§30. Optimization of M = 2 Stellarator

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Quasi-axisymmetric stellarator (QAS) configurations are considered for improvement of high energy reflected particle confinement [1]. A reference QAS configuration with the field period of $M = 2$ has been obtained by the optimization of the shape of the confinement region as shown in Fig. 1. The magnetic axis shift is rather large in the equilibrium without bootstrap current. The effects of boundary harmonics on the magnetic configuration are considered for reducing the Pfirsch-Schlüter current.

The Pfirsch-Schlüter current depends inversely on ι^2, where ι denotes the rotational transform. Therefore, it is crucial to obtain higher ι for reducing it.

The plasma boundary can be Fourier decomposed in the cylindrical coordinates (R, ϕ, Z) as

$$R(s,\theta,\zeta) = \sum_{mn} R_{mn}(s)\cos(m\theta - n\zeta),$$
$$Z(s,\theta,\zeta) = \sum_{mn} Z_{mn}(s)\sin(m\theta - n\zeta),$$

where s is the label of the magnetic surface and θ (ζ) is the poloidal (toroidal) angle in the VMEC coordinates [2].

We choose the exact axisymmetric configuration described by $R_{00} = 2.0$ m, $R_{10} = 0.4$ m, $Z_{00} = 0.0$ m and $Z_{10} = 0.6$ m as the basic configuration in the following.

When we put the helical harmonic R_{11} with $R_{11}/R_{10} = -0.5$ on the basic configuration, ι increases to about 0.1 with enhancing the vacuum magnetic well to 1.3%. The bumpy field B_{01} is significantly enhanced with the opposite sign to B_{10}. As for Z_{11} with $Z_{11}/R_{10} = 0.5$, $\iota \sim 0.05$ and the vacuum magnetic well is enhanced to 6.9%. The B_{01} is rather large with the same sign as B_{10}. Therefore, one can expect that the fine combination of R_{11} and Z_{11} control allows to obtain the QAS configuration with higher rotational transform.

The Z_{21} can modify the triangularity due to the coupling with R_{10} and Z_{10}. When Z_{21}/R_{10} is doubly increased on the reference, the vacuum magnetic well is enhanced from 0.6% to 4.1%. Therefore, it can be said that Z_{21} is effective to control the magnetic well depth.

Figure 2 shows the magnetic surfaces of the example QAS configuration with $\iota(0)/\iota(a) = 0.42/0.47$, which is twice larger than the reference. The vacuum magnetic well is also enhanced to 3.4%. The cross section at $\phi = 0$ is significantly deformed by R_{11} and Z_{11} from Fig. 1 and the increase of Z_{21} makes more tear-drop (triangular) shape at $\phi = (1/4)(2\pi/M)$ $((1/2)(2\pi/M))$. The magnetic axis shift in the equilibrium without the bootstrap current is reduced to about 1/4 of that in the reference.

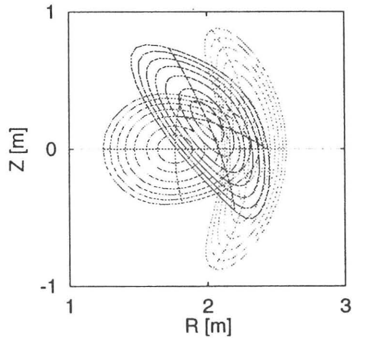

Fig. 1. The magnetic surfaces of the reference QAS configuration.

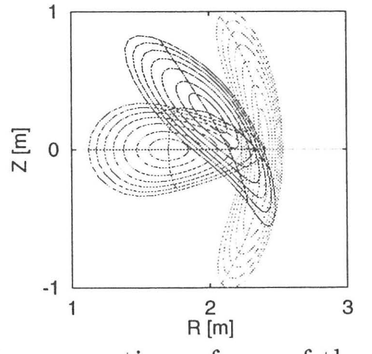

Fig. 2. The magnetic surfaces of the example QAS configuration.

References
[1] NÜHRENBERG, J., in Theory of Fusion Plasmas (Proc. Workshop Varenna, 1994) Editrice Compositori, Bologna (1994)3.
[2] HIRSHMAN, S. P., et al., Comput. Phys. Commun. 43(1986)143.