§18. Beta Dependence of Thermal Transport with Different Magnetic Configurations in High Beta Plasmas

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Recent high beta experiments on LHD are mainly carried out with $B = 1\,\mathrm{T}$ and the magnetic axis position in vacuum, $R_{\mathrm{ax}}^{\mathrm{vac}}$ is around 3.56 m. Although high beta plasmas more than 5 % of the volume averaged beta, $\langle\beta\rangle$, were produced in the magnetic configuration of $A_{\mathrm{p}} = 6.6$ and $R_{\mathrm{ax}}^{\mathrm{vac}} = 3.60\,\mathrm{m}$ in low B conditions under 0.5 T, the higher $\langle\beta\rangle$ was obtained in $A_{\mathrm{p}} = 5.8$ configuration with $B = 1\,\mathrm{T}$. The cause of this difference of A_{p} for producing high beta plasmas between with $B = 1\,\mathrm{T}$ and lower B is studied.

The transport property of the plasmas in the low beta range of LHD is similar to ISS04. Therefore, a modeled transport coefficient, χ^{ISS04}, which has the same non-dimensional parameter dependence of ISS04, is used as a reference for the experimentally evaluated thermal transport coefficients, χ^{eff} in high beta plasmas. This χ^{eff} is evaluated with the TASK4LHD system [1]. Then, χ^{eff} is compared with $g_{\mathrm{ren}}^{\mathrm{int}}\chi^{\mathrm{ISS04}}$, where $g_{\mathrm{ren}}^{\mathrm{int}}$ is a renormalization factor for transport coefficients, which represents the effects of devices or configurations. Figure 1 shows the dependence of the normalized thermal transport coefficients, $\chi^{\mathrm{eff}}/(g_{\mathrm{ren}}^{\mathrm{int}}\chi^{\mathrm{ISS04}})$, on $\langle\beta\rangle$ at $\rho = 0.5$ in the magnetic configurations of (a) $A_{\mathrm{p}} = 5.8$ (b) $A_{\mathrm{p}} = 6.6$. The results of the recent high beta experiment in $B = 1\,\mathrm{T}$ are denoted by closed circles (●) which locate at $\langle\beta\rangle > 3\%$ in Fig. 1(a) and $\langle\beta\rangle > 2.5\%$ in Fig. 1(b). The other data in $B \geq 1\,\mathrm{T}$ are in the range of $\langle\beta\rangle < 2.5\,\%$. The data in $R_{\mathrm{ax}}^{\mathrm{vac}} = 3.56\,\mathrm{m}$, $B = 1\,\mathrm{T}$ exist on the extended region of the data in $R_{\mathrm{ax}}^{\mathrm{vac}} = 3.60\,\mathrm{m}$ in Fig. 1(a) in spite of the small difference in $R_{\mathrm{ax}}^{\mathrm{vac}}$. From the results of the ideal MHD analysis, unstable region exists in $1\,\% < \langle\beta\rangle < 2\,\%$ at $\rho = 0.5$ in the $A_{\mathrm{p}} = 5.8$ case and it is studied that the beta gradient, $\frac{\partial\beta}{\partial\rho}$, is limited in such unstable region [2]. The value $\langle\beta\rangle = 3\,\%$ with $A_{\mathrm{p}} = 5.8$ is over this unstable region, while the region of $\chi^{\mathrm{eff}}/(g_{\mathrm{ren}}^{\mathrm{int}}\chi^{\mathrm{ISS04}}) > 1$ is observed around $\langle\beta\rangle = 3\,\%$ in the $A_{\mathrm{p}} = 6.6$ case.

Figure 2 shows examples of (a) the spatial profiles of χ^{eff} in $R_{\mathrm{ax}}^{\mathrm{vac}} = 3.56\,\mathrm{m}$ (solid curve : $A_{\mathrm{p}} = 5.8$, dotted curve : $A_{\mathrm{p}} = 6.6$) and (b) the main curvature, $\kappa_{\mathrm{n}} = \frac{\partial\Omega}{\partial\rho}$, of the magnetic flux surfaces in $R_{\mathrm{ax}}^{\mathrm{vac}} = 3.60\,\mathrm{m}$ which have similar beta values as those used for the plasmas of Fig. 2(a). In Fig. 2(a), a minimum value is observed around $\rho = 0.6 \sim 0.7$ in χ^{eff} of $A_{\mathrm{p}} = 5.8$. Since the negative region of Fig. 2(b) represents the magnetic well, a broad well region is expected in $A_{\mathrm{p}} = 5.8$ than in $A_{\mathrm{p}} = 6.6$.

Spatial profiles of $\chi^{\mathrm{eff}}/\chi^{\mathrm{GRB}}$, where χ^{GRB} is the gyro-reduced Bohm type transport coefficients, are shown in Fig. 3. These plasmas have almost same $\langle\beta\rangle$ values of about 3 %. In the case of $A_{\mathrm{p}} = 5.8$, $\chi^{\mathrm{eff}}/\chi^{\mathrm{GRB}}$ is close to unity in the range of $0.8 > \rho > 0.2$, while $\chi^{\mathrm{eff}}/\chi^{\mathrm{GRB}}$ is higher than unity in the case of $A_{\mathrm{p}} = 6.6$. This difference indicates that difference exists in the local transport property between the configurations of $A_{\mathrm{p}} = 5.8$ and $A_{\mathrm{p}} = 6.6$.

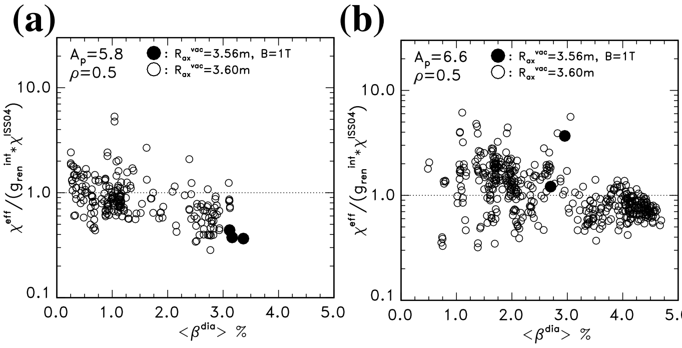

Fig. 1: Dependence of $\chi^{\mathrm{eff}}/(g_{\mathrm{ren}}^{\mathrm{int}}\chi^{\mathrm{ISS04}})$ on $\langle\beta\rangle$ at $\rho = 0.5$ in the configurations of (a) $A_{\mathrm{p}} = 5.8$ (b) $A_{\mathrm{p}} = 6.6$.

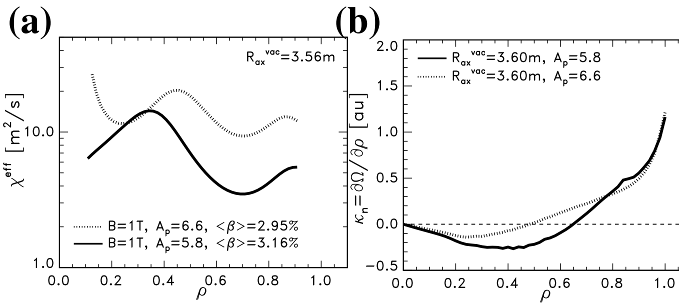

Fig. 2: Spatial profiles of (a) χ^{eff} in $R_{\mathrm{ax}}^{\mathrm{vac}} = 3.56\,\mathrm{m}$ and (b) the main curvature, $\kappa_{\mathrm{n}} = \frac{\partial\Omega}{\partial\rho}$.
Solid curve : $A_{\mathrm{p}} = 5.8$, dotted curve : $A_{\mathrm{p}} = 6.6$.

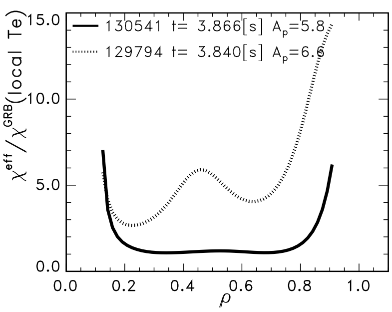

Fig. 3: Spatial profiles of $\chi^{\mathrm{eff}}/\chi^{\mathrm{GRB}}$ in $R_{\mathrm{ax}}^{\mathrm{vac}} = 3.56\,\mathrm{m}$.
Solid curve : $A_{\mathrm{p}} = 5.8$, dotted curve : $A_{\mathrm{p}} = 6.6$.

1) R. Seki, H. Funaba, *et al.*, Plasma Fusion Res., **6**, 2402081 (2011).
2) K.Y. Watanabe, *et al.*, Nucl. Fusion **45**, 1247 (2005).