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Effect of magnetic shear and the finite banana-orbit width on the neoclassical toroidal viscosity in perturbed tokamaks

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The effect of magnetic perturbations on the rotation profile in tokamak has been studied both experimentally and theoretically, since the prediction and control of the plasma rotation is one of the key issues for the stable operation. The NTV torque caused by magnetic perturbations is evaluated by adopting either a local or global drift-kinetic models. In the local models, the finiteness of the drift orbit width is neglected, and the magnetic-shear dependence of the precession frequency ω_B has been omitted. However, recent studies have found that the NTV evaluated from the global simulations, which keep the finite-orbit-width (FOW) effect and the magnetic-shear effect, are different from what the local models predict. Therefore, understanding the reason of this discrepancy in the NTV calculations is important.

Here, by comparing global and local simulations, the FOW effect and the magnetic-shear effect are investigated. To study these two effects separately, we prepared two local simulation models, one neglects the magnetic-shear effect while the other keeps it in the evaluation of ω_B.

For electrons, it is found that the NTV profiles from the global and local codes are similar. Strong resonance of drift motions with the perturbed field occurs if $\omega_B \simeq 0$, which causes the strong NTV in low-collisionality regimes. ω_B depends on the magnetic moment and the local shear. The resonant condition in the velocity space approaches to the trapped-passing boundary as the local magnetic shear becomes more positive. In the positive-shear case, the resonant orbits are easily disturbed by small collisions and therefore the NTV evaluated by the global model tends to be smaller than that by the local one. Opposite tendency can be seen in the negative-shear case. For ions, it is found that the difference in NTV between local and global simulation becomes significant and is caused not only by the magnetic-shear effect but also by the FOW effect. In the global calculation, trapped particles see the spatial variation of the magnetic perturbations along the perturbed drift motions, while the local model assumes that a trapped particle bounces along an unperturbed field line. The non-local effect causes a significant difference in the ion NTV and in the rotation profile predicted from global and local simulations.

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