Self-consistent Study of Fast Particle Redistribution by Alfvén Eigenmodes During Ion Cyclotron Resonance Heating

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Fusion born alpha particles can excite Alfvén eigenmodes (AEs), which degrade the heating efficiency of a burning plasma and throw out alpha particles. To experimentally study the effects of excitation of AEs and the redistribution of the fast ions, ion cyclotron resonance heating (ICRH) is often used. Interactions with cyclotron interactions lead to discrete changes of the orbit invariants in phase space, and consequently alter the phase between the particle and AE. Stronger interactions lead to larger phase changes, and hence decrease the AE interaction time, which increase the width of the resonant regions in phase space. This affects the growth rate and amplitude of the AE. The broadening of the resonant regions of the AEs can lead to that they overlap and result in a larger redistribution of the resonant particles and an increased transfer of energy to the AEs as the distribution function is flattened in a larger region. There are fundamental differences between excitation of AEs by thermonuclear alpha particles and by ion cyclotron heated particles. The distribution function of alpha particles is isotropic and constantly renewed through DT reactions, the decorrelation of the interaction between alphas and the AE is provided through collisions, which are rather ineffective at those energies. The distribution function of cyclotron heated ions is strongly anisotropic, and the cyclotron interactions do not only renew the distribution function but also provide a strong decorrelation mechanism between the fast ions and the AE. In absence of decorrelation of the AE interactions the particles will undergo a superadiabatic oscillation in energy. Because of the sensitivity of the AE dynamics on the details of the distribution function, as well as on the location of the resonance surfaces in phase space and the extent of the overlapping resonant regions for different AEs, a self-consistent treatment of the AE excitation and the ICRH is necessary. Such a treatment including interactions of fast ions with several AEs during ICRH has been implemented in the SELFO code, which solves the distribution function of the RF heated ions with the FIDO code given the wave field, and the wave field with the LION code given the dielectric tensor of the distribution function. Simulations of the AE dynamics are in good agreement with the experimentally observer pitch-fork splitting and rapid damping of the AE as ICRH is turned off.