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Interaction of dynamic magnetic island with bootstrap current in toroidal plasma

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In the present work, we have investigated the distributions of the bootstrap current with/without magnetic islands based on the first principles of the kinetic particle simulations. The perturbed magnetic and electric fields associated with the dynamic magnetic island are calculated self-consistently from a three-dimensional toroidal MHD code (CLT), instead of static and artificial imposed magnetic island perturbation. In this case, we use the initial equilibrium with q=2 to calculate the tearing mode instability with m/n=2/1 islands that are most catastrophic in tokamak experiment. If the induced perturbed electric field ***E*** is removed and only the perturbed magnetic field ***B*** retains, we call it as a "static magnetic island". If both the perturbed magnetic field ***B*** and electric field ***E*** are retained, we call it as a "dynamic magnetic island". The main achievement in the present study are summarized as follows:

(1) As predicted, the magnetic island makes the plasma density flattened because of fast parallel particle transport along magnetic field lines. Nevertheless, trapped particles are mainly in the LFS, resulting in a less flattened density profile in LFS than in HFS. Moreover, in low collisional region ($\nu^*<1$) particle collisions make the density profiles more flattened inside the islands. Due to the radial transport, the larger the effective collisional frequency ν^* , the weaker the fattening of the density profiles.

(2) Inside the static magnetic island, the bootstrap current is reduced as expected with the effective collision frequency. Inside the dynamic magnetic island, the induced electric field significantly changes the bootstrap current distribution. The bootstrap current is mainly affected by the radial electric field $\boldsymbol{E}_r$. The radial electric field $\boldsymbol{E}_r$ could cause the E×B drift. Consequently, particles accumulate near the X point of magnetic islands, which can noticeably modify the bootstrap current. If the bootstrap current turns on when the tearing mode saturates, the width of magnetic islands ascends rapidly and saturate again for both static and dynamic cases. In the dynamic case, the distribution of the bootstrap current in the vicinity of the X-points is strong asymmetric, which causes the rotation of the magnetic island. The island rotation leads to that the saturated level of the tearing mode is slightly smaller in the dynamic case than in the static case.

In fact, during the time evolution of the (neoclassical) tearing mode instability, the island always rotates with plasma flow. The electric field associated with the presence of a rotating magnetic island due to plasma flow is not studied in the present paper. These studies will be carried out in the near future.