Study of Transition Mechanism to Improved Confinement Mode in Helical Plasmas by Electrode Biasing

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Electrode biasing experiments were carried out in the Tohoku University Heliac (TU-Heliac) and the Compact Helical System (CHS) under the electrode current control. In both devices, nonlinear resistance was observed during electrode current sweeping. The electrode current has multiple values against the electrode voltage meaning bifurcation of the electrode current for electrode voltage in the nonlinear resistance phase. With this bifurcation of the electrode current, the formation of steep gradient of an electron density/electron pressure, a suppression of fluctuation level, a reduction of the particle flux caused by the fluctuation in the plasma, increase of electron stored energy, and improvement of the energy confinement time were observed. These results represent the improvement of the particle/energy confinement by the electrode biasing. In the forward/reverse transition experiments in TU-Heliac, the hysteresis in the relation between the radial electric field and some plasma parameters were observed. The data in the region where the hysteresis were emerged corresponded to those in nonlinear resistance. Thus the nonlinearity of the plasma resistance is understood as the characteristic behavior shown at the transition of the plasma confinement.

A dependence of the ion viscosity normalized by the ion pressure gradient on a poloidal Mach number was compared between two devices. In both devices, the dependence of the ion viscosity on the poloidal Mach number shows qualitative good agreement with the prediction from the neoclassical theory. In the transition phase, the local maximum of the ion viscosity is observed and the experimental ion viscosities in nonlinear resistance were located in the region where the ion viscosities decreased against the poloidal Mach number. This indicates that the plasma makes a transition to a high confinement state when the torque in the poloidal direction exceeds the local maximum. In order to clarify the dependence of the transition criterion on the ripple structure, a comparison between the experimental driving force required for the transition and the local maximum of the calculated ion viscosity was carried out. That dependence on the magnetic configuration showed good agreement in both devices. These results support the scenario that the LH transition mechanism can be explained as the bifurcation of the poloidal flow triggered by the local maximum of the ion viscosity.