§48. Observation of Magnetic Island Transition Hysteresis to Plasma Beta

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Magnetic islands play key roles in toroidal plasma confinement from the viewpoint of MHD stability. In a helical device, magnetic islands intrinsically disappear as they are stabilized during a plasma discharge under certain conditions [1, 2]. The nonlinear growth or suppression of the magnetic island during a discharge has been observed in the Large Helical Device (LHD) [1]. The resonant magnetic perturbation (RMP) coils make a vacuum magnetic island with m/n = 1/1 (here, m/n is poloidal/toroidal Fourier mode number) structure. Generally, at low beta (β) and high collisionality (ν), the plasma tends to make the island grow in width. However at sufficiently high β and/or low ν, the plasma abruptly changes to a configuration with no island. Recently, the magnetic island transition hysteresis to the poloidal rotation has been studied to clarify the dynamics of the magnetic island transition [2]. Figure 1 shows the waveform that the magnetic island shows two transitions in a single discharge. In the beginning of the discharge at $t \leq$ 4s, the magnetic island shows growth ($w > w_{vac}$) here, w (w_{vac}).means the width of (vacuum) island. When the additional NBI is injected at t = 4.1s, the β goes up prior to the island suppression (w = 0) at t = 4.4s. After that, the magnetic island shows regrowth ($w > w_{vac}$) at t = 4.8s after the β goes down by turned off NBI. The relationship between the phase difference, $\Delta\theta_{m=1}$, and the β is shown in Fig.2 in which arrows indicate the time trend. Here, the phase difference ($\Delta\theta_{m=1}$) is defined as the difference of the phase between the plasma response and the RMP. When the phase difference is zero ($\Delta\theta_{m=1}$ = 0), the magnetic island grows, when it is out of phase ($\Delta\theta_{m=1}$ = π), the magnetic island is suppressed. When the β increases, $\Delta\theta_{m=1}$ goes from 0 to $\Delta\theta_{m=1}$ = -π(rad) and finally island is suppressed at β = 0.3%. On the other hand, $\Delta\theta_{m=1}$ goes back to $\Delta\theta_{m=1}$ = 0 (growth) at β = 0.1%. The β for island suppression (0.3%) is larger than that for island regrowth (0.1%). These experimental results show the existence of a hysteresis in the magnetic island transition dynamics, i.e., once the magnetic island is suppressed by increasing beta, it lasts until the beta becomes sufficiently small. They are consistent to the theoretical prediction whose model is based on the balance of electromagnetic and viscous torques considering the curvature driven tearing mode [3, 4].

1) Y. Narushima, et al., (2008) Nucl. Fusion **48** 075010

2) Y. Narushima, et al., (2011) Nucl. Fusion **51** 083030

3) S. Nishimura, et al, *"Nonlinear stability of magnetic islands in a rotating helical plasma"* to be submitted

4) C. C. Hegna, (2011) Nucl. Fusion **51** (2011) 113017

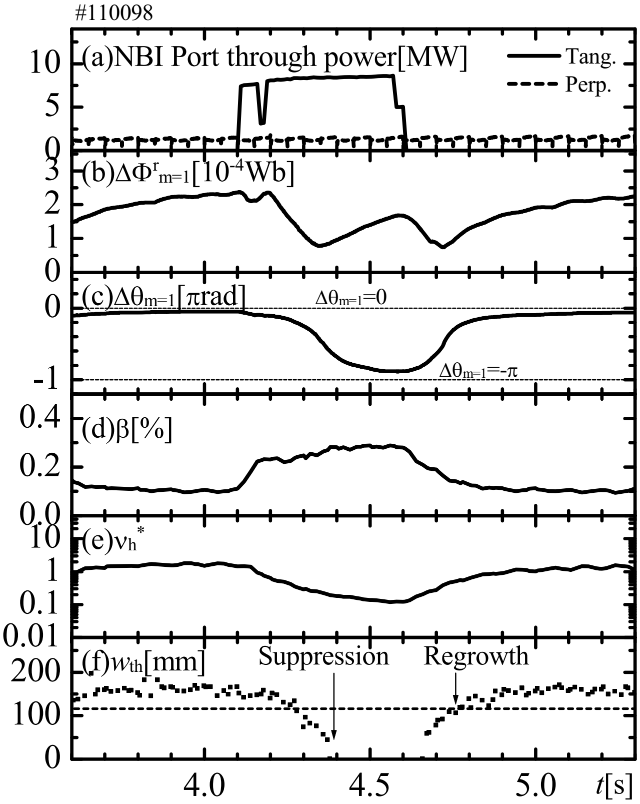

Fig.1 Time evolution of (a) NBI power, (b) plasma response field, (c) phase shift, (d) plasma beta, (e) collisionality and (f) island width.

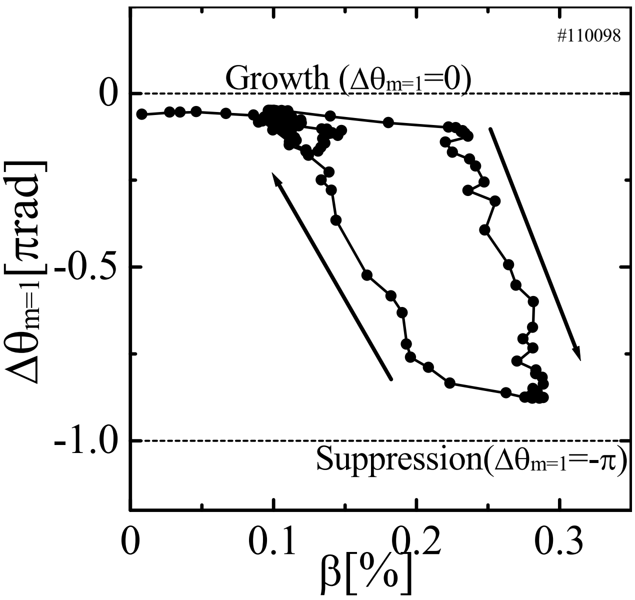

Fig.2 Relationship between phase shift ($\Delta\theta_{m=1}$) and beta. Time evolution is indicated by arrows.