§15. Considerations on Magnetic Configurations of Heliotron J towards Improved Confinement

Yokoyama, M.,
Yamamoto, S., Okada, H., Kobayashi, S., Sano, F.
(Institute of Advanced Energy, Kyoto Univ.)

The high flexibility of magnetic configurations is the advantage to perform a variety of experiments for pursuing the improved confinement. Especially, the controllability, through the toroidal field coils, of the bumpy field component is of vital importance. It is the component with which the magnetic field strength varies in the toroidal direction, and it is the basis of "quasi-isodynamicity" of Heliotron J.

The NBI-power scan experiments has revealed that the larger stored energy is realized in so-called "high-" and "medium- (standard)" bumpy configurations compared to that in "low-bumpy" configurations [1]. It is also the case for the improvement factor with respect to ISS95 scaling law. The former two configurations have relatively larger contributions from the bumpy field component rather compared to those from the helicity and the toroidicity. It leads the increase of "quasi-isodynamicity" at the straight section of plasmas. This would be the one of reasons to provide such dependence of confinement properties on magnetic configurations.

In such a manner, it is expected that the "quasi-isodynamicity" can be enhanced when the bumpy field is further increased. However, due to the simple coil systems, consisting of L=1 continuous helical coil, poloidal coils and toroidal coils, it had been known from the design phase of the Heliotron J, other magnetic spectrum with higher (poloidal and toroidal) mode numbers also appear when the bumpy field is aimed to be increased. Locally trapped particles in local ripples produced by such broadening of magnetic field spectrum can cause, for example, the increase of radial diffusion, loss of energetic particles.

Thus, it should be worthwhile increasing the bumpy field component without enhancing other field spectrum with higher mode numbers towards enhancement of "quasi-isodynamicity" of Heliotron J. For such a purpose, so-called "optimization" code of helical magnetic configurations has been implemented and applied based on the present Heliotron J configurations.

The estimate of longitudinal adiabatic invariance, $J_{\|}$, of particles has been included as the measure of particle orbit confinement. However, in terms of simplicity and faster calculations, the parallel velocity is integrated in the toroidal direction, which indeed should be done along the magnetic field line. This simplification can work in a circumstance of low rotational transform ($\iota/M<<1$, with ι the rotational transform and M the number of the toroidal field period). For a standard Heliotron J configuration, $\iota/M\sim0.12$ (with $\iota\sim0.5$ and M=4), and this simplification might be appropriate. However, it is not so huge computations to rigorously calculate $J_{\|}$ by following particle orbits, as done for quasi-axisymmetric and quasi-poloidally symmetric configurations [2,3].

The module of the "orbit-following" approach of calculating $J_{\|}$ has been implemented in the "optimization" code. By this introduction, it will be pursued to enhance the "quasi-isodynamicity" of Heliotron J, which will provide the new experimental flexibility towards improved confinement.

1) (for example) H.Okada et al.,: Nuclear Fusion, **47** (2007) 1346.
2) M.Yokoyama et al., : Nuclear Fusion, **42** (2002) 1094.
3) M.Yokoyama et al., Plasma and Fusion Research, **78** (2002) 291.