§20. Application of Evaluation Methods of Anisotropic Pressure Based on MHD Equilibrium Analysis to LHD Experiments

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In LHD-NBI experiments, the pressure anisotropy is expected because the LHD plasmas are heated by the powerful tangential NBI systems. In order to develop the identification method of the pressure anisotropy, we evaluate the magnetic flux loop's signals in LHD by a three dimensional MHD equilibrium analysis code, ANIMEC[1], which enable us to directly determine the calibration function between the anisotropic pressure and the measured fluxes for the non-axisymmetric plasmas for the first time. We find that the diamagnetic flux represents a nearly single-valued function of the beta perpendicular with respect to the field, and the saddle loop flux represents a nearly single-valued function of an equally weighted average of the beta value parallel and perpendicular to the field, even for the anisotropic plasmas with various level of the pressure anisotropy and the various shapes of the velocity distribution function[2, 3]. Moreover, the magnetic axis position a nearly single-valued function of the equally weighted average of the beta value, but the relationship between the the magnetic axis position and the saddle loop flux strongly depends on the flux averaged parallel beta profile. By using the above characteristics, we evaluate the parallel and perpendicular beta values and their radial profiles of the NBI heated LHD plasmas.

Figure 1 shows the time evolution of the volume averaged pressure anisotropy evaluated by the saddle loop flux signal and the diamagnetic flux signal in a LHD discharges heated by tangentially injected NB with the relatively low density regime, n_e~$1x10^{19}m^{-}$. under the various pressure profiles, p~$(1-\rho^2)$; moderate, and p~$(1-\rho^2)^2$; peaked. The magnetic configuration parameters are as follows; R_{ax}^V=3.6m, B_q-100% cancel, γ_c=1.254. In this discharge, the tangential NBs are injected from the beginning to the end od the discharge, and the perpendicular NBs from 3.8s to 4.8s. Then the pressure anisotropy in the beginning of discharge is expected much larger than that the latter phase, which is consistent with the behavior of the pressure anisotropy evaluated by the fluxes. As mentioned in the above, the the volume averaged pressure anisotropy evaluated by only magnetic fluxes strongly depends on the pressure profile. In the discharge of Fig.1, the pressure anisotropy evaluated under the moderate profile assumption is lager by about twice than that under the peaked profile assumption. In this study, in order to identify both the pressure profile and the pressure anisotropy, we use the relationships between the saddle loop flux signal and the magnetic axis position. Figure 2(a) shows the relationships between a saddle loop flux signal and the magnetic axis position for various pressure profile. It should be noted that the relationships is kept for various pressure anisotropic cases because the magnetic axis positions are also expressed by a single-valued function of the equal weighting averaged beta values as well as the saddle loop flux signals for the various pressure anisotropic plasmas, which suggests that the relationships are available for the identification of the pressure profile even in the isotropic pressure cases. Figure 2(b) shows time evaluation of the magnetic axis position evaluated by the saddle loop flux and measured by Thomson scattering measurement system in the discharge of Fig.1. From this figure, the pressure profile is peaked and the pressure anisotropy defined by the parallel beta divided by the perpendicular one is about two in the latter phase of the discharge, t~4.5s. In order to check the validity, we should compare the results with the theoretical predication based on the high energy ion distribution function evaluated by Monte Carlo method.

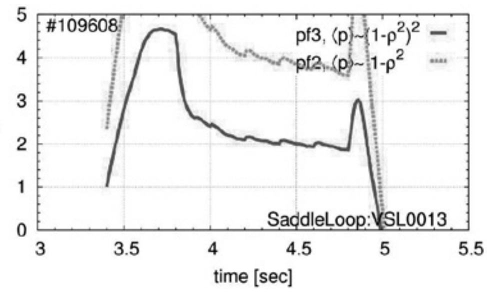

Fig. 1. Pressure anisotropy evaluated by the saddle loop flux signal and the diamagnetic flux signal in a LHD discharges heated by tangentially injected NB with the relatively low density regime, n_e~$1x10^{19}m^{-3}$.

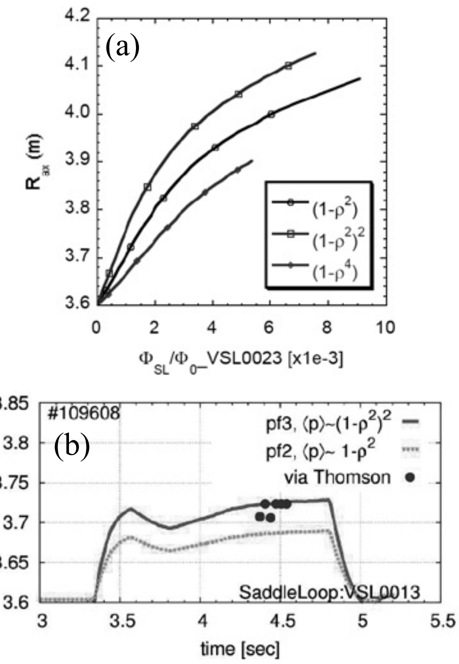

Fig. 2. (a) Relationships between a saddle loop flux signal, Φ_{PS}, and the magnetic axis position, R_{ax}, for various pressure profile. (b) R_{ax} evaluated by the saddle loop flux, and measured by Thomson scattering measurement system.

[1] Cooper, W.A., Comp. Phys. Com. 180 (2009) 1524.
[2] Asahi Y. et al., Phys. Plasma 20 (2013) 022503.
[3] Asahi Y. et al., Plasma Fusion Res. (2011) 2403123.