§21. Dynamics of Magnetic Shear and its Influence on Turbulent Transport in LHD Plasmas

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The determinant role of structure formation on turbulent transport has been extensively explored in various confinement systems, not only in tokamaks but also in helical devices. However, the influence of magnetic shear or magnetic topology has not yet been well resolved, which may have to do much with the evolution of turbulent spectra in the k-space or possibly with apparent non-linear and abrupt non-local observations. The advantage of magnetic shear for the transport reduction is often obscure but occasionally highlighted out of the shadow in the stability experiments in tokamaks, such as the high li mode in DIII-D (β_N~4li) as well as the scaling of the pedestal pressure (W_{ped}~I_p^2li), whereas ITB formation in electron systems (spontaneous barrier formation in T_e profile was found under negative shear) in particular. The conventional linear model proposed to date considers that the magnetic shear influences the growth rate of turbulence and thus the anomalous transport, as expressed in a form for ITG turbulence:

$$\gamma_L = k_\theta \rho_s \left(c_s/a\right)\left(a/R\right)^{1/2} f(s) a^{1/2} (L_n^{-1/2} + L_T^{-1/2})(T_i/T_e)^{1/2},$$

using the commonly accepted parameters. The function of magnetic shear f(s) is usually considered to reduce the value of γ_L. The simulation results by Maget et al. suggest that slightly negative shear is favorable to suppress the growth rate of instabilities[1]). On the other hand, it was found that the ratio of ω_s over γ_L always stays near unity within the error bars at the time of ion ITB formation in the actual JT-60U experiment, and applicability issue and further discussion have thereto been left in the *cul-de-sac*.

In order to depict the comprehensive pictures to resolve the definitive functions of magnetic shear or its dynamics, a beam switching experiment has been designed and performed in the 2006 LHD campaign. The direction of tangential NB injection was switched in time to either increase or decrease the central magnetic shear with the total heating power nearly fixed. Here, the density fluctuations have been mainly observed, taking advantages of the exploratory microwave reflectometer and PCI diagnostics under commissioning (BES was not yet available). The feasibility of the PCI diagnostic has also been examined in the neoclassical ion-root formation experiments, where a significant reduction of density fluctuations has been documented. The discussions related to the special resolution of PCI diagnostic are out of the scope of the report, but it is thought that PCI has stronger sensitivity in the edge. The evolution of the magnetic shear was also monitored with MSE spectroscopy. The range of n_e and T_i/T_e has also been scanned with the gas-feedback and #4 low energy (ion predominant heating) NB systems, detailed analysis of which are presently in progress.

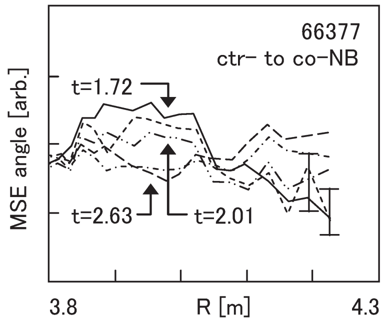

Fig. 1 Temporal evolution of the MSE angle in the ctr- to co-NB switch experiment, where substantial flattening i.e., reduction of the magnetic shear is observed.

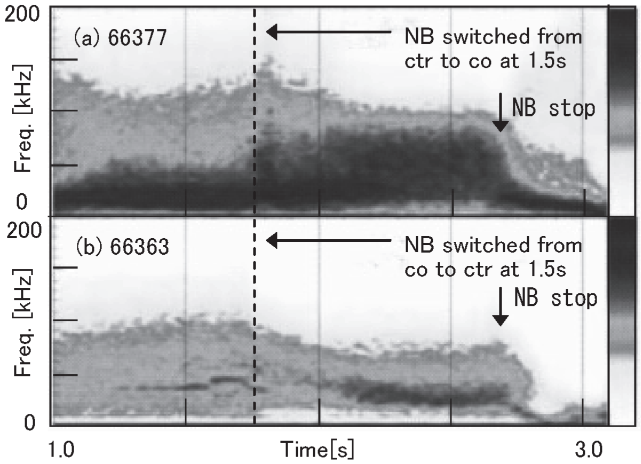

Fig. 2 Temporal evolution of density fluctuations measured by PCI diagnostic for cases when (a) NB is switched from ctr to co and (b)from co to ctr

The central magnetic shear follows the prediction based on the results obtained in 2005 campaign i.e., substantial reduction in the ctr-NB case and a global increase in the co-NB case. Fig. 1 shows the evolution of the MSE angle in the ctr- to co-NB experiment, and the contour of PCI density fluctuation intensities is indicated in Fig. 2. Here, the NBs are switched from ctr to co in (a) and vice versa in (b). According to the gradual changes in magnetic shear, which corresponds approximately to the characteristic current diffusion time. It can be seen that the broadband component (medium frequency part) of density fluctuations substantially increases at a similar rate to the current diffusion time in the case of ctr to co, whilst it (high frequency part above 50kHz) decreases in the co to ctr case. However, it should be mentioned that (1) abrupt spike in the whole frequency region is observed, soon after the time of beam switching and (2) high frequency part above 75kHz is increasing in (a). Furthermore, rather high intensity fluctuations appear at around 30kHz and persist till the time of NB termination, whilst the low frequency MHDs disappear right after the switch in (b). Thus, the influence of magnetic shear is indeed complex and calls for further quantitative documentations.

1) Maget, P. et al.: Nucl. Fusion 39(1999)949.