Drift Kinetic Effects on the Neoclassical Tearing Mode Threshold

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For successful operation of future tokamaks such as ITER, it is paramount that we control neoclassical tearing modes (NTMs): plasma instabilities characterised by the evolution of magnetic islands. Experimentally, a sufficiently small island (comparable in width to the ion banana width, ρ_{bi}) can heal itself and shrink away. An NTM control system could be deployed effectively by shrinking the seed islands to below the "threshold" level. The key questions to ask are: what is the threshold island width, w_c, and what are the essential pieces of physics?

We have developed a drift kinetic approach valid for small island cases, which we solve numerically for the perturbed ion distribution function [1]. One significant consequence of the finite orbit width effect, when $\rho_{bi} \sim w$ ($\rho_{bi} \sim \varepsilon^{1/2}\rho_{\theta i}$, $\rho_{\theta i}$ is the ion poloidal Larmor radius and w is the island half-width), is the "drift island" structure in the perturbed distribution function: the contours of constant distribution function resemble those for the magnetic island flux surfaces, but shifted radially by an amount comparable to $\rho_{\theta i}$. Consequently the flat-gradient regions of the distribution function no longer align with the magnetic island, the effect of which is to partially restore the density gradient across the island width, thus reducing the NTM drive.

Numerical solutions for the contribution to the island evolution, Δ'_{loc}, exhibits a clear threshold behaviour (see figure). For small island widths, $w \sim \rho_{\theta i}$, the curves start to deviate from the analytic limit of Ref.[2]. The threshold width w_c, for which $\Delta'_{loc} = 0$, scales linearly with $\rho_{\theta i}$: $w_c \sim 2.7\rho_{\theta i}$, which is in qualitative agreement with experimental measurements [3]. This arises from the electron response to the electrostatic potential required for quasineutrality, motivating our future work to further improve our treatment of the electrons.

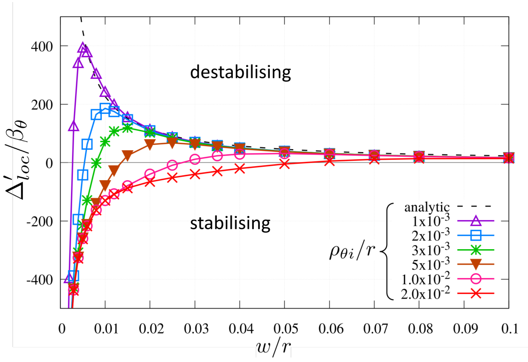

Figure 1: *Plot of Δ'_{loc} normalised to poloidal plasma beta, β_θ, as a function of w/r, for various values of $\rho_{\theta i}/r$ ($\rho_{\theta i}/r \sim 7 \times 10^{-3}$ for ITER). The analytic limit corresponds to $\rho_{\theta i} \ll w$.*

References

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[3] R.J. La Haye et al, Nucl. Fusion **46**, 451 (2006)