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Simulation Study on Neoclassical Poloidal Viscosity in Helical Plasmas[1]

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In helical plasma confinement devices such as LHD, CHS and TU-Heliac, biasing experiments have been carried out to study the relationships among the ExB rotation, neoclassical poloidal viscosity (NPV), JxB torque of biasing current, and plasma confinement properties. In earlier studies using simple analytic formulae, it has been suggested that the transition phenomena of plasma transport found in the biasing experiments is attributed to nonlinear dependence of NPV on poloidal Mach number of the ExB rotation speed, or Mp. To study the NPV dependence on Mp in LHD biasing plasmas more in detail, we have applied FORTEC-3D drift-kinetic Monte-Carlo simulation code which can evaluate NPV precisely in realistic 3-D magnetic configurations. This is the first application of the massive neoclassical transport simulation to study the dependence of NPV on the magnetic configuration and rotation speed. In LHD plasmas, neoclassical transport properties such as radial particle transport and viscosity can be controlled by shifting the magnetic axis position. Our simulation study revealed that the NPV is drastically reduced if magnetic axis moves from 3.75m to 3.53m. As the biasing voltage, or Mp increases, it is found that the local maximum of NPV appears when $|\mathrm{Mp}| \sim 1$, at which the transition of plasma transport properties is expected to happen. The transition Mp value is much smaller than that is predicted from simple analytic estimations. Comparing with the data from LHD biasing experiments, we confirmed that Mp near the electrode is about unity when a transition occurs, and also found that the peak NPV value at $|\mathrm{Mp}| \sim 1$ agrees with the magnitude of JxB torque at the transition point. This suggests that our simulation successfully explains the nonlinear dependence of NPV and can give a quantitative evaluation of NPV in realistic LHD biasing experiment.

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