1E52

Evaluation of Models for L-H Transition in Tokamak Plasmas

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Abstract

A model for the transition from L-mode to H-mode is required for use in predictive integrated modeling codes in order to simulate the time dependence of tokamak discharges that include the L-H transition. In order to develop and test a model for the L-H transition, two theories for the transition are analyzed and the resulting criteria for the transition are compared. One theory considered is based on the stabilization of a strongly ballooning resistive mode by the ion diamagnetic drift [1]. This theory provides the condition for the L-H transition in terms of $\eta_i = L_n/L_T$ (where L_n is the density scale length and L_T is the tempreture scale length) and indicates that the transition to H-mode can occur without toroidal rotation, when the ion temperature gradients are sufficiently steep at the edge of the plasma. The second L-H theory is based on the idea of the generation of flow shear by finite β drift waves [2]. In this case, the criterion for L-H transition is expressed in the terms of electron temperature. This criterion depends on the electron density gradients, but does not depend on the ion or electron temperature gradients. To test the latter theory, an analytical expression for the critical value of electron temperature is employed in the BALDUR code. The critical electron temperature depends on the global plasma parameters such as major radius, toroidal magnetic field, and effective impurity content. Discharges with a variety of values of these parameters are considered in order to form systematic scans and to test the model in the different operational regimes. Also implemented in the BALDUR code is an empirical model in which the condition for the L-H transition is expressed in terms of a critical value for the heating power [3]. The theory model based on flow shear and the empirical model are tested against each other and against experimental data from the Alcator C-Mod, DIII-D, and JET tokamaks. Simulation results obtained with the theory-based model and some experimental observations [4] suggest that edge plasma profile gradients are responsible for the L-H transition. Future work will include developing and applying a model associated with theory for the L-H transition, which is based on the stabilization of resistive edge modes [1].

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