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Electrostatic potentials generated by NBI fast ions in tokamak and helical plasmas

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Neutral beam injection (NBI) is one of the trusted methods of plasma heating and is widely used in the present-day tokamaks and stelalrator experimental devices, as well as ITER. The fast ions produced by NBI generally have strongly anisotropic velocity distribution depending on the injection direction. A perpendicular NBI produces fast ions in the trapped orbit that are trapped and localized in the outer side of the torus where the magnetic field is weak, creating non-uniform density distribution of fast ions on the flux surface. As a consequence, NBI generates equilibrium electrostatic potential that varies on the flux surface [1].

Electrostatic potential varying on flux surface may affect radial transport of the high-Z impurity ions because the ratio of parallel electrostatic force to the magnetic mirror force becomes larger for high-Z impurity ions, as numerically investigated in [2] for several stellarator devices. In the previous numerical study, it has been found that the electrostatic potential generated by a perpendicular NBI has three-dimensional structure even in axisymmetric tokamaks [3]. We also have studied the electrostatic potential generated by a perpendicular NBI in the helical plasma of the Large Helical Device [4] and found that the generated electrostatic potential can alter the neoclassical transport of carbon impurity ion. These previous studies were focusing on perpendicular injection case. On the other hand, the electrostatic potentials generated by tangential NBI, which also generates non-uniform fast ion density distribution due to the radial drift of fast ions, has not been clarified.

In this study, we investigate the fast ion distributions and electrostatic potentials associated with NBI in tokamak and helical plasmas for a variety of injection conditions including tangential injection case using the global neoclassical code GNET [5]. GNET is based on Monte Carlo technique and can accurately evaluate the five-dimensional distribution function of the fast ions in general magnetic configuration. The fast ion birth points are evaluated using the FIT3D code considering geometry of plasma and beam injector. By using the fast ion distribution function obtained with GNET, we evaluate the electrostatic potential assuming the quasi-neutrality condition. The effect of the electrostatic potential on transport of the impurity ions such as carbon will be investigated using Monte Carlo method.

References

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