Nonlinear Evolution of Edge Localized Modes in Extended MHD*

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Abstract

A predictive understanding of edge localized modes (ELMs), including onset conditions and dynamic evolution, is crucial to present day tokamaks and next generation burning plasma experiments such as ITER. The study of the nonlinear evolution of ELMs using extended MHD codes has only recently begun. A new initiative was formed to study the dynamic evolution of ELMs with the 3D extended MHD code NIMROD. This paper summarizes recent results from this effort. The first objective is to understand the basic physics of the nonlinear ELM evolution in resistive MHD, and the dynamics of thermal energy transport in mode structures. For this study, a simple equilibrium configuration was constructed to be unstable only to a robust edge instability with parameters typical of DIII-D H-mode discharges. NIMROD linear results compare favorably to those from the linear ideal ELITE and GATO codes in both the mode structure and ballooning/pealing characteristics of these modes. Furthermore, the growth rates in NIMROD depend weakly on the resistivity and viscosity in the vicinity of the mode, with overstable resistive components to the modes evident at low n. The early nonlinear evolution of the edge mode shows an energy spectrum peaked at high and low n, with high n~20 modes having largest growth rates and the low n~1 modes being nonlinearly driven by nearest neighbor coupling of high n modes. The mode structure shows filaments of high temperature flowing outward. Thermal anisotropy and rotational shear weakly affect growth rates but significantly modify the mode structure. Separately, hyperviscosity has been applied to stabilize the high n modes and retain toroidal resolution. In these cases, low n modes remain unstable and eventually nonlinearly couple and drive high n modes unstable, despite the artificially applied stabilizing hyperviscous force. The stability boundary in (s,α) space is reached below the ideal boundary and nonlinear simulations from cases near this boundary in different regions differ somewhat in unstable spectrum and therefore mode structure. Challenges to the numerical simulation well into the late nonlinear phase are significant, with coupling always causing increased growth rates for groups of driven modes regardless of linear characteristics. Also, high k, fast moving structures are eventually inevitable for strongly unstable modes.

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