§40. Quantitative Evaluation of Pressure Anisotropy by Magnetic Measurements

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It has been pointed out that the characteristics of the MHD equilibrium and the instability under the anisotropic pressure are different from those under the isotropic pressure. Therefore a quantitative evaluation of anisotropy is important for the MHD equilibrium and the instability study. Magnetic measurements are useful tools for measuring a pressure anisotropy.

The diamagnetic loop measures the diamagnetic current and the saddle loops measure the Pfirsch-Schlüter(P.S.) current. The P.S. current is induced by $p_\perp + p_\parallel$, whereas the diamagnetic current is induced by $p_\perp$ only. Here $p_\perp$ and $p_\parallel$ denote the plasma pressure perpendicular and parallel to the magnetic field, respectively. Saddle loops and the diamagnetic loop are adequate to pick up the vertical magnetic field induced by the P.S. current and the toroidal magnetic flux induced by the diamagnetic current, respectively. As another difference, the saddle loops are sensitive to a pressure profile while the diamagnetic loop is not sensitive. In order to evaluate the quantitative anisotropy, the effect of the pressure profile on the magnetic measurements should be avoided.

In Fig.1, the relationship between the line-averaged electron density and $\Phi_{SLexp}/\Phi_{SLiso}$ is shown in many NBI discharges with R_{ax}=3.6m, B_t=0.5, 0.75 and 1.5T. $<\beta_{dia}>$ is in the range between 1% and 2%. Here Φ_{SLexp} denotes the saddle loop flux which experimentally observed. Φ_{SLiso} is the saddle loop flux evaluated by the VMEC-DIAGNO code for the plasmas with the isotropic pressure. In order to estimate Φ_{SLiso}, the electron pressure profiles measured by Thomson scattering and FIR laser interferometer are used and volume averaged values of those pressures are adjusted to agree with the volume averaged pressure values evaluated by the diamagnetic loop. Therefore, an inconsistency of the isotropic estimation with experimental data can be shown by the difference of $\Phi_{SLexp}/\Phi_{SLiso}$ from unity. Furthermore, we suggest that $\Phi_{SLexp}/\Phi_{SLiso}$ depends on $(W_\perp+W_\parallel)/1.5W_\perp$ because Φ_{SLexp} depends on the flux due to the P.S. current and Φ_{SLiso} is derived based on the measured diamagnetic flux. Here $W_\parallel$ and $W_\perp$ are the parallel and perpendicular stored plasma energy. Note, $W_\parallel = W_\perp/2$ in the case of an isotropic pressure. $\Phi_{SLexp}/\Phi_{SLiso}$ approaches unity as the density increases and does not change so much for $\bar{n}_e > 3\times10^{19}\mathrm{m}^{-3}$.

In order to study the contribution of the anisotropic beam pressure, the beam pressure is estimated based on the Monte Carlo technique and the steady state Fokker-Planck solution(FIT code). To compare with $\Phi_{SLexp}/\Phi_{SLiso}$, we estimate $W_\parallel/W_\perp$ which would be more intuitive than $(W_\perp+W_\parallel)/1.5W_\perp$ as the anisotropic index. $W_\parallel$ and $W_\perp$ are expressed as the followings with the thermal energy, $W_{thermal}$, and the perpendicular and parallel beam stored energy, $W_{beam\perp}$ and $W_{beam\parallel}$,

$$W_\parallel = (1/3)W_{thermal} + W_{beam\parallel} \quad (1)$$

$$W_\perp = (2/3)W_{thermal} + W_{beam\perp} \quad (2)$$

Usually, the diamagnetic plasma energy, W_{dia} is estimated under the isotropic pressure, and W_{dia} is expressed as follows:

$$W_{dia} = (2/3)W_{thermal} + W_{beam\perp} \quad (3)$$

From those equations, $W_\parallel/W_\perp$ can be expressed by W_{dia}, $W_{beam\perp}$ and $W_{beam\parallel}$. W_{dia} is estimated based on the diamagnetic measurement. $W_{beam\perp}$ and $W_{beam\parallel}$ are estimated based on numerical calculation by the FIT code. Figure 2 shows the relationship between the anisotropic index $W_\parallel/W_\perp$ and $\Phi_{SLexp}/\Phi_{SLiso}$. The correlation coefficient of them is 0.97, therefore, strong correlation can been shown. Then $\Phi_{SLexp}/\Phi_{SLiso}$ is considered a useful index to evaluate pressure anisotropy. From Fig. 2, in the LHD discharges with R_{ax}=3.6m configuration, the anisotropy $W_\parallel/W_\perp$ is scaled as a function of $\Phi_{SLexp}/\Phi_{SLiso}$ as follows:

$$W_\parallel / W_\perp = -0.8 + 1.3(\Phi_{SL\exp} / \Phi_{SLiso}) \quad (4)$$

The examination of the accuracy of this relationship is a future plan because the scattering of the data is large in Fig. 2.

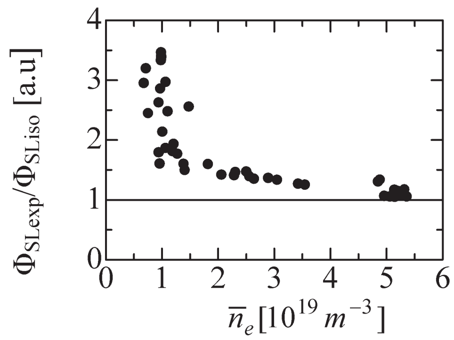

Fig.1 The relationship between $\bar{n}_e$ and $\Phi_{SLexp}/\Phi_{SLiso}$.

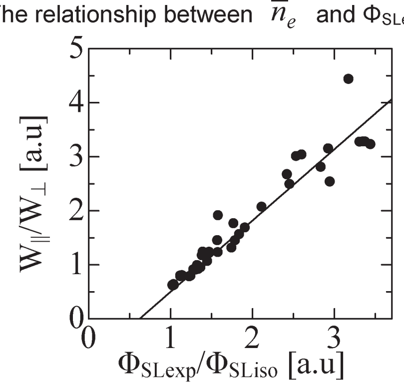

Fig.2 The relationship between $\Phi_{SLexp}/\Phi_{SLiso}$ and $W_\parallel/W_\perp$.