§45. Analysis of Toroidal Asymmetric Properties of RMP-induced Detached Divertor Plasma

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Establishment of handling the huge divertor heat flux is the essential issue to design a realistic fusion reactor. One of the effective solutions is employing the "plasma detachment," which uses plasma-gas interactions. In LHD, an n/m = 1/1 resonant magnetic perturbation (RMP) field stabilizes the detached plasma condition with a highly-radiating zone near the island X-point inside the ergodic region[1)]. In the fiscal year 2015, we have analyzed the toroidal distribution of the divertor foot-print distributions before and during the plasma detachment assisted by the RMP.

On the closed helical divertor in LHD, divertor probe arrays are installed in 7 toroidal sections. In each toroidal section, 20 pin Langmuir probes are embedded on left- and right-hand side divertor tiles near the mid-plane viewed from the outer-port. Figure 1 shows an example of ion saturation current (I_{sat}) distributions on a divertor tile (right-hand side tile at section 6: 6R) in attached and detached divertor states for R_{ax} = 3.9 m with RMP. It can be found that the divertor particle flux peaking at the strike point broadens to the private side after the detachment. Such a broadening region corresponds to the position where positive spikes of I_{sat} are observed; therefore, non-diffusive transport would conduce the distribution change of the divertor particle flux.

In order to analyze the toroidal behaviors, we characterized such I_{sat} distributions with techniques in probability statistics. Firstly, we defined the ratio of I_{sat} on a probe number n to the I_{sat} summation on a divertor tile as follows:

$$p_{\mathrm{d}}(n) \equiv I_{\mathrm{sat}}(n) \Big/ \sum\nolimits_n I_{\mathrm{sat}}(n). \qquad (1)$$

The center position μ_d, the characteristic width σ_d, and the skewness of distribution S_d are defined with $p_d(n)$ as

$$\mu_{\mathrm{d}} = \sum\nolimits_n n p_{\mathrm{d}}(n), \qquad (2)$$

$$\sigma_{\mathrm{d}} = \left[\sum\nolimits_n (n-\mu_{\mathrm{d}})^2 p_{\mathrm{d}}(n)\right]^{1/2}, \qquad (3)$$

$$S_{\mathrm{d}} = \left[\sum\nolimits_n (n-\mu_{\mathrm{d}})^3 p_{\mathrm{d}}(n)\right] \Big/ \sigma_{\mathrm{d}}^3. \qquad (4)$$

Figure 2 shows time trends of σ_d and S_d on left-hand side divertor plates at sections 2, 4, 6, 7, 8, and 10. In order to remove undesirous effects from low signal-to-noise ratio probes, summation areas are limited at positions where time-averaged I_{sat} has over 2 mA. After the detachment transition, σ_d at sections 4 and 8 increase, indicating that both I_{sat} distributions become wider. At section 4, S_d has negative value during the detachment and thus the broadening direction corresponds to the private side. In contrast, S_d is positive at section 8, suggesting that the divertor particle flux broadens to the SOL side.

In future, we will apply such effective analyses to the multi-point data set for understanding toroidal behaviors.

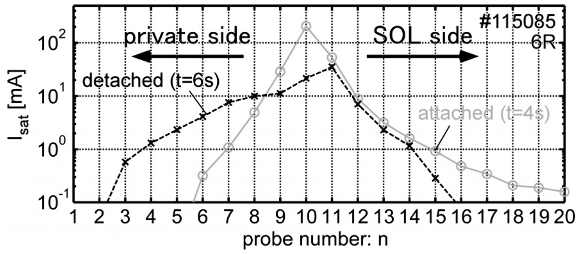

Fig. 1. Ion saturation current distributions on 6R tile in attached (solid line) and detached divertor states (dashed line).

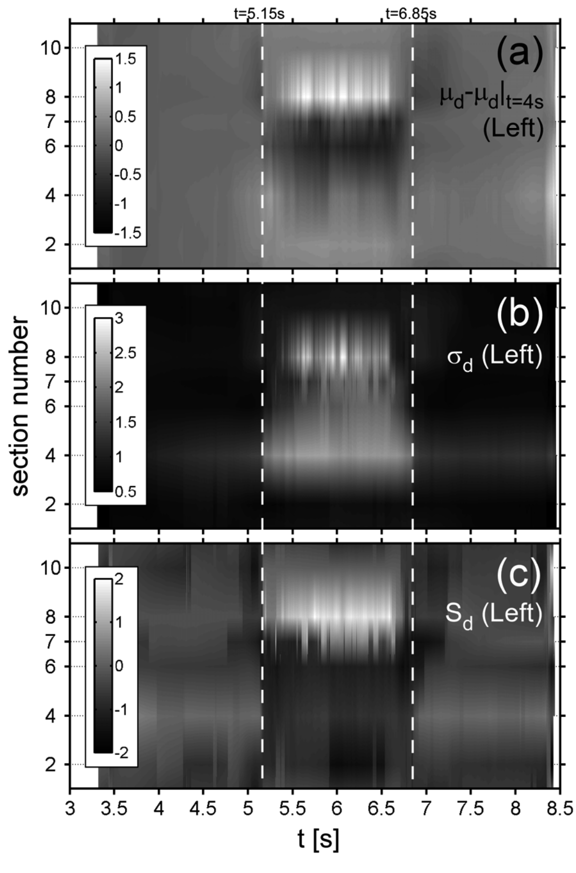

Fig. 2. Time trends of (a) difference of μ_d from that at t = 4 s, (b) σ_d, and (b) S_d of I_{sat} distributions on left-hand side divertor plates. Vertical axis indicates the section number.

1) Kobayashi, M. et al.: Nucl. Fusion **53** (2013) 093032.