§38. Measurement of Magnetic Axis Shift in High Beta and High Density LHD Plasmas Using a Soft X-ray CCD Camera

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In recent LHD experiments, extremely high density and/or high central beta plasmas have been produced by direct core fueling using repetitive pellet injection[1). A characteristic feature in such a discharge is that the magnetic axis tends to be largely shifted outward (Shafranov shift) because of a strongly peaked pressure profile during temperature recovery phase after the pellet injection. Precise measurements of the magnetic axis shift would be important in physics studies on high beta plasmas in terms of MHD stability.

An imaging system using a soft X-ray CCD camera and beryllium filters has been installed to a tangential viewport in LHD. The system consists of a CCD camera (Andor Technology, DO435-BV) of frame transfer type, a pneumatic mechanical shutter, a pinhole disk and a filter disk[2). Assuming that the soft X-ray emissivity could be expressed by Fourier-Bessel series expansion as a function of minor radius, toroidally averaged magnetic axis position can be precisely derived from the choice of the equilibrium best fitted to the measured (line-integrated) two-dimensional soft X-ray profile from the pre-calculated database[3). In this study, Shafranov shifts in high density and high beta LHD plasmas are measured in this way and systematically analyzed.

An example of the time evolution of a high beta discharge with a reduced magnetic field (0.65 T) is shown in Fig. 1. The magnetic axis shift derived from the above procedure is also drawn in the bottom panel. The frame rate of the CCD camera is 0.26 s which is determined by the minimum readout time. After the repetitive pellet injection, the maximum shafranov shift of 0.285 m was obtained at the time 0.91 s when the central beta value is 3.86 % determined from a Thomson scattering diagnostic.

The dependence of Shafranov shift on central beta value in various high density and/or high beta discharges have been systematically collected and summarized. As an example, the data collected from high beta discharges for vacuum magnetic axis (R_{ax}^{v}) of 3.60 and 3.65 m are displayed in Fig. 2. The solid and broken lines are the dependences predicted from the equilibrium code (VMEC) calculations under the standard and peaked pressure profiles, respectively. Further investigations would be necessary for understanding the scatter of the measured data and the discrepancy between the measurement and calculation.

1) Sakamoto, R. et al.: Plasma Fusion Res. **2** (2007) 047.

2) Suzuki, C., Ida, K., Kobuchi, T., and Yoshinuma, M.: Rev. Sci. Instrum. **79** (2008) 10E929.

3) Liang, Y. et al.: Plasma Phys. Control. Fusion **44** (2002) 1383.

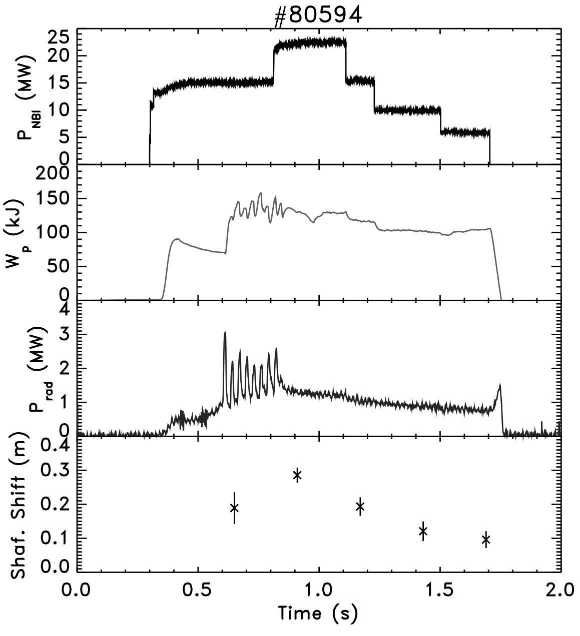

Fig. 1: The time evolution of NBI heating power (P_{NBI}), stored energy (W_p), radiated power (P_{rad}), and Shafranov shift in a high beta discharge.

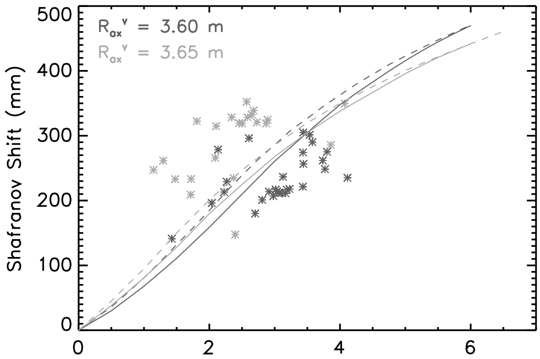

Fig. 2: The dependence of the measured Shafranov shift on central beta value for high beta discharges for configurations of $R_{ax}^{v} = 3.60$ and 3.65 m. The solid and broken lines are the dependences predicted from the equilibrium code calculations.