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The Temperature Pedestal and ELMs: A Model Based on Coupled Peeling-Ballooning Modes[1]

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Maximizing the pedestal height (T_{ped}) while maintaining acceptable ELMs is a key issue for optimizing tokamak performance. In this paper we develop a model for ELMs and pedestal characteristics based upon theoretical analysis of edge instabilities which can limit the pedestal height and drive ELMs. The sharp pressure gradients, and consequent large bootstrap currents in the pedestal region can destabilize peeling, ballooning, and kink modes over a wide range of toroidal mode numbers (n). The dominant modes are often coupled "peeling-ballooning" modes, driven by both parallel current and the pressure gradient. A new 2-D edge MHD stability code, ELITE, together with low-n MHD codes, allows the study of the ideal MHD edge stability over essentially the full spectrum of toroidal modes, leading to insight on the sensitivity of finite-n modes to pedestal height as well as gradient, and on the dual role played by the parallel current in enhancing second stability access for ballooning modes, while providing the drive for peeling modes. The strong collisionality dependence of the bootstrap current introduces separate temperature and density dependence into pedestal MHD stability, leading to direct MHD limits on the temperature pedestal. We investigate the variation of the maximum temperature pedestal with shape and collisionality, and analyze the type and structure of instability limiting T_{ped} in various regimes. Predicted T_{ped} limits are compared with experiment, and found to agree with observed trends. A model of ELM behavior predicting a correlation of ELM size with the radial extent of the most unstable mode is compared with observations on several tokamaks. The impact of X-point geometry, non-ideal effects, and nonlinear dynamics on peeling-ballooning modes are investigated with the electromagnetic edge turbulence code BOUT, enhanced to include parallel current terms.

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