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Steady-state distribution of neutral beam fast ions in EAST tokamak with three-dimensional external magnetic perturbations

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A comprehensive Monte-Carlo code modeling continuous neutral beam injection, ionization, and the resulting collisional fast ions transport was developed and applied to calculate the steady state distribution of neutral beam fast ions under the influence of three-dimensional resonant magnetic perturbations (RMPs) produced by the edge localized modes (ELMs) controlling coils in the EAST tokamak. Simulations indicate that RMPs enhance the edge loss of fast ions, and this effect reduces the fast ion steady-state stored energy for most RMP up-down phases. However, for some RMP phases, the fast ion stored energy is increased when RMP is imposed even though the edge loss is increased, which does not agree with our usual expectation. We found that the increase in the stored energy is due to the increase of the slowing-down time when RMPs are imposed. Using a semi-analytical theory, we reproduced the simulation results, as is shown in Fig. 1, giving us confidence in the conclusion.

A systematical parameter scanning is performed for the RMP coil currents and up-down phases. There is a linear dependence of the fast ion stored energy on the coil currents for most up-down phases. However, for some up-down phases, the dependence is neither linear nor monotonic.

In this work, we consider only the n=1 RMPs, where n is the toroidal mode number of the RMP coil current. The magnetic perturbation is directly calculated by integrating the coil current. For simplicity the plasma response to the RMPs is ignored. The simulations include the spatial region between the last-closed-flux-surface (LCFS) and the first wall, taking into account the realistic shape of the first wall and the fast ion losses on the wall. The collision of fast ions with the background electrons and ions includes the effects of the slowing-down, energy diffusion, and pitch angle scattering.

The fast ion driven current is also calculated, where the fast ion current is directly simulated by the Monte-Carlo particle method while the electron shielding current is approximated by a fitting formula similar to the neoclassical bootstrap current formulas of Sauter et al..

References

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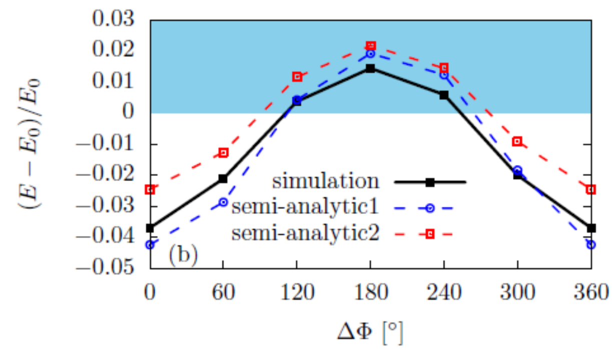

Figure 1. Phase dependence of the steady-state fast ion stored energy, where E0 is the stored energy of fast ions when no RMP is imposed, E is the stored energy when RMPs are imposed. The shaded region indicates the region where the stored energy is larger than the case without RMP. The RMP coil current amplitude is 10kA. n=1.