03aE44P

JT-60U における新古典トロイダル粘性の影響

Effects of the neoclassical toroidal viscosity in JT-60U

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The integrated code, the TOPICS suite, has recently gained the capability to self-consistently calculate the radial electric field E_r and the evolution of poloidal and toroidal flows [1]. With the aid of the orbit-following Monte Carlo code F3D-OFMC, toroidal rotation driven by neutral beams has been calculated in plasmas with toroidal field (TF) ripple. Recently the neoclassical toroidal viscosity (NTV) in tokamaks acting on thermal ions has attracted attention in that the NTV damps or sometimes accelerates toroidal rotation towards a certain rotation level, called the offset rotation. The NTV is a non-axisymmetric 3D effect in tokamaks due to the toroidally-asymmetric perturbed magnetic field that stems from not only the discrete toroidal field coils but also the application of the external perturbation coil current. Given that tokamaks are actually not axisymmetric, the NTV is ubiquitous and is therefore an indispensable piece of toroidal rotation predictions. In contrast, transport simulations with the NTV taken into account have seldom been performed. This is partly because due partly to its complicated 3D nature. A drift-kinetic δf Monte Carlo code, FORTEC-3D, which has originally been developed for neoclassical transport analyses in heliotron/stellarator, is able to compute the NTV [2,3], including effects of E_r in tokamaks [4]. A numerical tool like FORTEC-3D has many advantages in that it does not essentially require a simplified combined-viscosity formula that covers all collisionality regimes It can compute the NTV using the actual equilibrium and magnetic field with the aid of the 3D equilibrium code, VMEC [5].

The framework of the collaborative execution of TOPICS with VMEC and FORTEC-3D has been developed. In this work, it is applied to JT-60U experimental analyses. In JT-60U discharges with somewhat larger TF ripple amplitude, 3D effects probably play a significant role on toroidal rotation through not only fast-ion channels, which have already been dealt with [1], but also thermal ions'. We show the computed NTV profile in JT-60U L-mode discharges w/ and w/o ferromagnetic steel tiles (FSTs) (see Figure 1) and its impact on toroidal rotation by TOPICS simulations.

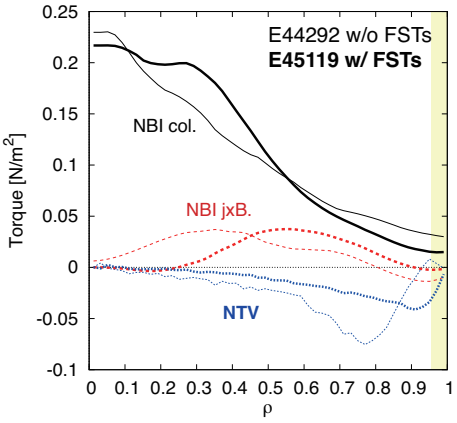

Figure 1: Profiles of collisional torque, the $\vec{j} \times \vec{B}$ torque, those of which are due to NBI, and the NTV torque for two JT-60U L-mode discharges w/ and w/o FSTs.

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[5] S. P. Hirshman, W. I. van RIJ and P. Merkel, *Comput. Phys. Commun.* **43** (1986) 143.