial problems for predicting the onset of neoclassical tearing modes (NTMs) in high temperature tokamaks is to understand the nature of the seeding process, whereby a magnetic perturbation of sufficient amplitude is required in order to exceed the threshold width for NTM excitation. We present a simple model for this process based on the neoclassical polarization current threshold mechanism and a heuristic model for the island frequency evolution.

Neoclassical polarization currents can be stabilizing to island growth [1]. For islands widths smaller than a critical width of order the ion banana width, the stabilizing polarization mechanism dominates the destabilizing bootstrap current drive and island growth is inhibited. A crucial feature of the neoclassical polarization threshold model is that stability properties depend upon the island rotation frequency, with stability occuring in the range $\omega_i^* < \omega < 0^*$ in the $\mathbf{E}\times\mathbf{B}$ rest frame. The island frequency depends upon transport properties in the island region. As such, we introduce the relation $D(\omega-\omega_e^*)+\gamma_I w^2(\omega-\omega_i^*) = 0$ to track the island frequency, where the first term represents transport processes in the plasma that tend to cause the island to rotate in the electron drift direction [2] while the last term represents transport processes on ions that arise through island induced toroidal viscosity where γ_I depends upon the ion collisionality [3]. A simultaneous solution of the island evolution and frequency equations uncovers a critical parameter of order $D/(\gamma_I \rho_{\theta,i}^2)$. For sufficiently small values of this parameter, the polarization effect is stabilizing and can provide a threshold. As the value of this parameter rises, the frequency tends toward the destabilizing electron drift direction and at a sufficiently high value, the polarization threshold mechanism is eliminated. As such, seed islands may form when the background plasma transport rises with a transient MHD event such as a sawtooth crash or an ELM.

References

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