§23. Optimization of Magnetic Configuration Using Additional Trim Coils

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Helical plasmas including heliotron and stellarator can confine steady state plasma in principle because their three-dimensional magnetic field for plasma confinement is mainly produced by external coils. However, the complex nature of three-dimensional would lead to degradation of plasma confinement and optimization aiming at improvement of neoclassical and anomalous transport, and MHD stability is needed.

In order to improve the magnetic configuration of helical-axis heliotron which has simple l=1 helical coil, we try to optimize the magnetic configuration of Heliotron J using stellarator optimizer "STELLOPT" suite mainly developed by ORNL [1]. STELLOPT can take into account several physics such as neoclassical transport, energetic particle confinement and MHD stability, and in addition, engineering request. In this study, we mainly target on particle confinement of both thermal and energetic particle because other calculation results and experimental results show higher harmonics of Fourier component of magnetic field by helical coil breaks quasi-omnigenous of magnetic configuration and disturbs the good particle confinement. In the optimization with regard to good particle confinement, we measured and optimized the values of both second adiabatic invariants J and B minimum ($B_{\min}$), which represent the orbit of helically trapped particle. Figure 1 shows the $B_{\min}$ contour of optimized configuration by STELLOPT. The concentric circle contour, which well aligned the magnetic surface are shown in Fig. 1. However, $B_{\min}$ contour do not continue (close) in the region of $\theta \sim 0$ (deg) where magnetic field tends to be modulated by high harmonics of Fourier component with small amplitude because magnetic field strength is weak and constant. STELLOPT cannot take into account this effect. We investigated the effect of each higher harmonics of B on the contour of J and $B_{\min}$. Figure 2 shows the $B_{\min}$ contour applied the each major high harmonics of Fourier component to ideal magnetic configuration consisted of only main four Fourier components with toroidictiy, helicity and bumpy field. Discontinuous of contour at region of $\theta \sim 0$ (deg) are only observed in the case of the additions of n=2 component, as shown in Fig. 2 (a) and (b). In the region of $\theta \sim 0$ (deg) where well region produced by bumpy field, n=2 component would additionally produce the shallow dent region of magnetic field strength and contour cannot be closed. On the contrary, we suppressed all components of n=2, as shown in Fig. 3. Another discontinuous regions unfortunately are observed. Therefore it seems that the suppression of certain component of high harmonics cannot be optimize the particle confinement well. We should optimize the magnetic configuration by the adjustment of all higher harmonics of Fourier componenet.

[1] D. Spong, et al., Nucl Fusion **41**, 711 (2001).

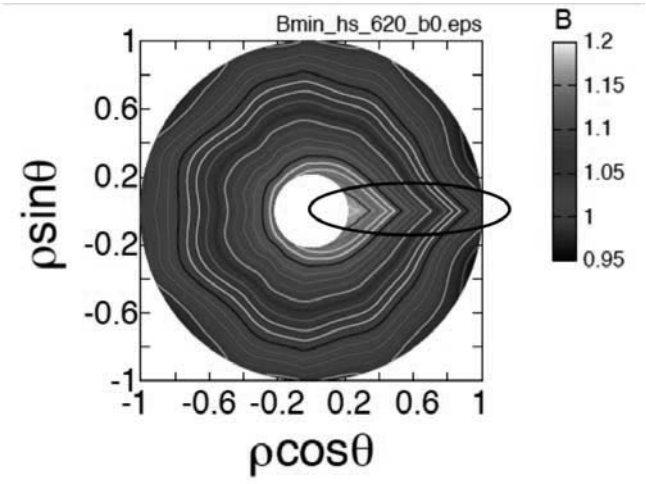

Fig. 1. $B_{\min}$ contour of optimized magnetic configuration. The elliptic circle with solid line means the region of θ = 0 (deg).

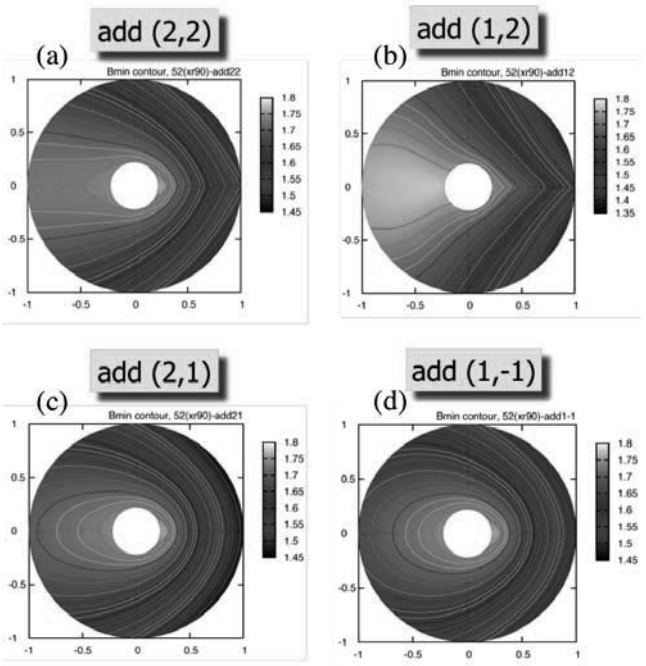

Fig. 2. $B_{\min}$ contour applied major Fourier component of higher harmonics to ideal magnetic configuration of Heliotron J.

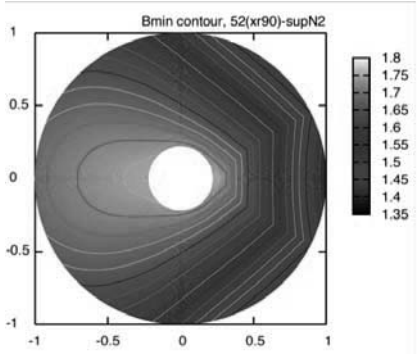

Fig. 3. $B_{\min}$ contour where major Fourier components of n = 2 are suppressed.