§7. Comparisons of Edge Pedestal Structure in Tokamak and Helical Systems

Urano, H., Kamada, Y., Oyama, N., Takenaga, H., Yoshida, M. (JAEA), Toi, K., Ohdachi, S., Yamada, H., Ida, K., Okamura, S., Tanaka, K., Miyazawa, J., Yoshinuma, M., Morita, S., Morisaki, T., Narihara, K., Masuzaki, S.,
Watanabe, F. (Nagoya Univ.), Sano, F., Mizuuchi, T. (Kyoto Univ.)

It is important for integrated understanding of toroidal system to compare the edge pedestal structure in fusion plasmas between tokamak and helical devices and investigate the process of the formation of the edge pedestal structure. It has been well known in H-mode plasmas observed in tokamaks that the edge pedestal structure is formed by the improvement of the reduced heat and particle transport. However, a plasma parameter determining the spatial width of the edge transport barrier (ETB) has been unknown, and thus this is one of the most crucial issues in the international tokamak physics activity (ITPA). Main difficulties of identifying a decisive factor which determines the edge pedestal structure are as follows: (1) Since the edge magnetic shear, radial electric field, rotation profile, edge current, pressure profile, and particle orbit loss are strongly correlated in physics and/or in experimentally accessible region, it is hard to separate the process of the ETB formation; (2) While temperature profile is determined by the heat transport, density profile is strongly influenced by the particle source profile (neutral penetration). Therefore, the ETB formation is related to both plasma process and atomic process; (3) The ETB formation is affected by the transport and MHD instability (ELM).

On the other hand, a priority of Japan which owns both large tokamak and helical devices is a large capability of understanding of the toroidal system using these plasmas in reactor size devices by dimensionless parameters, such as, collisionality, Lamor radius and beta value. Comparison of spatial structure of temperature, density, rotation and ELM perturbation in a similar edge pedestal condition between LHD and JT-60 enables us to separate several processes correlated to each other and to examine the physics process predicted by theory based model. In addition, understanding of the edge pedestal structure in H-mode accompanied by the ergodic layer in peripheral flux surfaces could largely contribute to the mitigation and stabilization of type-I ELM observed in tokamaks.

In LHD, the low to high confinement transition (L-H transition) was observed in a unique helical divertor configuration surrounded by ergodic layer, exhibiting rapid increase in edge electron density with sudden depression of Hα emission. Just after the transition, edge transport barrier (ETB) is formed at edge region in magnetic hill region, developing a steep density gradient. ETB region extends in ergodic layer beyond the last closed flux surface defined by the vacuum field. The transition occurs in relatively high beta plasmas when neutral beam absorbed power (P_{abs}) exceeds 1-2 times of the ITER H-mode power threshold. Improvement of energy confinement time is modest (<1.1) for the ISS95 international stellarator scaling, while the particle confinement is clearly improved. ETB width increases with the toroidal beta at the ETB shoulder instead of simple $1/B_t$ dependence. ETB formation leads to destabilization of edge MHD modes with m/n=2/3 or 1/2 (m, n: poloidal and toroidal mode numbers) of the rational surfaces locate in ETB region in the inward-shifted configurations. Edge localized modes (ELMs) are excited by these edge MHD modes through nonlinear evolution. In a few cases of outward-shifted plasmas, edge MHD modes are clearly suppressed in the H-phase without ELMs. When large m/n=1/1 static field perturbations are applied to neutral beam injection heated plasmas, the transition takes place at lower line averaged electron density having small amplitude ELMs.

Similarly to LHD, it has been found in JT-60U that the spatial width of the ETB in H-mode plasmas depends strongly on the beta value through the dimensionless transport experiment using hydrogen and deuterium plasmas. In addition, the dependence of the spatial width of the ETB on the edge density is weak. It is observed that the spatial width of the ETB does not depend on the influx of neutral particles. In JT-60U, it has also been found that dependence of the spatial width of the ETB on the normalized Larmor radius is very weak. Since the normalized Larmor radius in future device is expected to be smaller than the present device, this result is favorable for the next step device including ITER. A detailed analysis on the edge pedestal structure, such as, the spatial width of the ETB and density and temperature at the shoulder of ETB, will be compared between LHD and JT-60.

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