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Neoclassical Tearing Mode Simulations with Integral Heat Flow Closures *

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Abstract

The rapid thermal motion of electrons and ions along magnetic field lines represents a dominant process in astrophysical and terrestrial plasmas. In this work, we describe the incorporation of this dominant physics in toroidal plasma fluid simulations of neoclassical tearing modes (NTMs). Pressure flattening across magnetic islands is responsible for the bootstrap current perturbation that drives NTMs. This pressure evolution is dominated by the large anisotropy in the parallel and perpendicular heat transport. The higher-order-element formulation of the NIMROD code [1] is able to account for anisotropies greater than $\kappa_{\|}/\kappa_{\perp} \sim 10^{10}$ in the form of a diffusive operator which relates the parallel heat flows to local thermodynamic gradients. Using this formulation, we present numerical convergence studies of a NIMROD NTM simulation of DIII-D discharge 86144. In this discharge a 3/2 NTM is presumably excited above the threshold island width via coupling to a 1/1 mode. Once above the threshold, the NTM in the experiment grows and saturates at an island width of about 1/10 the minor radius. Comparative simulations are also performed using a quantitative, integral form for the parallel heat flow closure that incorporates the kinetic effects of free-streaming, pitch-angle scattering and particle trapping [2]. This closure has recently been implemented in NIMROD's ion and electron temperature equations. In plasmas where different components of the magnetic spectrum overlap radially, temperature variations along magnetic field lines possess multiple scale lengths. In such instances, the integral closure predicts comparable heat flows from all scale lengths for nearly collisionless plasmas of interest. In contrast, because the diffusive form for the closure relies on the local parallel gradient, it underestimates temperature flattening over longer scale lengths [2]. This result is borne out in converged simulations using the diffusive closure where pressure flattening is only able to drive the 3/2 island to about a $2cm$ saturated width. Results showing the enhanced NTM drive provided by the integral form for the parallel heat flow closure are presented.

References

[1] C. R. Sovinec, et al, UW CPTC Report 02-5 (2003).
[2] E. D. Held, J. D. Callen, C. C. Hegna and C. R. Sovinec, Phys. Plasmas **8**, 1171 (2001).

*Research supported by the U.S DOE under grants no. DE-FG03-01ER54618.