§9. Study of the Transition Mechanism Based on a Neoclassical Poloidal Ion Viscosity by Electrode Biasing

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Neoclassical theories point out that a poloidal ion viscosity has an important role for sudden transition to high confinement mode from the degraded mode[1]. In toroidal plasmas, a momentum for poloidal direction is balanced by a driving force of $\boldsymbol{J}_r \times \boldsymbol{B}_t$ and a damping force consisted of ion viscosity and friction force. The ion viscosity has local maxima for poloidal flow velocity. Neoclassical theory indicates that the transition with a formation of a poloidal rotation is triggered when the driving force exceed the local maximum in the ion viscosities. A neoclassical ion viscosity is a momentum damping force caused by magnetic ripple in toroidal systems, thus it is important to carry out the transition experiments in toroidal devices, which can change the magnetic structure widely, and investigate a dependence of a poloidal ion viscosity on magnetic structures in order to clarify a transition mechanism.

Motivated by mentioned above, we carried out the electrode biasing experiments in the Tohoku University Heliac and the Compact Helical System. The electrode biasing experiments have an advantage for the estimation of the ion viscosity from the electrode current corresponding to the poloidal-flow driving force of $\boldsymbol{J}_r \times \boldsymbol{B}_t$.

The dependence of the poloidal ion viscosity on the poloidal Mach number is shown in Fig. 1. The squares are the experimentally evaluated viscosity and the solid lines with triangles are the theoretically calculated one based on Shaing model, which is taking account of the effects of the higher-order helical ripple. Solid marks in experimental viscosities are the data in the phase when plasma shows nonlinear electric resistance[2, 3] during electrode biasing. As can be seen in Fig.1, the experimental ion viscosity has local maximum and the dependence on the poloidal Mach number shows good agreement with the theoretical one. Moreover, the data in the phase when plasma shows nonlinear resistance locate in the region where the viscosity decreases with increase of the poloidal Mach number. These results support the prediction from the neoclassical theories that the plasma makes transition to high confinement mode when the poloidal-flow driving force has exceeded local maxima of the ion viscosity.

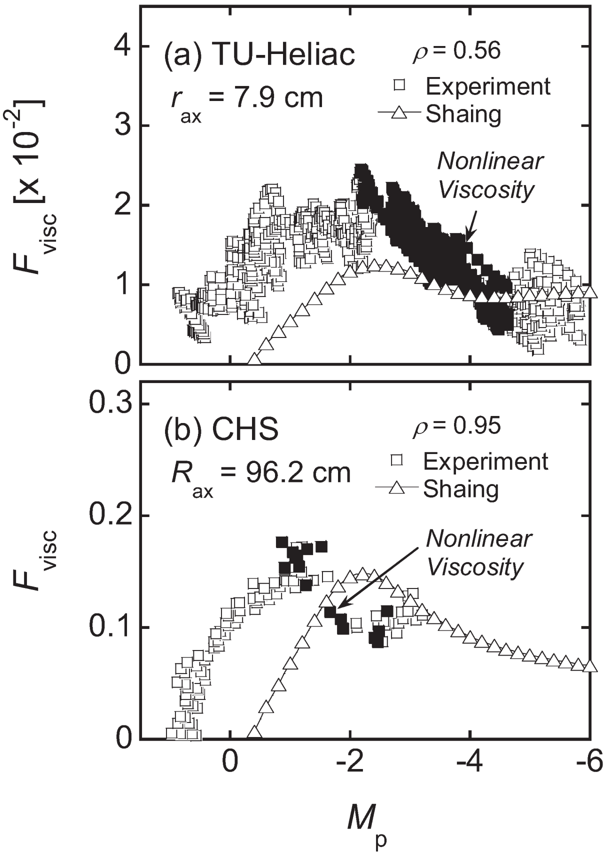

Fig. 1. The dependence of the poloidal ion viscosity on the poloidal Mach number. The solid squares are the data when plasma makes transition with nonlinear electric resistance.

1) Shaing, K. C., Phys Rev. Lett. **76**, (1996) 4364
2) Takahashi, H. *et al*., Plasma Phys. Control. Fusion **48**, (2006) 39
3) Kitajima, S. *et al*., Nucl. Fusion **46**, (2006) 200