§10. Nonlinear Analysis of Non-Resonant Mode in LHD

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In the LHD configuration with the vacuum magnetic axis located at R_{ax}=3.6m, sawtooth-like oscillations were observed with the soft X-ray camera system in fairly high density plasmas produced by pellet injection, although the effect of the MHD activity on the global confinement was small[1]. The instability is localized around the magnetic axis and has an $m = 3$ mode structure. The beta value is not limited by the activity. For this magnetic configuration, there is no magnetic surface with $\iota = 1/3$. Therefore, there is a possibility that the mode observed experimentally is a non-resonant mode. In the linear analysis in the last year, it was obtained that such non-resonant mode can be unstable when the following three conditions are satisfied around the magnetic axis. The first is that the pressure gradient is steep as in the profile of

$$P(\rho) = P_0 \begin{cases} (1 - a\rho^2) & for \quad 0 \le \rho \le \rho_f \\ b(1-\rho)(1-\rho^8) & for \quad \rho_f \le \rho \le 1 \end{cases} \quad (1)$$

with $\rho_f = 0.1$. The second is that the value of the rotational transform is close to the ratio of the poloidal and the toroidal mode numbers. The third is that there exists a sufficient large region with a weak magnetic shear.

Thus, the nonlinear evolution in the beta increasing phase is examined to study whether the sawtooth-like oscillation can be caused by the non-resonant mode[2]. For this purpose, we use the multi-scale simulation approach[3, 4]. We increase the pressure every short time by adding a small increment with the profile of (1). Figure 1 shows the time evolution of the kinetic energy of the perturbation and the beta values. Two peaks appear at $t \simeq 39000\tau_A$ and $t \simeq 79000\tau_A$ during the time evolution of the kinetic energy. The axis beta degrades after the kinetic energy shows the peaks, while the average beta increases monotonously. The feature of the beta values seems to be consistent with the experimental results[1] because the axis beta shows a sawtooth-like behavior.

The dominant mode is an $(m, n) = (3, 1)$ mode at both peaks. Figure 2 shows the profiles of the total pressure at $t = 39500\tau_A$ and $t = 79500\tau_A$. The $m = 3$ triangular shape is formed around the magnetic axis. In both cases, there is no magnetic surface with $\iota = 1/3$ in the plasma column. The magnetic shear is very weak and the pressure gradient is quite steep in the region of $\rho \lesssim 0.2$. Hence, it is the $(m, n) = (3, 1)$ non-resonant mode excited around the axis that causes the reduction of the axis beta. As a result, the sawtooth-like oscillations observed in the experiment seem to be excited by the non-resonant mode around the magnetic axis.

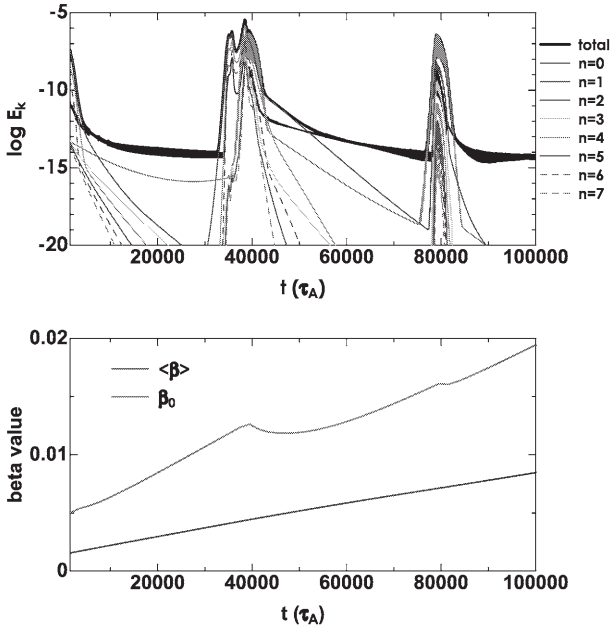

Fig. 1: Time evolution of kinetic energy (top) and beta values (bottom).

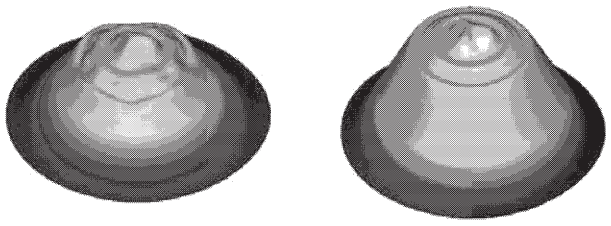

Fig. 2: Bird's eye view of the pressure at $t = 39500\tau_A$ and $\langle\beta\rangle = 0.442\%$ (left) and $t = 79500\tau_A$ and $\langle\beta\rangle = 0.712\%$ (right).

1) Ohdachi, S. et al., Proc. Fusion Energy Conf. 2006, EX/P8-15.

2) Ichiguchi, K., Carreras, B. A., Abstracts of 35th EPS Conference on Plasma Physics, Hersonissos, 9-13 June 28, ECA Vol.32D, 2008, P-2.053.

3) Ichiguchi, K., Carreras, B. A., J. Plasma Phys. **72** (2006) 1117-1121.

4) Ichiguchi, K., Carreras, B. A., Plasma and Fusion Research **3** (2008) S1033.