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# §9. Threshold of Mode Penetration

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Threshold of mode penetration has been investigated by using resonant magnetic perturbation (RMP) field with $m/n = 1/1$ in LHD. Previous RMP experiments show that the mode penetration depends on the beta, collisionality and poloidal flow.[1-3] Also, it linearly increases by increasing the magnetic shear, and mitigation of the magnetic hill is effective for avoiding the penetration.[4] In order to clarify their configurational effects on the penetration further and the relationship with the plasma flows, RMP ramp-up experiments were done in different magnetic axis ($R_{ax}$) configurations. When the $R_{ax}$ is shifted from 3.55 m to 3.8 m in $<\beta> \sim 1$ % plasmas, the second order differential of specific volume, $V$", around the $\iota/2\pi = 1$ resonance is decreased from 0.375 to 0.243 with keeping the constant magnetic shear (2.5~2.7), which means that the magnetic hill is mitigated by the outward shift of $R_{ax}$. Then the index of ideal interchange stability, $D_I$, is decreased from -0.08 to -0.28 when the pressure profile is assumed as $P = P_0(1-\rho^2)(1-\rho^8)$.

In the experiments, toroidal field at $R_{ax}$, $B_t$, was set at -1.2 T and $R_{ax}$ was selected 3.55, 3.6, 3.65, 3.7, 3.75 and 3.8m. Figure 1 shows an example discharge of $R_{ax}$ = 3.55 m configuration. Two co- and a counter neutral beam injections (NBI) were applied for producing a target plasma at 3.3-3.8s, and the plasma was maintained at 3.8-6.3s by the balanced NBI because of suppression of induced plasma current. When the RMP current normalized by $B_t$, $I_{RMP}/B_t$, exceeded a threshold at 5.2s, the flattening structure of $T_e$ profile was formed around the $\iota/2\pi = 1$ resonance (Fig.1(b)). The negative sign of toroidal (poloidal) flow corresponds to flow in the co- (electron diamagnetic) direction. Both toroidal and poloidal flow velocities around the resonance gradually increased with time, while they started to decelerate just before the penetration as shown in Fig.1(c).

The results of $R_{ax}$ scan experiments are summalized in Fig.2. The data was obtained in the ranges of $\nu^* = 0.7$-1.7 and $\beta = 0.15$-0.4. The threshold of the mode penetration gradually increases with the outward shift of $R_{ax}$. The angular frequencies of toroidal and poloidal flows around the resonance before the penetration are plotted at the bottom figure. The toroidal flow hardly depends on the $R_{ax}$, whereas the poloidal one gradually decreases with the outward shift of $R_{ax}$. This tendency suggests that the configurational effects are stronger than the plasma flow effects because the increase in the plasma flow contributes the increment of the threshold of the penetration.

1) Narushima, Y. et al.: Nucl. Fusion **48** (2008) 075010.
2) Narushima, Y. et al.: Nucl. Fusion **51** (2011) 083030.
3) Sakakibara, S. et al.: Plasma Phys. Control. Fusion **55** (2013) 014014.
4) Sakakibara, S. et al.: Nucl. Fusion **53** (2013) 043010.

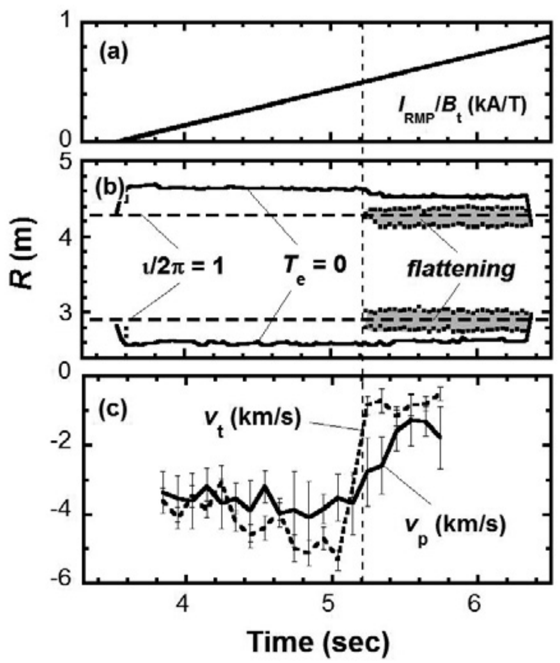


Fig.1 Time evolutions of (a) normalized RMP current and (b) plasma boundary, $\iota/2\pi = 1$ surface, $T_e$ profile flattening and (c) toroidal and poloidal flow velocities around $\iota/2\pi = 1$ resonance.

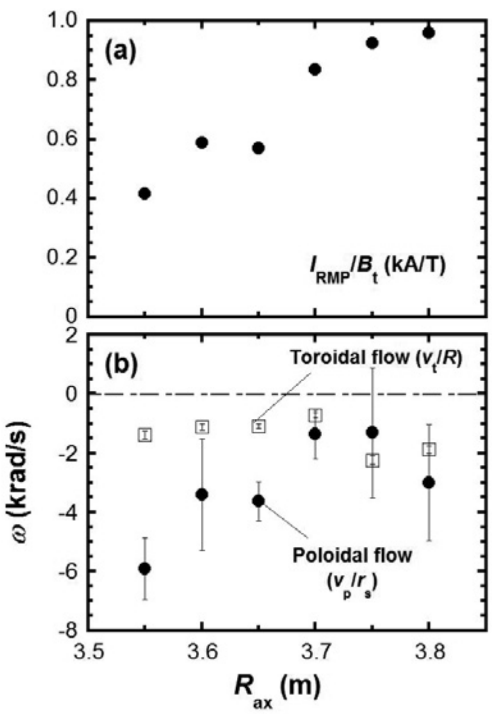


Fig.2 Changes of (a) threshold of mode penetration and (b) angular frequencies of toroidal and poloidal flows around $\iota/2\pi = 1$ resonance as a function of $R_{ax}$.