§2. Investigations on Dynamics of Magnetic Field in Fusion Plasmas and Its Influence on Turbulent Transport

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For the comprehensive understandings of transport phenomena in toroidal confinement systems and improvement of the predictive capability of burning plasmas, the impact of magnetic shear has been extensively investigated in LHD for comparison with tokamaks. Consequently, it was heuristically documented that the pronounced effect of magnetic shear [1-3], which has hitherto been considered to be ubiquitous and strongly impacts the core transport in tokamaks, is not quite obvious. On the other hand, vigorous dynamics of turbulent fluctuations and noticeable changes in thermal diffusivity have occasionally been observed under the magnetic shear modulation, which respond in much faster time scale than the characteristic time scale for either the magnetic diffusion time or the profile evolution.

In order to extract the magnetic shear contribution, dedicated experiment has been designed and performed in LHD, where inherently weak negative shear is modified solely by the beam driven current. The tangential NB was switched from co- to ctr-direction and vice versa at different densities and T_i/T_e values. In addition, modulated ECH was applied at 29Hz for the perturbative transport analysis.

In weak shear plasmas with the magnetic axis R_{ax} located inbound side (R_{ax} =3.6m), MHD characteristics are largely modified by the magnetic topology, and local flattening of the T_e profile is observed [4] due to the island formation when the magnetic shear is reduced. As shown in Fig. 1(a), an abrupt reduction in $dT_e/d\rho$ is observed when the $\iota(\iota/2\pi)=0.5$ surface resides in the low shear region. For discharges with larger R_{ax} (R_{ax} =3.6m), which is less vulnerable to MHDs, due to the extended magnetic well structure over half the minor radius, it has been found that the responses of T_e gradient and thermal diffusivity to the magnetic shear are quite subtle. Fig.1(b) depicts that $dT_e/d\rho$ remains around 1.5 even though the magnetic shear at the ι=0.5 surface is decreased monotonically under the nearly constant heating power. Here, NB was switched from co- to ctr-direction, and the magnetic shear was evaluated using the MSE diagnostic. Indeed, not only the equilibrium but also L_n, L_T and (T_i/T_e) are sustained within a few percent during the magnetic shear modification.

The contour of density fluctuations have also been measured using the phase contrast imaging diagnostic (PCI), where the NBs are switched from the ctr- to co-directions. PCI technique is based on the 2-D CO_2 laser interferometry, and it is intrinsically sensitive to k_θ~200m^{-1} at around the mid-radius[5]. The peaking and flattening of $\overline{\iota}$ profiles are observed respectively in both cases, similar to the tokamak experiments. According to the gradual changes in the magnetic shear due to the beam switching, the broadband component (medium frequency part) increases as a whole at a similar rate to the current diffusion time, whilst the component above 50kHz decreases, following the conventional paradigm. However, it should be noted that (1) higher frequency part above 75kHz is decreasing in the ctr- to co- case soon after the beam switching at 1.7s, and (2) the fluctuations at around 30kHz are enhanced and persist until the time of NB termination after the short interval in the co- to ctr- case. Furthermore, an abrupt spike was observed over the whole frequency region at around 1.75s in ctr- to co- case. Thus, turbulent fluctuations do not provide simple interpretations, indicating that the magnetic shear may only carry a subsidiary role.

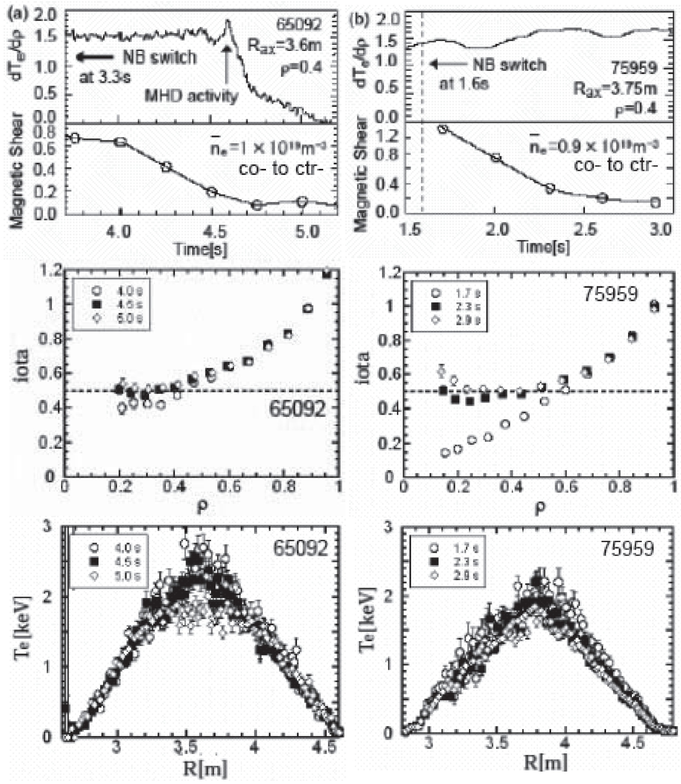

Fig.1 Evolutions of $dT_e/d\rho$, magnetic shear and dynamic behavior of the iota and T_e profiles for (a) R_{ax}=3.6m and (b)R_{ax}=3.75m equilibrium configurations.

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