§33. Experimental Observation of Hysteresis in Magnetic Island Dynamics

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Magnetic islands play key roles in toroidal plasma confinement from the viewpoint of MHD stability. In Tokamaks, for example, a seed island triggers a neoclassical tearing mode, and its growth leads to serious deterioration of the confinement. On the other hand, 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. Both magnetic island growth and suppression is seen with the two disparate plasma responses distinguished by a sharp boundary in the parameter space defined by the plasma β and collisionality at the rational surface. 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 causal relations between the island dynamics and the plasma rotation attract attention experimentally [3] and/or theoretically [4, 5]. Experimental results showing that the poloidal rotation ω_{pol} increases prior to the island suppression regardless of its direction have been observed in LHD and TJ-II [3]. Theoretical studies have addressed this problem, in which the viscous torque and electromagnetic torque have key roles to explain the above phenomena in helical plasmas. The purpose of this study is to clarify the dynamics of the poloidal rotation during the island transition and its hysteresis. Figure 1 shows the relationship between the phase difference, $\Delta\theta_{m=1}$, and the poloidal rotation, ω_{pol}, at just outside the $\iota/2\pi = 1$, 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 ($\Delta\theta_{m=1} = \pi$), the magnetic island is suppressed. In the case of the transition from growth to suppression (fig.1 (a)) the phase shift $\Delta\theta_{m=1}$ transits from $\Delta\theta_{m=1} \sim -0.1\pi$rad to $\Delta\theta_{m=1} \sim -\pi$rad. The threshold value of the poloidal rotation, ω_{pol}^{th}, derived from the fitting of a Heaviside-function is $\omega_{pol}^{th} = -9.0$krad/s. In the other case of the transition from suppression to growth (fig.1 (b)) $\omega_{pol}^{th} = -6.6$krad/s. These experimental observations imply that when the magnetic island is suppressed by the poloidal rotation once, the suppression lasts until the poloidal rotation becomes small enough. And it is an advantageous behavior from the viewpoint of the magnetic island stabilization. To explain the island dynamics, one candidate

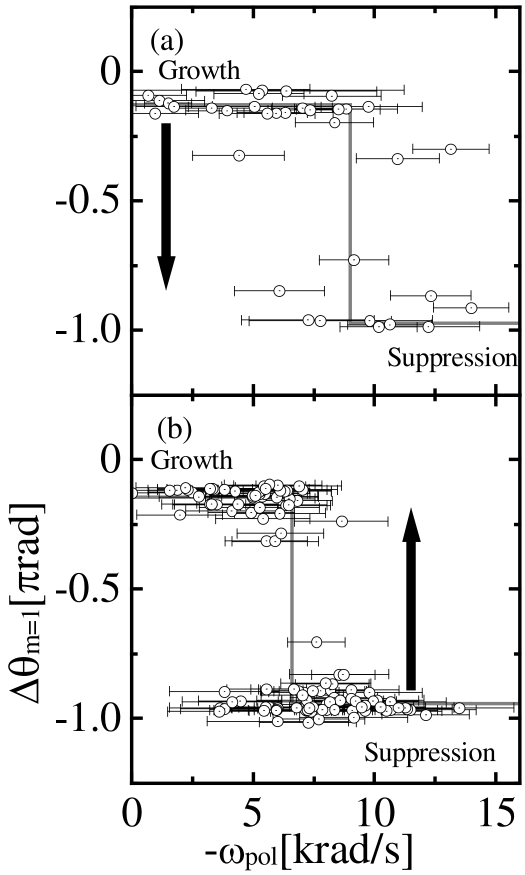

Fig.1 Relationship between $\Delta\theta_{m=1}$ and ω_{pol}. Case of (a) growth to suppression, (b) suppression to growth. Arrows indicate time trend. Grey solid line indicates threshold of poloidal rotation for transition (ω_{pol}^{th}). Threshold values of poloidal rotation are (a) ω_{pol}^{th} = -9.0krad/s and (b) ω_{pol}^{th} = -6.6krad/s, respectively

is the relationship between the poloidal viscous drag force and the magnetic torque [4, 5]. Due to the increase of the poloidal flow, the viscous drag force overcomes the magnetic torque between the externally imposed field and some kind of current structure with $m/n = 1/1$, which causes the current structure to be shifted (rotated) to suppress the magnetic island and vice versa. In the above situation, the hysteresis is predicted by theoretical study.

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