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3D Modeling of the Sawtooth Instability in a Small Tokamak

JOSHUA BRESLAU, Princeton Plasma Physics Laboratory

The sawtooth instability [1] is the most fundamental dynamic of an inductive tokamak discharge such as will occur in ITER. Sawtooth behavior is complex and remains incompletely explained. While the instability is confined to the center of the plasma in low-pressure, low-current, large aspect ratio discharges, under certain conditions it can create magnetic islands at the outer resonant surfaces and may set off a sequence of events that leads to a major disruption. Under some circumstances the reconnection following the sawtooth is observed to be complete; in others, it is incomplete. As part of the CEMM SciDAC project, we have undertaken an ambitious campaign to model this periodic motion as accurately as possible using the most complete fluid- like description of the plasma, the Extended MHD model. Both NIMROD and M3D have been applied to this problem, and we are also using it as a non-trivial test problem to compare these two codes far into the nonlinear regime. Compared to the MHD model, Extended MHD predicts plasma rotation, faster reconnection, and reduced field line stochasticity in the crash aftermath. The multiple time scales associated with the reconnection layer and growth time make this an extremely challenging computational problem. A recent M3D simulation used over 500,000 elements for 400,000 partially implicit time steps, and there still remain some resolution issues. However these calculations are providing insight into the nonlinear mechanisms of surface breakup and healing. We have been able to match many features of a small tokamak and can now project to the computational requirements for simulations of larger, hotter devices such as ITER. These simulations form the basis for studying more complex phenomena such as the effect on these modes of an energetic particle component, or of externally generated electromagnetic waves (RF). [1] R.J. Hastie, Astrophys. Space Sci. **256** 177 (1997).