§ 3. Nonlinear MHD Analysis for LHD Plasmas

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In the recent experiments in LHD, high performance discharges have been successfully carried out in the configuration with the inward shift of the vacuum magnetic axis. On the other hand, the linear MHD stability analysis of the plasmas using smooth pressure profiles showed that low-n ideal interchange modes are unstable for beta values lower than the experimental ones. Here, n denotes the toroidal mode number. For this discrepancy between the theory and the experiment, another linear analysis showed that the local flattening of the pressure profile at resonant surfaces can stabilize multiple interchange modes simultaneously, and therefore, it can be an effective stabilizing mechanism in the LHD plasma.

To examine whether such pressure profile is self-organized, the nonlinear evolution of the LHD equilibria that are linearly unstable to ideal interchange modes is studied using the reduced MHD equations[1]. At sufficiently low beta, each individual mode saturates without affecting directly the evolution of the other modes. They only couple through the modification of the averaged pressure profile. The change of the averaged pressure profile is limited to the local flattening near the resonant surfaces as shown in Fig.1, where the profiles of the averaged pressure at $t_0 = 0\tau_A$, $t_1 = 4800\tau_A$, $t_2 = 11325\tau_A$ and $t_3 = 24000\tau_A$ and the averaged rotational transform. (τ_A denotes the poloidal Alfvén time.) The saturated pressure profile is staircase-like at $t = t_3$, which was expected in the linear analysis.

At higher beta values and for the same initial pressure profile, a bursting phenomenon in the kinetic energy is observed. This bursting activity is caused by the overlap of multiple modes shown in Fig.2, which results in the global reduction of the pressure. However, increasing the beta value and using a pressure profile obtained from the nonlinear evolution at the lower beta suppress this bursting behavior. This result indicates that the pressure profile can be self-organized so that the LHD plasma could reach a high beta regime through a stable path as shown in Fig.3.

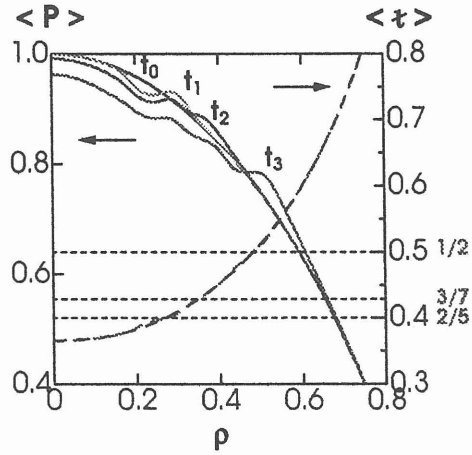

Fig.1 Time evolution of averaged pressure plofile at $\beta_0 = 0.5\%$.

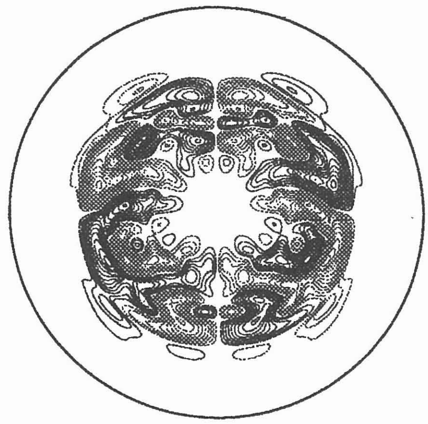

Fig.2 Merged vortices due to the mode overlapping at $\beta_0 = 1\%$.

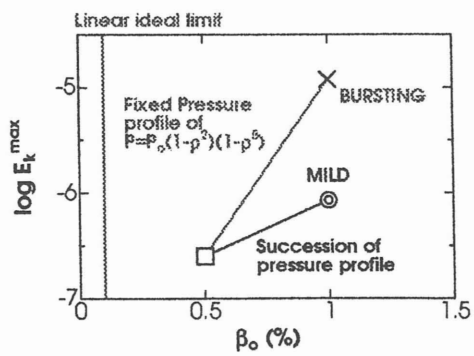

Fig.3 Diagram of the path in the beta increase in the (maximum kinetic energy, β_0) plane.

References

1) Ichiguchi, K., et al., Proc. 19th IAEA Fusion Energy Conf. IAEA-CN-94/TH/6-1(2002).