Configuration dependence of the transition criterion to an improved confinement mode using a biased electrode in the LHD
LHDにおける電極バイアスによる閉じ込め改善モード遷移に対する磁場リップル構造依存性

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In order to examine the role of the neoclassical poloidal viscosity for the transition to improved confinement mode, the configuration dependence of the transition criterion was investigated in the Large Helical Device (LHD) using the biasing electrode. The electrode biasing experiments were carried out for three configuration cases with different magnetic axis position. The critical driving force required for the transition was found to be large in the outward-axis configuration. This result qualitatively agreed with the theoretical predictions based on the Shaing model.

1. Introduction

In the neoclassical theory, the poloidal ion viscosity has local maxima against the rotation velocity [1]. When the driving force in poloidal direction exceeds a critical value, the poloidal rotation velocity increases rapidly and the plasma makes transition to the H mode.

The electrode biasing experiment has the advantage of ability to control radial electric field externally by controlling the electrode voltage and/or the electrode current and to estimate the driving force from the electrode current [2, 3].

In LHD, electrode biasing experiments have been performed in the standard configuration and the transition to an improved mode was successfully obtained [4]. Once the transition occurred, the decrease of electrode current, the suppression of the density fluctuation and the improvement of the energy confinement time were observed.

In the research, we carried out the biasing experiments for three configuration cases in LHD. It was expected that the difference of the transition criterion due to the configuration was clearly observed by choosing the target configurations appropriately because the magnetic ripple structure of LHD widely changes depending on the configuration especially in the plasma edge region.

2. Experimental Setup

The LHD is the largest heliotron device with R = 3.9 m, a = 0.6 m, and has a pole number of 2 and a toroidal period of 10. The heliotron configurations are produced by a set of helical winding coils and three sets of poloidal field coils, which are all superconducting magnets. The magnetic field on the axis is ~2.9 T. The disc-shaped electrode (ϕ = 100 mm, l = 40 mm) made of isotropic graphite was inserted from the lower port and set at the position at the normalized minor radius of ~0.85.

3. Experimental Results

Figure 1 shows the temporal behaviors of (a) the bias voltage V_E and the electrode current I_A, (b) the line-averaged density and (c) the spectrum of the electron-density fluctuation. The target plasma was produced and sustained by 280-kW ECRH under the configuration of R_{ax} = 3.53 m/ B_t = +2.705 T. The electrode was biased against the vacuum vessel by DC power supply. In this study, the electrode voltage was ramped up to +620 V from t = 4.51 s to 4.66 s and was ramped down after t = 4.66 s. As can be seen in Fig. 1, the electrode current dropped and the plasma showed negative resistance in 4.65 s < t < 4.71 s. The region was considered to be the

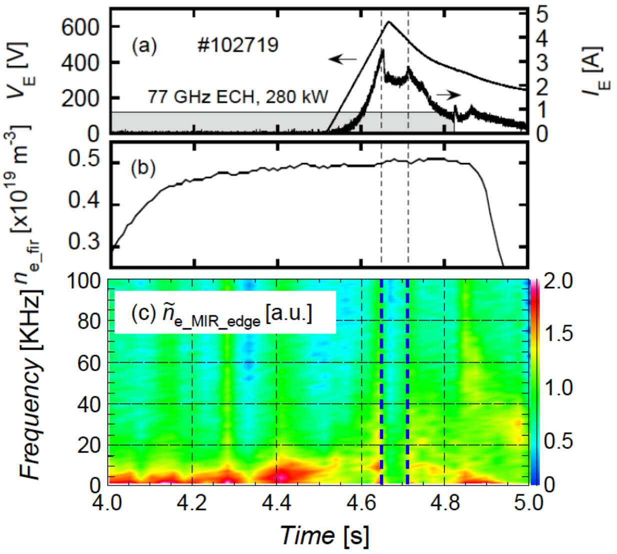

Fig. 1 The temporal behaviors of (a) V_E and I_A, (b) the line-averaged density and (c) the spectrum of the electron-density fluctuation.

transition area and the density fluctuation significantly suppressed in wide frequency region. The energy confinement time slightly increased after the transition.

4. Discussion and Conclusion

Figure 2 shows the relation between V_E and I_E during the discharge. The characteristic curve illustrated N-shape and I_E has the local maximum and the local minimum against V_E. Moreover, hysteresis was observed in 520 V < V_E < 580 V. This implies that the plasma makes transition to high (low) confinement state when the torque in poloidal direction $\boldsymbol{J}_r$x$\boldsymbol{B}_t$ exceeds to the local maximum of the poloidal ion viscosity (fall down to the local minimum). Similar results were observed in the Tohoku University Heliac [3].

Figure 3 shows the configuration dependence of the poloidal driving force required for the transition and the value of the local maximum in the neoclassical poloidal viscosity calculated using Shaing model [1]. The critical driving forces were evaluated using the value of the electrode current at the timing that the negative resistance occurred in the voltage-ramped-up phase. As can be seen from the figure, the critical driving force required for the transition was found to be larger for the configuration of R_{ax} = 3.6 m than that for R_{ax} = 3.53 m. Although the poloidal damping force, which balances with the poloidal driving force, includes the contribution of the friction force, the tendency of the configuration dependence is qualitatively agreed with the theoretical prediction. The experiments for further outward configuration with

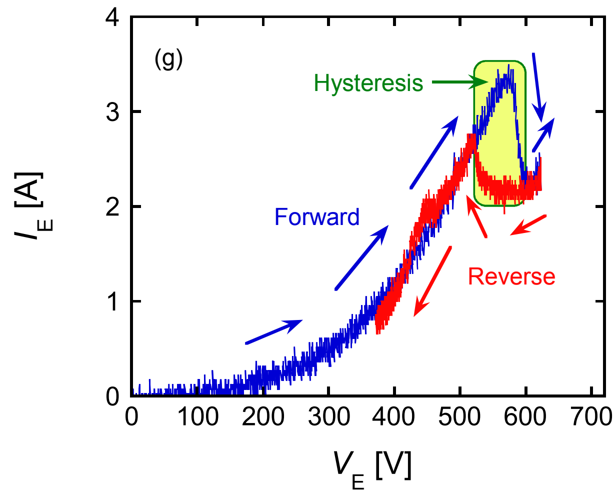

Fig. 2 The characteristic curve of I_E during the discharge.

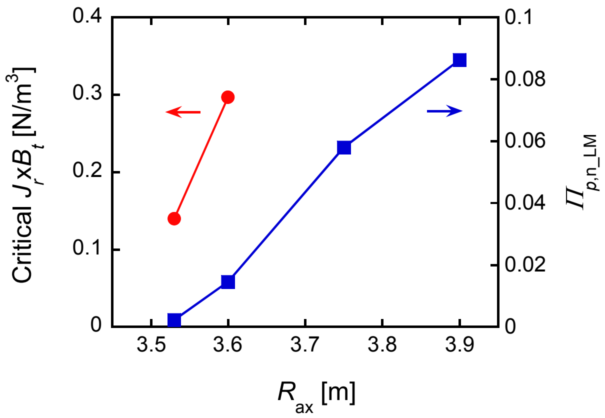

Fig. 3 The configuration dependence of the critical driving force and the value of the local maximum in the poloidal viscosity.

R_{ax} = 3.75 m was carried out but the transition was not triggered under the capability of the DC power supply (650 V/ 23 A). This implies that the larger driving force is required for outward configurations and is consistent with the theory.

In the future work, the transition criterion will be compared with that of the other toroidal devices to advance understanding of the dependence of the poloidal ion viscosity on the ripple structure.

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