§4. Simulation Study of Intermittent Beam Ion Loss due to Alfvén Eigenmode Bursts

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The toroidicity-induced Alfven eigenmode (TAE) is a shear-Alfven eigenmode in toroidal plasmas [1]. TAEs can be destabilized by fast ions which have velocities comparable to the Alfven velocity. A decade ago recurrent bursts of TAEs were observed with drops in neutron emission during neutral beam injection (NBI) in the Tokamak Fusion Test Reactor (TFTR) [2] and DIII-D [3]. The drops in neutron emission have been recognized as a manifestation of TAE-induced beam ion loss. In the experiments cited multiple TAEs were destabilized during TAE bursts that took place at regular time intervals. The modulation depth of the drop in neutron emission in the TFTR plasma was typically ~10% (Fig. 4 of Ref. [2]). The most important result is that the beam confinement time is much shorter than the collisional slowing-down time. This means that TAE activity expels beam ions before their energy is absorbed by the core plasma. In this article we report on an investigation for a configuration typical of the TFTR experiment [2].

The simulation uses a perturbative approach where the TAE spatial profile is assumed to be independent of mode amplitude, while the amplitudes and phases and the nonlinear fast-ion dynamics are followed self-consistently. Particles are injected with a constant velocity (corresponding to 110keV which is roughly the Alfven velocity parallel to the magnetic field) and the NBI heating power is 10MW. The particles that are transported to the plasma edge are removed. Concentric circular magnetic surfaces are considered. Three eigenmodes with the toroidal mode numbers of n=1, 2, and 3 are taken into account. The linear damping rate of each mode is assumed to be constant at 2 x 103 s-1. The magnetic field is 1.0 T on axis, the aspect ratio is 3.2, the q-profile varies quadratically with minor radius with the central value of 1.2, an edge value of 3.0, and the slowing-down time is 100 ms. It is found that synchronized TAE bursts take place with a fairly regular time interval of 1.9 ms, which is close to the experimental value of 2.2 ms [Fig. 1]. The stored beam energy saturates at 23% of that of the classical slowing-down distribution. The stored beam energy drop associated with each burst has a modulation depth of 9% which is also close to the inferred experimental value of 7% [Fig. 2]. The fast-ion distribution hovers around a marginal stability state.

The simulation results have reproduced quite closely the following aspects of the experimental parameters; a) synchronized bursts of multiple TAEs taking place at regular time intervals close to the experimental value; b) a modulation depth in the stored energetic particles that is close to the one inferred in experiment; c) a beam confinement time that is much shorter than the classical slowing-down time. We have also analyzed: (a) the particle loss mechanism using test particle tracing, and (b) the nonlinear MHD effects on the saturation amplitude and on the mode profile by using a fully nonlinear Fokker-Planck-MHD simulation.

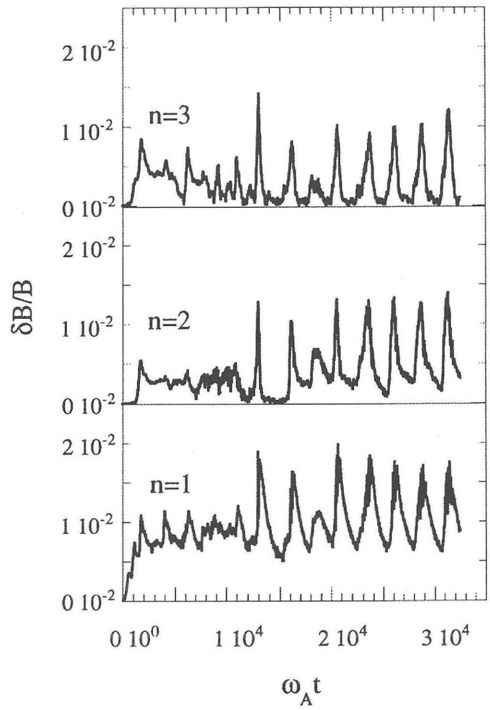

Fig. 1. Amplitude evolutions of the n=1-3 eigenmodes.

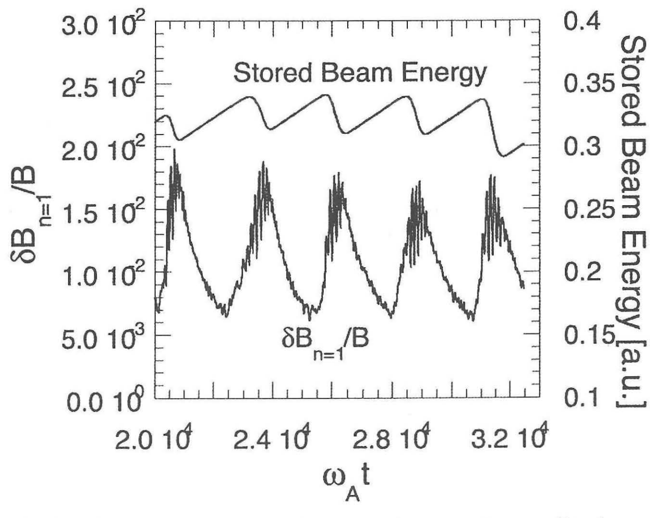

Fig. 2. Time evolutions of the n=1 eigenmode amplitude and the stored beam energy.

References

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[3] W. W. Heidbrink *et al.*, Nucl. Fusion **31**, 1635 (1991).