§32. Relation between Quasi-axisymmetry and Aspect Ratio

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A quasi-axisymmetric configuration has a small but finite level of non-axisymmetric ripple components. When the fraction of trapped particles in these ripples is evaluated, the relative values of such components to the average toroidal magnetic field strength does not give a good measure by itself. General characteristics of toroidal system such as the aspect ratio and the rotational transform should be considered.

Following to the procedures in tokamaks to evaluate the acceptable ripple level introduced by a finite number of toroidal coils, the magnetic field strength along the field line is described by

$$B=B_0\left(1-\frac{r}{R}\cos\theta+\delta\cos N_c\phi\right) \qquad (1)$$

where θ is the poloidal angle, ϕ is the toroidal angle, δ is the amplitude of ripple and N_c is the number of toroidal coils.

The condition of creating no trapped particles in the local field ripple is written as

$$\delta < \frac{r}{RN_c q}\left|\sin\theta_t\right| \qquad (2)$$

where q is a safety factor and θ_t is the poloidal angle of particle turning point. At the outboard side of torus ($\theta_t = 0$), trapped particles exist even for the very small level of ripples.

For the helical magnetic configuration, the equation (1) is written as

$$B=B_0\left(1-\frac{r}{R}\cos\theta+\delta\cos(N-\iota)\phi\right) \qquad (3)$$

where N is the number of toroidal periods and ι is the rotational transform. The equation (2) is then modified to

$$\delta = B_{mn} < \frac{r\iota}{R(N-\iota)}\left|\sin\theta_t\right| \qquad (4)$$

Because the radial distribution of B_{mn} is basically $B_{mn} \propto r^m$, the condition of ripple amplitude to have no trapped particles is more severe at the plasma boundary. So the condition should be given as

$$B_{mn}(a) < \frac{\iota}{A_p(N-\iota)}\left|\sin\theta_t\right| \quad (m \neq 0) \qquad (5)$$

where A_p is the aspect ratio.

Wendelstein 7a device, which was a standard stellarator, was known to have a small helical ripple amplitude. The relative value of ripple spectrum to the toroidal magnetic field strength was of the order of 1 %. But the acceptable value of B_{mn} for having no trapped particles is much smaller following to the equation (5). The ratio of the acceptable ripple level for a CHS-qa device (A_p = 4.2, N = 2, ι = 0.28) to the one for W-7a (A_p = 20, N = 5, ι = 0.5) is calculated as

$$\frac{B_{mn}(\text{CHS-qa})}{B_{mn}(\text{W-7a})} = \left(\frac{20}{4.2}\right)_{A_p}\left(\frac{4.5}{1.72}\right)_{(N-\iota)}\left(\frac{0.28}{0.5}\right)_{\iota} \cong 7$$

The acceptable ripple level in CHS-qa is effectively about one order lower than a high aspect ratio device in terms of the creation of trapped particles.

The field ripple structures at half radius (r/a = 0.5) are shown in Fig. 1 for W-7a and in Fig. 2 for the present design of CHS-qa device.

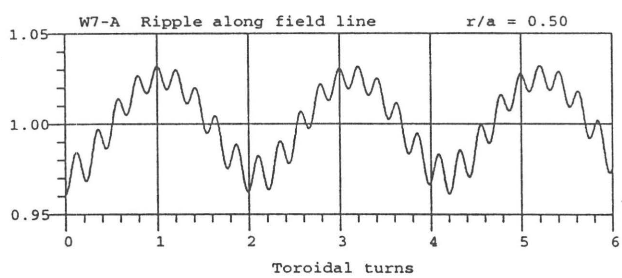

Fig. 1 Field ripple structure of W-7a

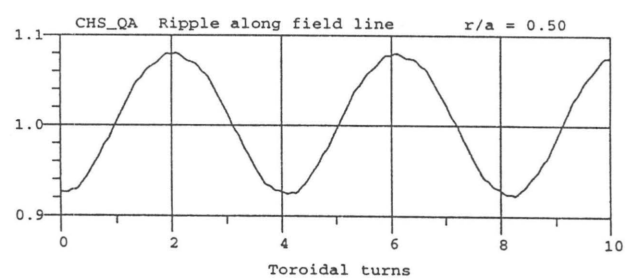

Fig. 2 Field ripple structure of CHS-qa