§17. Investigation of the Intermittent Properties of the Ion Saturation Current in the LHD SOL

Masuzaki, S., Morisaki, T., Kobayashi, M., Komori, A., Ohno, N. (Nagoya Univ.),
Budaev, V.P. (RRC Kurchatov Institute)

Intermittent properties of the ion saturation current (I_{sat}) measured by using the fast scanning Langmuir probe (FSP) in the LHD SOL were investigated based on probability distribution function (PDF) analysis, and both positive and negatively skewed PDFs were observed. Unlike poloidal divertor configuration tokamaks cases, negatively skewed PDFs were found at divertor legs.

Hydrogen plasmas heated and sustained by the neutral beam injection (NBI) are investigated in this study. Figure 1 shows position of FSP. It moves 500 mm vertically from the top wall along Z-axis as shown in Fig. 1 using a pneumatic cylinder. The position of first wall is Z~1.6 m. The maximum velocity of FSP is about 1 m/s. One electrode made of graphite, dome-type with 2 mm of diameter, was provided for this study, and I_{sat} profiles along Z-axis were measured. Sampling frequencies and dynamic ranges of the FSP data acquisition was 1 MHz. The fluctuation properties of I_{sat} signals measured by FSP were analyzed based on PDF analysis. For fully random signal, PDF has a Gaussian distribution. The deviation of PDF from Gaussian distribution function can be characterized by skewness, $S = \langle x^3\rangle/\langle x^2\rangle^{3/2}$, and flatness, $F = \langle x^4\rangle/\langle x^2\rangle^2$. Skewness and flatness are measures of asymmetry and of the tail's weight with respect to core of PDF, respectively, and $S = 0$, $F = 3$ for Gaussian distribution.

I_{sat} profiles in the edge plasma were measured during discharges with a magnetic configuration of R_{ax} = 3.60 m, where R_{ax} is major radius of magnetic axis. An I_{sat} profile during a discharge with 2×10^{19} m^{-3} of line averaged electron density and 3 MW of NBI heating power is shown in Fig. 2(a). Figure 2(b) shows field lines connection length, L_c, profile along Z-axis calculated with field lines tracing code. Smaller Z is closer to the last closed flux surface (LCFS). The field lines tracing was conducted for two directions. One is the same direction as magnetic field, and another one is the opposite direction. In Fig. 2(a), two peaks of I_{sat} appear at Z = 1.0 m and 1.2 m, and they correspond to long L_c groups positions in Fig. 2 (b). The difference of positions between I_{sat} peaks and L_c peaks is considered to be caused by the miss-alignment of FSP. These long field lines approach the vicinity of LCFS, and they are main channel of the pallarel flows of particle and energy from LCFS to the divertor. On the other hand, field lines less than 100 m do not approach LCFS. Skewness profile along Z-axis is also plotted in Fig. 2(a). Skewness was estimated after removing DC component from raw I_{sat} signal using high-pass digital filter (>100Hz), and using 1000 data points (1 ms). Therefore the spatial resolution of this analysis is about 1 mm. In tokamaks, negative skewness has been observed near or inside LCFS, and skewness is positive and becomes

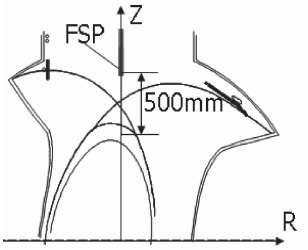

Fig. 1. Poloidal cross-sections of LHD plasma and vacuum vessel at the positions of the fast scanning Langmuir probe (FSP).

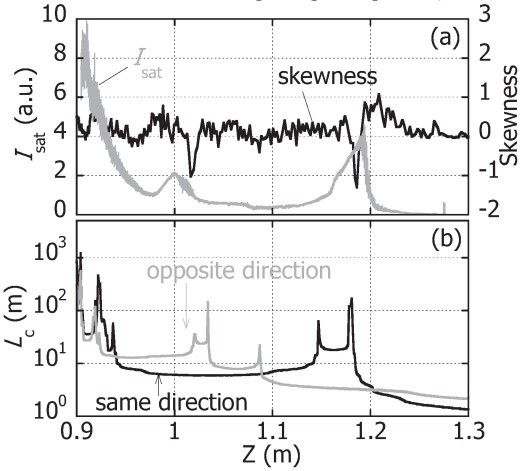

Fig. 2. (a) I_{sat} profile along Z axis measured by using FSP and skewness profile estimated using every 1000 data points. (b) Profiles of connection length of magnetic field lines (L_c) along Z axis calculated with field lines tracing code. black and gray lines show L_c profiles calculated for same and opposite directions of magnetic field direction, respectively.

larger with increase the distance from LCFS [1]. In LHD R_{ax}=3.60 m configuration case, there are two negative peaks at the vicinity of I_{sat} peaks (Z ~ 1.02 m and ~ 1.18 m) , that is the vicinity of L_c peaks as shown in Fig. 2. This result indicates that negative bursts corresponding to density drops are dominant in this region. Fig. 2(b) shows that these field lines at the L_c peak positions connect to divertor plates less than 10 m, and that means these L_c peaks are divertor legs. Relatively large positive skewness appears beside negative peaks of skewness as shown in Fig. 2(a). This observation is consistent with previous observation in divertor plasma [2]. From Z ~ 1.20 m to 1.28 m, skewness decreases from 1 to 0 with decay length of about 2 cm, and I_{sat} becomes noise level at Z > 1.28 m. It suggests that transport becomes diffusive in the outermost region. Assuming that the positive spikes in I_{sat} at Z > 1.21 m region are blobs, a possible explanation of determining the decay length of skewness is lifetime of blobs. Lifetime of blob is roughly estimated as L_c/C_s, where C_s is ion sound speed. In the case of around Z = 1.21 m, L_c ~ 10 m and C_s ~ 3×10^4 m/s (assuming T_e = 10eV), and the lifetime is ~ 0.3 ms. Assuming the cross-field speed of blob to be 100 m/s, the propagation length is 3 cm, and the length is almost same as the observed decay length of blob.

[1] J.A. Boedo *et al*, Phys. Plasma **10**, 1670 (2003).
[2] N. Ohno *et al*., Contrib. Plasma Phys. **46**, 692 (2006).