§40. Effect of Edge Ergodicity on Energy Transport

Morisaki, T.

The heliotron configuration intrinsically has a thick open ergodic region outside of the closed magnetic flux surfaces. It is known that the ergodic region becomes thicker as the magnetic axis shifts outward by means of the vertical field control or the increase of the beta value.

From the viewpoint of energy transport in the edge region, it is interesting to study the effect of ergodicity on heat and particle transport via the formation of density and temperature profiles. In this report ergodicity of the edge region in the Large Helical Device (LHD) is estimated quantitatively for each vacuum magnetic field configuration and the relationship between ergodicity and the edge transport property is described.

In order to estimate the ergodicity, the Kolmogorov length L_K is employed, which represents chaotic behavior of magnetic field lines in the ergodic region, i.e., a flux tube there deforms its shape and the circumference d of the tube increases exponentially. The definition of L_K is expressed as following equation,

$$d(l)=d_0\exp(l/L_K) \qquad (1)$$

where d_0 and l are initial value of the circumference and length of the flux tube, respectively. Since L_K is the e-folding length of the exponential increase of the circumference, it can be a good measure of ergodicity.1) On the other hand, if the initial small flux tube is in the closed region or in the island, even if the island is in a ergodic sea, d increases linearly or slowly depending on the magnetic shear at that point. Consequently one can easily distinguish the ordered region, i.e., inside the island or the last closed flux surface (LCFS), from the ergodic region.

Experiments in LHD were carried out with neutral beam heated hydrogen plasmas. The magnetic axis position R_{ax} was set at 3.6m and 3.7m. The line averaged electron density measured with the far infrared interferometer and the electron temperature at the magnetic axis measured with the Thomson scattering system were $\sim 2\times10^{19}\mathrm{m}^{-3}$ and ~1keV, respectively.

In order to study the effect of ergodicity on the edge transport property, the relationship between L_K^{-1} and the radial effective electron heat conductivity χ_e^{eff} was investigated quantitatively. For the χ_e^{eff} extraction, a simple one dimensional energy balance equation is applied to the edge region, as follows,

$$\frac{d}{dt}\left(\frac{3}{2}n_e kT_e\right)=P_{abs}-P_{loss}+\frac{1}{r}\frac{\partial}{\partial r}r\left(n_e\chi_e^{eff}\frac{\partial kT_e}{\partial r}+D\frac{3}{2}kT_e\frac{\partial n_e}{\partial r}\right) \qquad (2)$$

where no energy transfer between ions and electrons, no energy loss by the radiation or the charge exchange process, and no energy absorption are assumed in the steady state edge region. Neglecting the convection term in Eq.(1), the result was not so different from that substituting $0.1\mathrm{m}^2/\mathrm{s}$ for the diffusion coefficient D which has been found in another experiment. Figure 1 shows the effective edge electron heat conductivity χ_e^{eff} as a function of inverse Kolmogorov length L_K^{-1}. It is found that χ_e^{eff} does not change so much when L_K^{-1} is small. However it increases rapidly at the region where $L_K^{-1}\sim0.2\text{-}0.4\mathrm{m}^{-1}$, that is, L_K^{-1} has a threshold for χ_e^{eff}. The position where χ_e^{eff} begins to increase is a few cm outside of LCFS, in other words, in the ergodic region. Nothing happens at LCFS. This result may be explained that quasi closed flux surfaces exist a few cm outside of LCFS, although magnetic field lines there never form surfaces because of those radial diffusions. Thus it may be possible to define the practical new LCFS by using the threshold of $L_K^{-1}\sim0.2\text{-}0.4\mathrm{m}^{-1}$.

Accumulating the database about the relationship between L_K^{-1} and χ_e^{eff}, the experiment-based new definition of LCFS may be proposed for a practical usage, e.g., boundary conditions for the equilibrium calculations

.

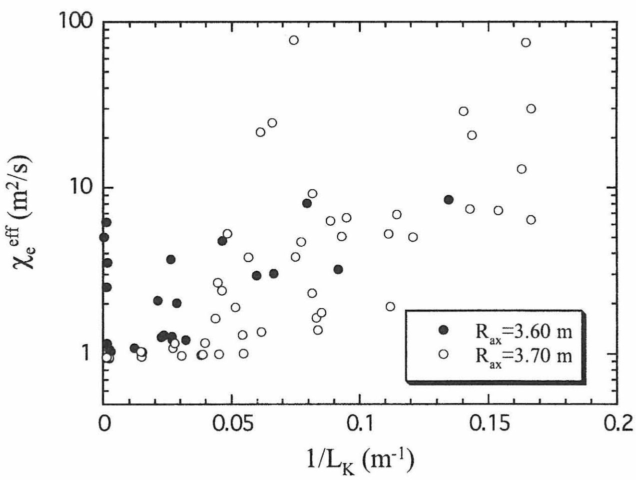

Fig. 1. Effective edge electron heat conductivity χ_e^{eff} as a function of inverse Kolmogorov length L_K^{-1}.

Reference

1) Morisaki, T., et al., 27th EPS ECA **24B**, (2000) 780.