§14. Magnetic Island Formation in Locked-like Mode in LHD

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We report the discovery of the magnetic island formed in the locked-like mode in helical plasma. New analysis and observation techniques applied to the ECE signal and poloidal flow in LHD experiments show the following results. (i) The magnetic island structure is present. This indicates that the resistive interchange mode can induce the rotating magnetic island in the locking phase. (ii) The rotation speed of the island is not uniform in space. The toroidal structure of the island changes in the locking-phase, and the deformation increases till the mode is locked.

Figure 1 shows the time trace of the locked-like mode discharge. The magnetic field strength (1.375 T) is set for the availability of ECE measurements. During the continuous NBI heating, the rotating m/n=1/1 magnetic fluctuation appears at around t=4.5 s. This magnetic fluctuation frequency gradually decreases after around t=4.8 s then reaches almost zero at t= 5.2 s as shown in Fig. 1(e) (locking-phase). Just at this time the strong m/n=1/1 component of the radial magnetic field rises rapidly as shown in Fig. 1(b) and the minor collapse occurs (locked-phase). At the beginning of the locking phase, the clear indication of the magnetic island is obtained by ECE. The rotating m/n=1/1 mode component included in the fluctuation amplitude and the phase difference of ECE intensity can be extracted. The odd radial structure and the flattened T_e profile clearly appear. It is also found that the inverse position is mostly the same as the $\iota/2\pi$=1 surface.

Newly installed toroidally-correlated microwave Doppler reflectometers[1-2] give the temporal behavior of poloidal velocity V_p and shows that V_p is oscillated at the same frequency of magnetic fluctuation shown in Fig. 1(c) and (d). The value of V_p is changed back and forth from around -4 to 0 km/s during the locking-phase. It should be noted that V_p ~0 means that the O-point of the rotating magnetic island comes to the observation region. The time evolutions of phase averaged V_p observed at two toroidally separated locations are plotted as shown in Fig. 2. Here, the horizontal axis represents one period of fluctuation at t=5.1 s. Sojourn time corresponding to the staying time of the O-point of rotating island in the observation region (torus outside region) is different in the different toroidal locations. It suggests that the island structure is toroidally non-uniform because if the rotation is constant, the sojourn time must be the same at two positions. Also, the phase difference between two V_p measurements is changed in time as shown in Fig. 1(f). At first, it is steady and equal to the separated toroidal angle of each diagnostics. Then after t=4.9 s during the locking-phase, the phase difference starts to change. It is possible to explain as the distortion of the rotation structure that is the twisting rotating island structure disobeys the equilibrium magnetic structure. This distortion would lead to the damping of the rotation velocity.

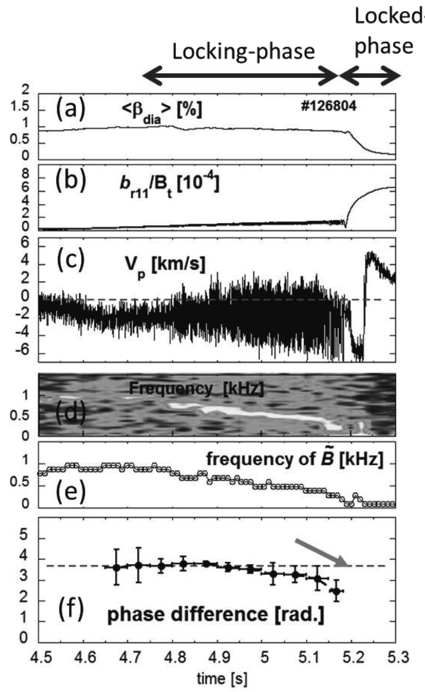

Fig. 1. Oscillating V_p and the deformed rotation feature are observed during the locking-phase in NBI heating plasma. Time evolution of (a) volume-averaged β, (b) m/n=1/1 component of the radial magnetic field, (c) poloidal velocity V_p at r_{eff}/a_{99}=0.9, (d) frequency spectrogram of V_p, (e) frequency of m/n=1/1 magnetic fluctuation component, and (f) toroidal phase difference of V_p oscillation component.

1) T. Tokuzawa et al., Rev. Sci. Instrum. **83** 10E322 (2012)
2) T. Tokuzawa et al., Plasma Fusion Res. **9** 1402149 (2014)

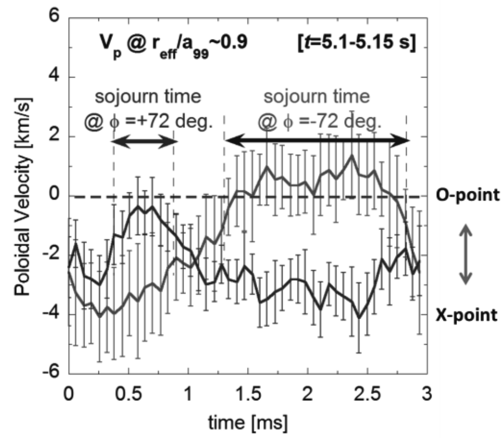

Fig. 2. Non-uniform rotation is clearly observed. Phase averaged time evolutions of V_p with one-period of the fluctuation observed at two toroidal locations of the toroidal angle φ = - 72 and + 72 degrees. Here, 19 ensembles are averaged according to the specific phase of B_{r11} component. The sojourn time in O-point is considered to be indicated by V_p~0.