§3. Strength of Adiabaticity as a Criterion for the Selection Rule of Magnetic Field Configuration

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The concept of adiabaticity is introduced for the coil currents to optimize the LHD magnetic field configuration.

Volume enclosed with the last closed magnetic surface, $V_{\rm lcfs}$, is one of the most important parameters for the plasma confinement performance. In the LHD, $V_{\rm lcfs}$ is determined by the magnetic axis position, $R_{\rm ax}$, and the coil pitch parameter $\gamma\,(\equiv\, m/\ell \cdot a_{\rm c}/R_0$, where m, ℓ, $a_{\rm c}$ and R_0 are toroidal mode number, poloidal mode number, minor radius and major radius, of center of helical coil currents, respectively).

In general, $V_{\rm lcfs}$ increases with the inner shift of the magnetic axis due to the increase of average toroidal magnetic field which intensifies the adiabaticity of the equation of the lines of force. The coil pitch parameter γ determines the outer boundary of the chaotic field line region.

Reduction of γ brings the helical coil currents close to the magnetic surface. This causes the increase of the rotational transform of the last closed magnetic surface, $\iota_{\rm lcfs}/2\pi$, which decreases the intensity of the adiabaticity of the lines of force. Then, $V_{\rm lcfs}$ is reduced and the volume of the chaotic field line region is increased by the reduction of γ, in general.

The intensity of adiabaticity of lines of force ($V_{\rm lcfs}$, equivalently) is possible to be maximized by the control of the current distribution of three sets of vertical field coils (OV, IS and IV coils), under the specified value of the $R_{\rm ax}$ and γ as shown in Fig.1.

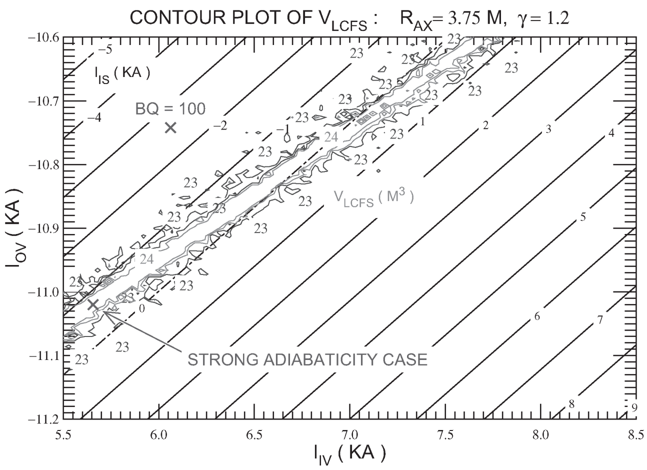

Fig. 1: Contour plot of $V_{\rm lcfs}$ in IV and OV coil currents plane. Current of IS coil is adjusted by the condition of $R_{\rm ax} = 3.75$m.

Coil currents specified by the symbol $\times$ in Fig.1 is chosen as an example of optimized case (detailed coil current values are summarized in Table 1). The lines of force are traced numerically and compared with the standard configuration case ($BQ = 100$ case), shown also by the symbol $\times$ in Fig.1.

Table 1: Example of coil currents distribution and the values of $V_{\rm lcfs}$ and $\iota_{\rm lcfs}/2\pi$ for the standard configuration ($BQ = 100$) case and for strong adiabaticity case.

	$BQ = 100$	strong adiabaticity
I_HC_O	$2,095.00$ A	$2,095.00$ A
I_HC_M	$7,212.00$ A	$7,212.00$ A
I_HC_I	$11,000.00$ A	$11,000.00$ A
I_OV	$-10,742.00$ A	$-11,020.00$ A
I_IS	$-2,593.90$ A	-748.75 A
I_IV	$6,062.00$ A	$5,656.00$ A
$\iota_{\rm LCFS}/2\pi$	1.389	1.883
$V_{\rm LCFS}$	$21.846\,{\rm m}^3$	$25.963\,{\rm m}^3$

Poincaré plot of lines of force are shown in Fig.2, for the case of standard configuration ($BQ = 100$) and for the strong adiabaticity case.

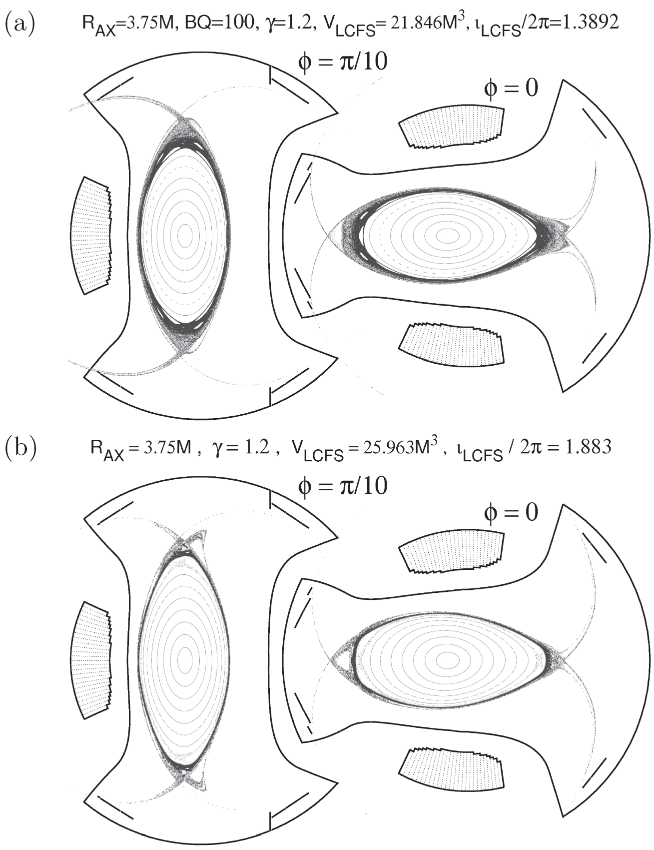

Fig. 2: Poincaré plot of lines of force. Coil currents are shown in Table 1. (a) is the standard configuration case and (b) is the strong adiabaticity case.

Increase of $V_{\rm LCFS}$, increase of $\iota_{\rm LCFS}/2\pi$ and decrease of the volume of chaotic filed line region are possible to be satisfied simultaneously by selecting currents distribution of three sets of vertical field coils so as to maximize the adiabaticity of lines of force.