§1. Multi-Scale MHD Analysis of LHD Plasmas with Background Field Changing

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The LHD plasma with the background magnetic field changing, which corresponds to the magnetic axis swing experiment, is numerically analyzed with a new multi-scale simulation scheme. In the experiment, the field is changed during each shot so that the corresponding vacuum magnetic axis position, R_{vax}, is shifted inwardly [1]. In the present numerical scheme, the time evolutions of the equilibrium and the perturbation in different time scales are simultaneously treated. The changes of the pressure and the rotational transform due to the perturbation dynamics are reflected in the equilibrium evolution. Furthermore, in the present study, the pressure profile close to the profile observed in the experiment and the rotational transform obtained in the nonlinearly saturated state of a preparatory simulation are employed for the initial condition.

By applying the scheme, as shown in Fig.1, we obtain the time evolutions with a partial collapse of the plasma pressure in the case with the background field changing and with no excitation of instabilities in the case without the background field changing, as observed in the experiment. In the partial collapse, the $m = 2$ structure is generated in the pressure profile, as shown in Fig.2.

In the experiment, an abrupt inward shift of the magnetic axis is observed just after the partial collapse. The mechanism is found to be the reduction of the Shafranov shift. The decrease of the axis beta by the partial collapse reduces the shift as shown in Fig.3. Therefore, the time scale of the shift is much faster than the change rate of the background field changing. The simulation result also indicates that the repetition of the partial collapse can be caused by the continuous heating as shown in Fig.1. The subsequent collapse occurs at the lower beta value than the former collapse, because the threshold beta of the mode excitation is reduced by the magnetic hill enhancement due to the background field changing. This mechanism explains the experimental observation that the axis beta decreases in average in the whole time evolution in spite of the continuous heating.

1) Sakakibara, S., et al., Proc. 23rd Fusion Energy Conf. Oct.11-16, 2010, Deajeon, EXS/P5-13.

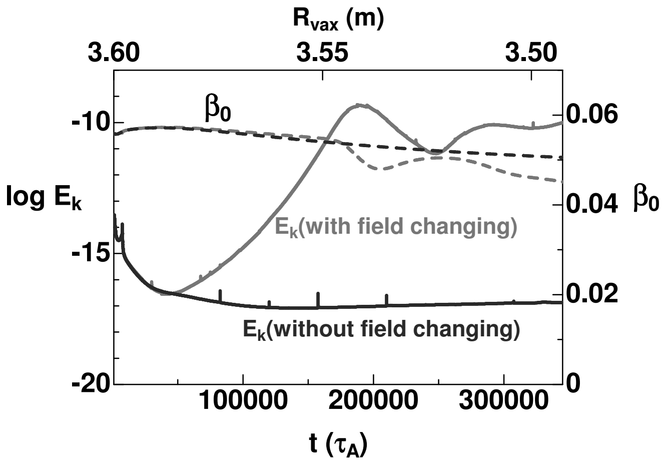

Fig. 1: Time evolution of kinetic energy (E_k, solid lines) of the $n = 1$ component of the perturbation and axis beta (β_0, dashed lines) in the cases with and without the background field changing.

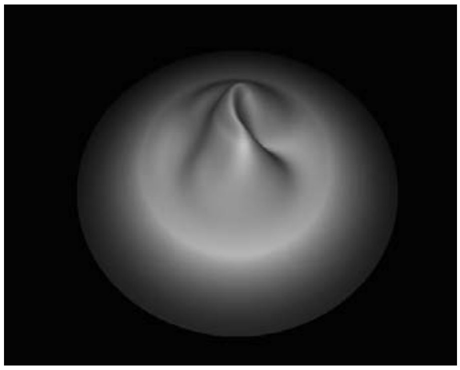

Fig. 2: Bird's eye view of total pressure in the $\zeta = 0$ plane at $t = 202500\tau_A$, in the background field changing.

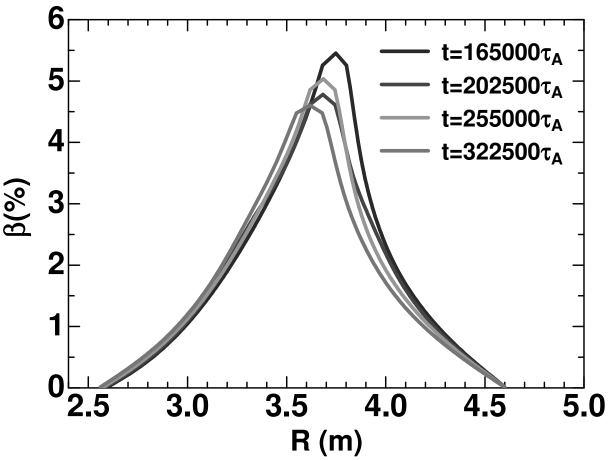

Fig. 3: Profiles of $\langle P \rangle$ at $t = 165000\tau_A$, $t = 202500\tau_A$, $t = 255000\tau_A$ and $t = 322500\tau_A$ in the background field changing.