§9. Global Energy Confinement Properties in LHD High Beta Plasmas

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In recent LHD experiments, the highest operational averaged beta value has been expanded up to 4.3% by increasing the heating capability and exploring a new magnetic configuration with a high aspect ratio. Although the MHD stability properties are considered to be unfavourable in the new high aspect configuration, the heating efficiency due to neutral beams and the transport properties are expected to be favourable in a high beta range. Here we study the global energy confinement properties in LHD high beta plasmas.

Figure 1 shows the improvement factor (H_{ISS}) of the global energy confinement time with respect to the ISS95 (International Stellarator Scaling 1995) empirical scaling in the new high aspect configuration (R_{ax}^{V}=3.6m/A_p=6.3) as a function of $<\beta_{dia}>$. Here $H_{ISS\text{-}dia}$ and $H_{ISS\text{-}kin}$ are based on the diamagnetic flux measurement and the electron temperature and density profile measurements under the assumption of Z_{eff}=1 and T_i=T_e, respectively. Z_{eff}, T_i and T_e are the effective electric charge, the ion and the electron temperature, respectively. The $<\beta_{dia}>$ is estimated based on the diamagnetic energy. A disruptive degradation of both global energy confinement times based on the diamagnetic flux measurement and the profile measurements have not been observed up to $<\beta_{dia}>$ ~4%. However, the enhancement factors are gradually reduced as beta increases. In Fig.1, $H_{ISS\text{-}dia}$ is better than $H_{ISS\text{-}kin}$, especially in high beta range. One of the reasons is why the beam contribution to the beta value.

As shown in Fig.1, though a gradual degradation of a global energy confinement on beta value is observed based on the ISS95 transport model, the disruptive degradation of the global confinement has not been observed around $<\beta_{dia}>$=3-4%, where the global ideal MHD modes is predicted to be marginally unstable. Figure 2 shows the electron density normalized by a density limit scaling proposed by Sudo et al. [1], H_{Sudo}, as a function of the beta value. High beta discharges are done in a high collisionality range close to the density limit, H_{Sudo} >0.5 in $<\beta_{dia}>$ >2% and H_{Sudo} ~1 in $<\beta_{dia}>$ ~4%. According to a recent LHD transport scaling analysis at high collisionality [2], the dependence of the global energy confinement time on the electron density changes from the ISS95 scaling, $\tau_E \sim n_e^{0.51}$ in the low collisionality range to $\tau_E \sim n_e^{0.28}$ in the high collisionality range. Figure 3 shows the results when the above new scaling law is applied to $H_{ISS\text{-}kin}$ (closed squares) in Fig.1 for the data with H_{Sudo}>0.5. Closed squares, open squares and open triangles correspond to H_{Sudo} <0.5, 0.5< H_{Sudo} <0.7 and H_{Sudo} >0.7, respectively. The scatter of data in the low beta range becomes smaller than that in Fig.1. However, the degradation in the high beta range, $<\beta_{dia}>$ =2~4%, is still observed, where the beta gradients in the peripheral region are in the Mercier unstable region ($<\beta_{dia}>$ >2%). The above suggests the possibility that the high mode number ideal MHD instabilities affects the global confinement. As other explanations of the degradation, the high number resistive MHD instabilities and the invasion of stochastic region are considered. Further study on the degradation mechanism is also one of our important future subjects.

[1] Sudo S. et al 1990 Nucl. Fusion 30 11
[2] Miyazawa J. et al 2005 J. Plasma and Fusion Res. 81 302

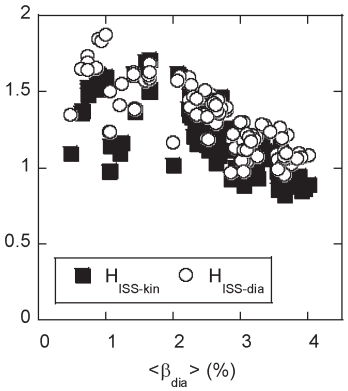

Fig.1 The beta dependence of the improvement factor of the global energy confinement time with respect to the ISS95 empirical scaling.

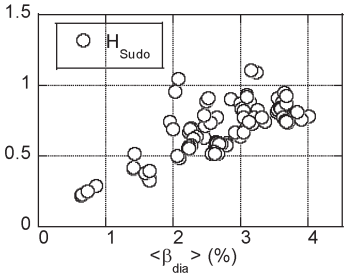

Fig.2 The electron density normalized to a density limit model proposed by Sudo et al. as a function of the beta value.

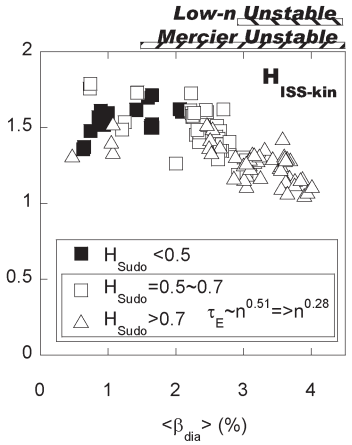

Fig.3 The modified beta dependence of the improvement factor of the global energy confinement time based on a new scaling in the high collisionality regime.